Working with air valves
The company was founded in 1987 by transforming the former CSA, which was a trading company dealing with pipes and valves for water networks, into a manufacturing company, through the research and realization of pillar fire hydrants. These were compliant with the UNI 9485 regulation, which was at the approval stage. Since then many other products have been added.

The history of our company is characterised by years of technical and commercial research, which have enabled us to offer a complete range of valves designed for controlling, regulating and protecting the pipelines under pressure in both waterworks and sewage lines as well as fire hydrants.

Our many industrial patents and innovative technical solutions, together with modern and attractive style of design, have made it possible to differentiate our products from those offered by competitors and have allowed us to become a point of reference in our sector.

Flexibility and reliability have been the key points of CSA’s rapid growth over the last few years. We are perfectly aware that we are managing the world’s most precious resource and, motivated by this responsibility and the commitment towards our customers, we have dedicated ourselves to constantly improving our products, placing them at the highest levels of quality.

Quality
In the manufacturing business today, quality is the fundamental requirement for achieving and maintaining a growing market share. For this reason we have always aimed at developing a synergy between the various sectors of the company and thus ensuring:
- Quick and precise answers;
- Evaluation of data received and immediate response;
- Rigorous control of incoming and outgoing products.

Since 1998 CSA is certified according to regulation ISO 9001 by RINA (Italian Naval Registry) recently converted into ISO 9001/2008.
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 predetermined 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 gas. 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;
- 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.
- localized head losses like modulating valves, variations of pipe DN, changes of direction.
**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 pockets 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;
- Air pockets, if not properly released, will grow up to a certain volume given by the hydrodynamic force, above which they split causing variations in pressure;
- 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 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

On the pictures depicted below it is clearly shown what happens during pipe filling without air valves, both in case of gravity and pumping mains. On the first phase water is moving downwards pushing air to the end of the line. At the high points, or changes in slopes in descending segments, some of the air remains localized on the upper part of the pipe, while the rest is pushed by the force of water flowing underneath. As soon as this happens the air pocket is pressurized, and it moves to reach the final position of balance with its volume slightly reduced.

The hydraulic flush of air pockets is possible in descending segments only and if the velocity is high enough. In some situations the total head loss obtained by the sum of all the air pockets, localized throughout the systems, is higher than the hydraulic energy available to allow the water supply (like pump’s head and difference in tank elevation). If that happens we will be likely to generate a dangerous increase in pressure at the pumping stations or, in case of gravity lines, spillover from the upstream tank.
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 slopes and 0.2-0.3% for upward slopes. 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. We recommend to carry out the analysis for the hydraulic removal of air pockets throughout the entire profile.

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. The dimension and shape of the air pockets is related to the fluid parameters along with pipe DN and slope. On air pockets three forces are acting such as the buoyancy force, the hydrodynamic force and the friction force against the pipe’s wall. Once air pockets, are large enough they split and part of the air goes downstream producing unexpected and dangerous variation in pressure. On descending slopes the resultant force can be directed upwards, and strong enough to move the pockets upstream or even preventing the air pockets from moving and creating even more headlosses. This is common in case of low velocities or during the night.

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 even by CSA srl. 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. Purely as an indication below one of the formula, that is valid only for a certain range of diameters and descending segments, needed to calculate the critical velocity. 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).

\[ v_c = \frac{4 \sqrt{\frac{g}{\pi}} D}{\tan \alpha} \]
Fundamentals of air valves
Before talking about air valves sizing, and to CSA methodology for calculation, 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.

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

Example of CSA air release valve Mod. Ventolo.

Example of CSA air/vacuum air valve Mod. FOX 2F.
Combination air valves

Combination 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 HGL 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 one of the few companies 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

- **High points**
  - Combination air valves

- **Changes in slopes descending**
  - Combination air valves

- **Changes in slopes ascending**
  - Vacuum air valves

- **Long ascending segments**
  - Vacuum air valves every 600/800 mt

- **Long descending segments**
  - Combination air valves every 600/800 mt

- **Long horizontal run**
  - Avoid if possible if unavoidable air release valves or combination air 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 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

$$Q_{burst} = \frac{1.852 \sqrt{SD \cdot 4.87 \cdot C \cdot 1.852}}{10.69}$$

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

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

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
For the proper air valves sizing, once obtained the air flow rate through burst or drainage analysis, it is important to evaluate the difference in pressure created across the air valve during intake. That is shown on the air flow capacity curves of air valves manufacturer. Purely as an indication, for easier consultation resulting flow rates have been traced for each DN from free discharge on given slopes (in case of new steel pipes). As an example if we had to calculate the flow discharged by a pipe with an internal diameter of 500 mm, and a slope of 2,5%, the value would be 2500 m3/h.

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, expressed in m3/h, depicted on the horizontal axis versus the correspondent negative pressure on the vertical axis where, as an example, 0,9 means a negative of -0,1 bar.

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. 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. For easier consultation we have divided the chart into three zones, the red with the negative pressure which we consider to be dangerous for the pipe , the yellow where the inflow may create problems to some situations, sometimes used for ductile cast iron pipes only, and the green that CSA consider to be suitable for the proper air valves sizing and designers should work with.

The allowable differential pressure on the pipe depends on the material, thickness and other parameters. Please contact CSA for further information.

Going back to our example, where 2500 m 3/h is the calculated amount of water discharged, it goes without saying that using a CSA FOX 3F DN 100 air valve we would produce a negative of almost 1,9 meters becoming 0,75 meters with the DN 125 mm. A DN 80 air valve in this condition would create full vacuum since the maximum capacity, going to sonic at certain value, is way below the requested 2500 m3/h. The procedure explained above has to be carried out throughout the entire pipeline.
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 will carry out 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.

\[ a = \sqrt{\frac{K}{\rho_w}} \sqrt{1 + c_1 K \frac{D}{E e}} \]

Where:
- \( K \) is the bulk modulus of water
- \( \rho_w \) is the density of water
- \( D \) is the pipe DN
- \( E \) is the elastic modulus of the pipe
- \( e \) is the pipe thickness
- \( c_1 \) 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 other than segments of the pipe subject to negative pressure conditions, particular attentions has to be 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 and rapid filling of pipelines.
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 assess 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 CSÅ 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.

With vertical/submersible pumps
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, sited in the horizontal section downstream of the 90° bend, 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 than 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 pressure conditions.
The following pictures has to be considered as a pure indication for air valves location along the profile, also considering transients effects, providing protection against water hammer. The proper choice of air valves depends on many factors such as profile, pipe materials, and other 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 assess 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, purely as an indication, we mark in red the segments involved on the transient followed by a sudden pump failure. It will be necessary to install antihammer air valves, CSA AS technology, at those locations while for the rest of the line the RFP models will provide the protection without reducing too much the air discharge during filling operations.

**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.

Standard 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.

**Air valves location**

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 m 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 hydraulic control valves, direct acting PRV or PSV modulating devices are needed. Whenever we produce a pressure drop air is released 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 and the pipeline is recommended.

In the following installation we do have two triple function air valve, located upstream and downstream of the control valve next to the changes in slope. Also in this case accumulation chambers on both sides are recommended.
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 outflow 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 gaskets. 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.
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 has specialized in hydraulic modelling and transients analysis, entirely through the use of modern computational tools and advanced 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.