AIR AND AIR VALVES IN PIPING - PART 2

A little about "water hammer"

Water hammer, pressure surge, or pressure waves are different names for phenomena that occur in piping systems and can be defined as a variation in pressure (values that are much greater and much lower than those expected under normal operating conditions) caused by a ***fast change the velocity of the water.***

With water hammer, when water travelling through the piping system at a certain velocity is stopped suddenly, the energy of its movement is transformed into pressure energy.

KINETIC ENERGY → PRESSURE ENERGY

The overpressure created, called a *high pressure wave,* travels through the pipe. After this, a second phase of decompression is produced, called a *low pressure wave.*

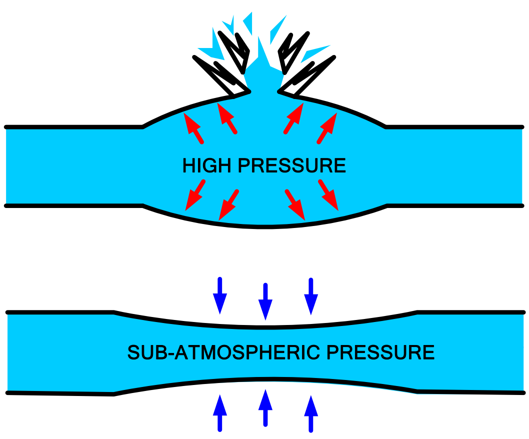
The cycle of a high pressure wave followed by a low pressure wave repeats over and over, slowly reducing due to friction losses in the pipeline until the complete attenuation of the event.

The waves travel within the pipe in both directions and can cause serious damage to the pipe.

Water hammer takes place in both gravity-driven and pump-driven pipelines, and affects the pipes, fittings, and pumps.

In a HIGH-pressure wave-phase, pipes can break because their maximum pressure is exceeded.

In the LOW-pressure wave-phase (often more risky than the first), pipes can break due to inward collapse.



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*Note: there are various safety and control devices for limiting water-hammer: surge anticipating valve (**RE), ** pump control valve (**BC**), deep well valve (**DW**), two-stage opening valve (**TO**), quick relief valve (**QR**), etc. One or more of these may be selected for each hydraulic situation. Dorot has an experienced and respected technical department specialized in studying and resolving water hammer and pressure surge phenomena.*

Can air-valves amplify or attenuate water hammer?

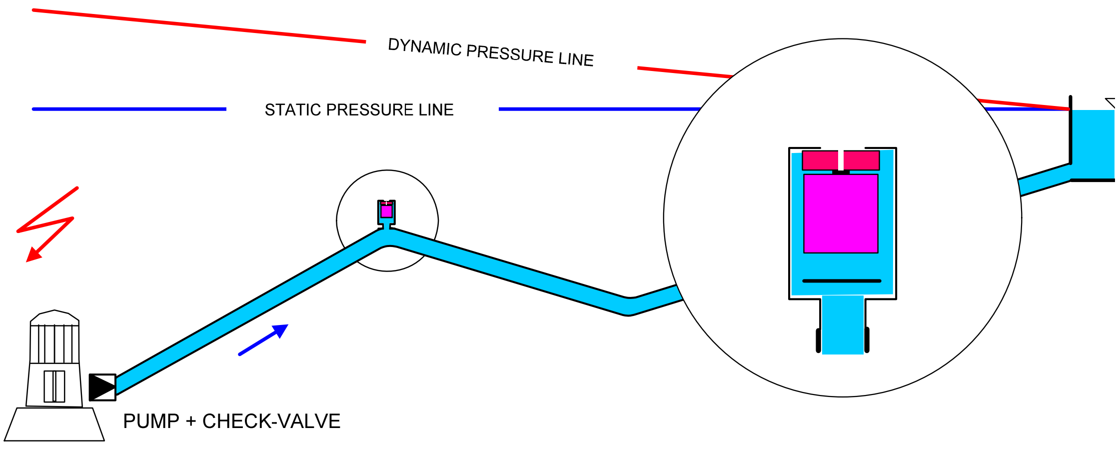
No one denies the importance of air valves in piping systems and PIPELINEs. But this device, which is so important in allowing the exchange of air between the piping system and the atmosphere, can turn into a dangerous element.

Let's look at a couple of examples where air valves can work against us.

Example #1. Air valve at intermediate high points

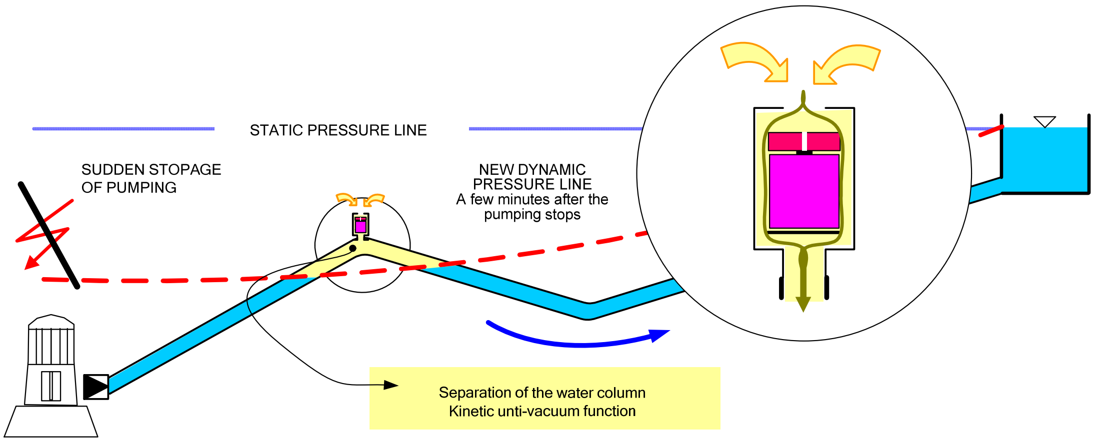
Phase 1. PRESSURIZED PIPELINE

- The pipeline is full of water, pressurized and functioning normally.
- The air-valve's float is up, and no air or water escapes, except that which escapes through the automatic-orifice during its normal functioning



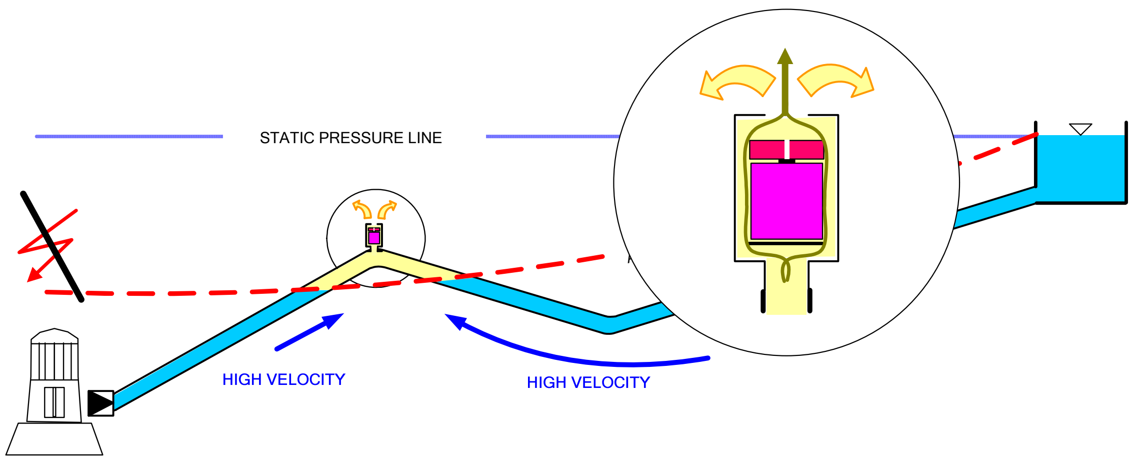
Phase 2. SUDDEN, UNEXPECTED PUMP STOPPAGE

- Power is cut off, and the pump stops.
- Sub-atmospheric pressure wave is created at the intermediate high points, and the water column separates.
- The kinetic-vacuum function of the valve activates, allowing large amounts of air to be reintroduced into the line (the negative pressure never reaches dangerous level)



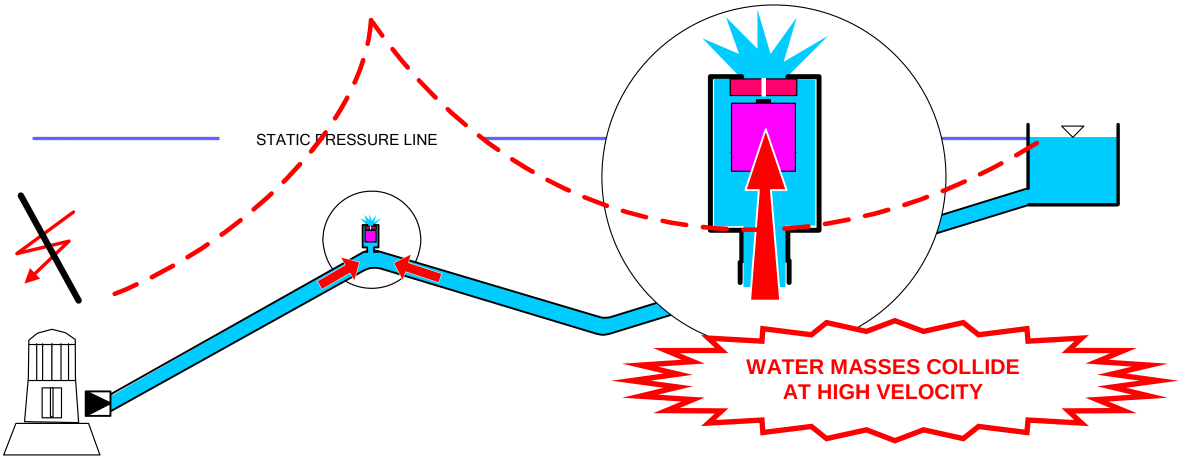
Phase 3. RETURN OF WATER FLOW TOWARDS THE AIR VALVE

- The water masses returns towards the air valve.
- The air masses that had previously been introduced are pushed by the water to escape through the air valve.
- The air escapes at high velocity, allowing the water to move at high velocity.



Phase 4. THE WATER MASSES COLLIDE, CAUSING WATER HAMMER

– The water masses that were travelling at high velocity (a high load of kinetic energy) meet, The air valve closes and the flow is stopped - creating a high load of pressure energy → WATER HAMMER



Example #2.

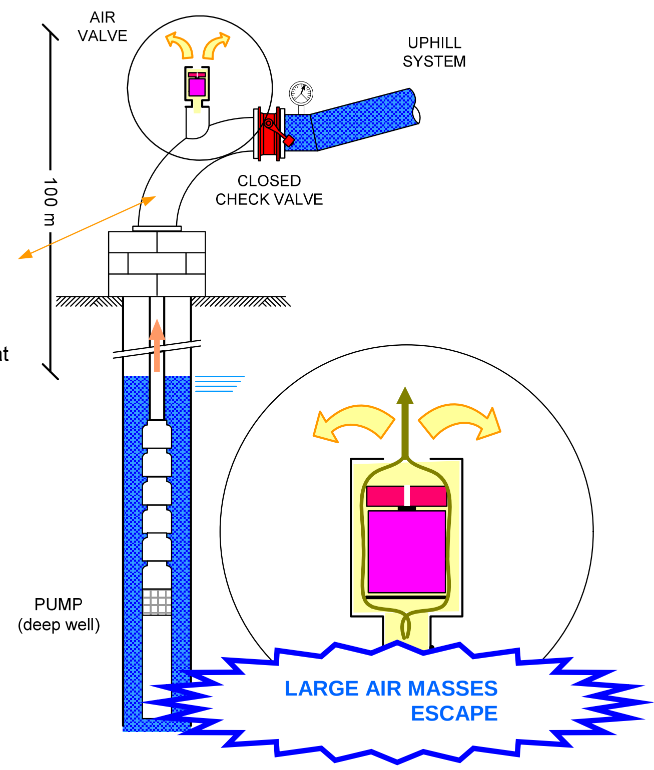
Air valve at the outlet of a deep well pump

Deep well pump, located at significant depth.

- "Uphill" discharge.
- Closed check valve.
- Significant static pressure.
- Empty riser pipe.

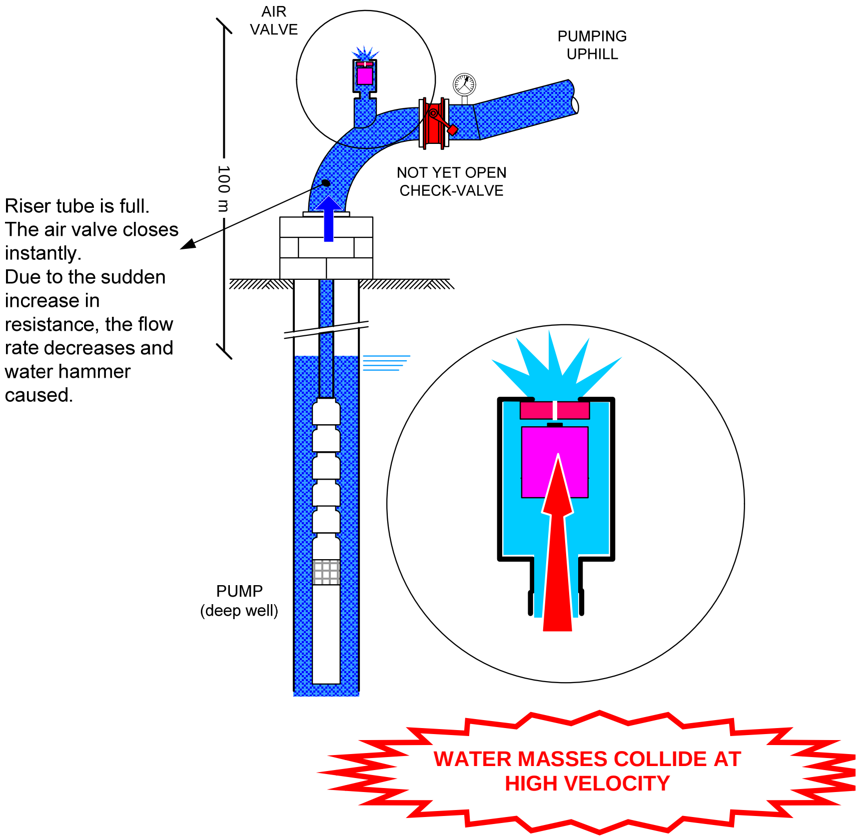
Phase 1. PUMP START-UP

- The pump is started.
- Because the riser pipe is empty, the discharge pressure is low and pump propels a HIGH-VELOCITY flow into the riser.
- The air valve allows a large quantity of air to escape, creating no resistance that will limit the discharge velocity.



Phase 2. THE RISER PIPE FILLS UP. THE AIR VALVE CLOSES

- The riser pipe fills up.
- The air valve closes suddenly.
- The check valve is not yet open.
- The water mass that was travelling at high velocity (a high KINETIC-ENERGY load) is stopped suddenly when colliding into the closed check valve, creating a high PRESSURE-ENERGY load → WATER HAMMER



What conclusions can we make based on these examples?

- ✓ Air valves are very efficient and important device for preventing risky sub-atmospheric pressure in the pipelineAir valves are very efficient and important device for preventing risky sub-atmospheric pressure in the pipeline
  However,
- ✓ The standard kinetic air-valve will not create ant substantial resistance for discharge air flow.
- ✓ If the water doesn't encounter any restrictions, it achieves a high velocity.
- ✓ When the air valve closes suddenly, it results an instant stoppage of water flow.
- ✓ This sudden stoppage of the flow transforms kinetic energy into pressure energy that creates a WATER HAMMER.

Can anything be done to prevent water hammer caused by too fast air-discharge in air-valves?

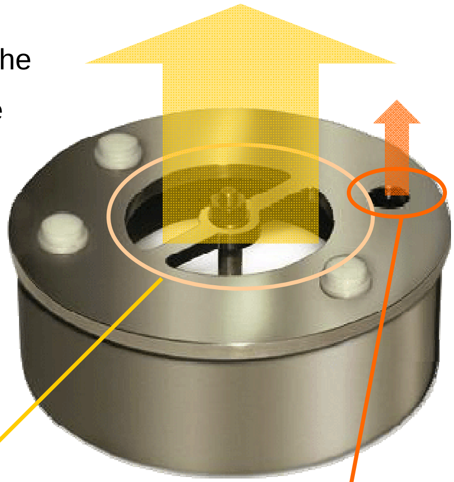
If the air's escape is restricted, the water's velocity will also be restricted.
A reduction in the velocity of the water will reduce the KINETIC ENERGY and thus limit the magnitude of the consequent water hammer.
Air in the pipeline will be used in such a case as a sort of cushion or air bag.

the lower the		the lower the		the lower the
SPEED AT WHICH AIR IS ESCAPING	→	***SPEED OF THE WATER'S MOVEMENT***	→	***PRESSURE ENERGY OF THE WATER***

What is the Surge Arrester (SA) devise for the DAV-M valves?

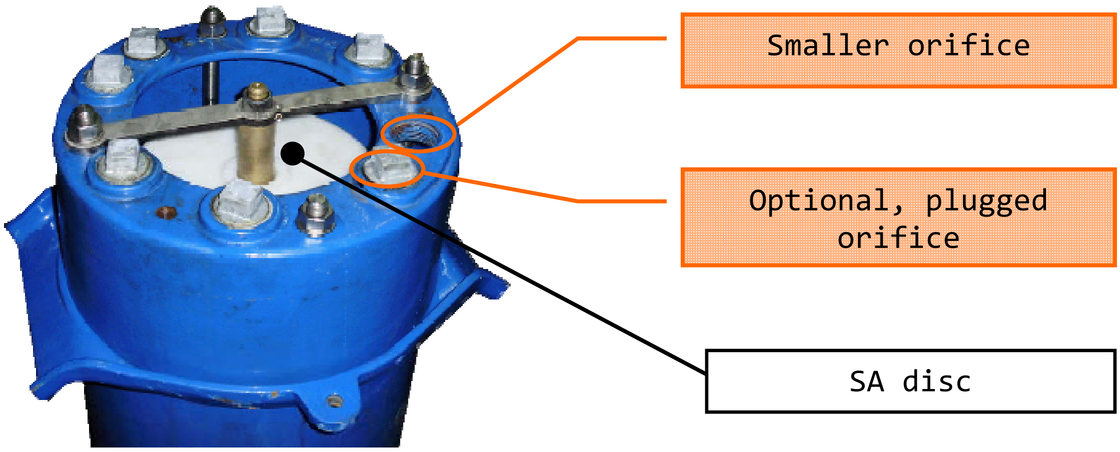
An SA device is a device that is installed on any air valve in the DAV-M series which is equipped with a air-flow lifted disc. The device is used to limit the velocity at which air escapes.

- If the air is exiting the valve at low velocity, it will do so through the main kinetic orifice. The SA device performs no other function. The disc will be in the lower position.
- In case the air is exiting at high a velocity, the SA disk will be lifted by the air-flow and close the **kinetic orifice**. The air must exit through the **smaller orifice(s)** that are left open, and the discharge airflow will thus be slower.

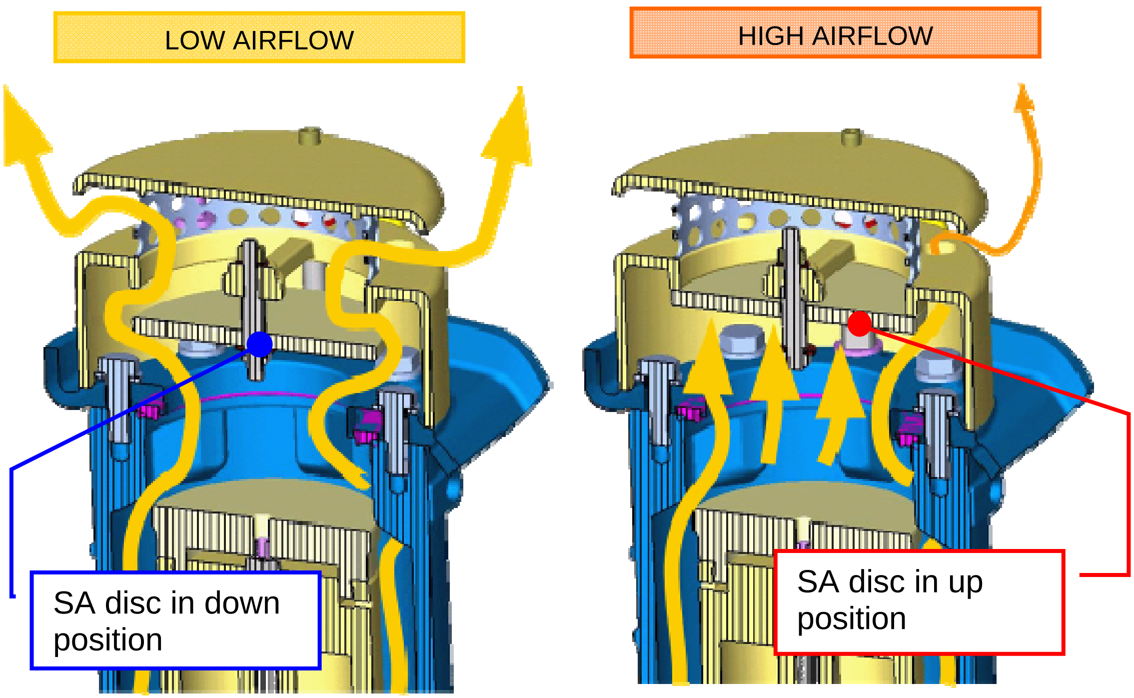


The number of smaller orifices that are left open varies and can be calculated.

Consult the Dorot technical department about sizing the SA surge arrester.



<u>The SA device only acts when air is escaping at high velocity.</u>



AIR ESCAPING AT LOW VELOCITY

- ✓Main float and top float both at their low position.
- ✓The SA device disc will be at its low position.

AIR ESCAPING AT HIGH VELOCITY

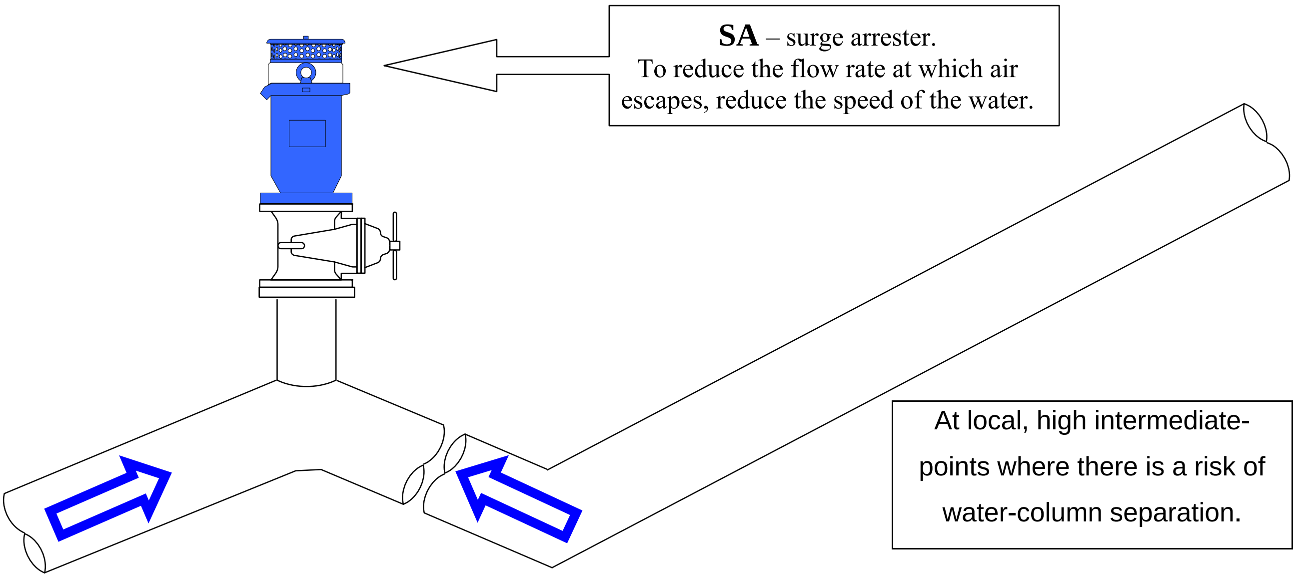
- ✓ Main float and top float both at their low position.
- ✓ The SA device disc is pushed up by the air flow and closes the main orifice.
- ✓ Air can escape only through the small discharge orifices.

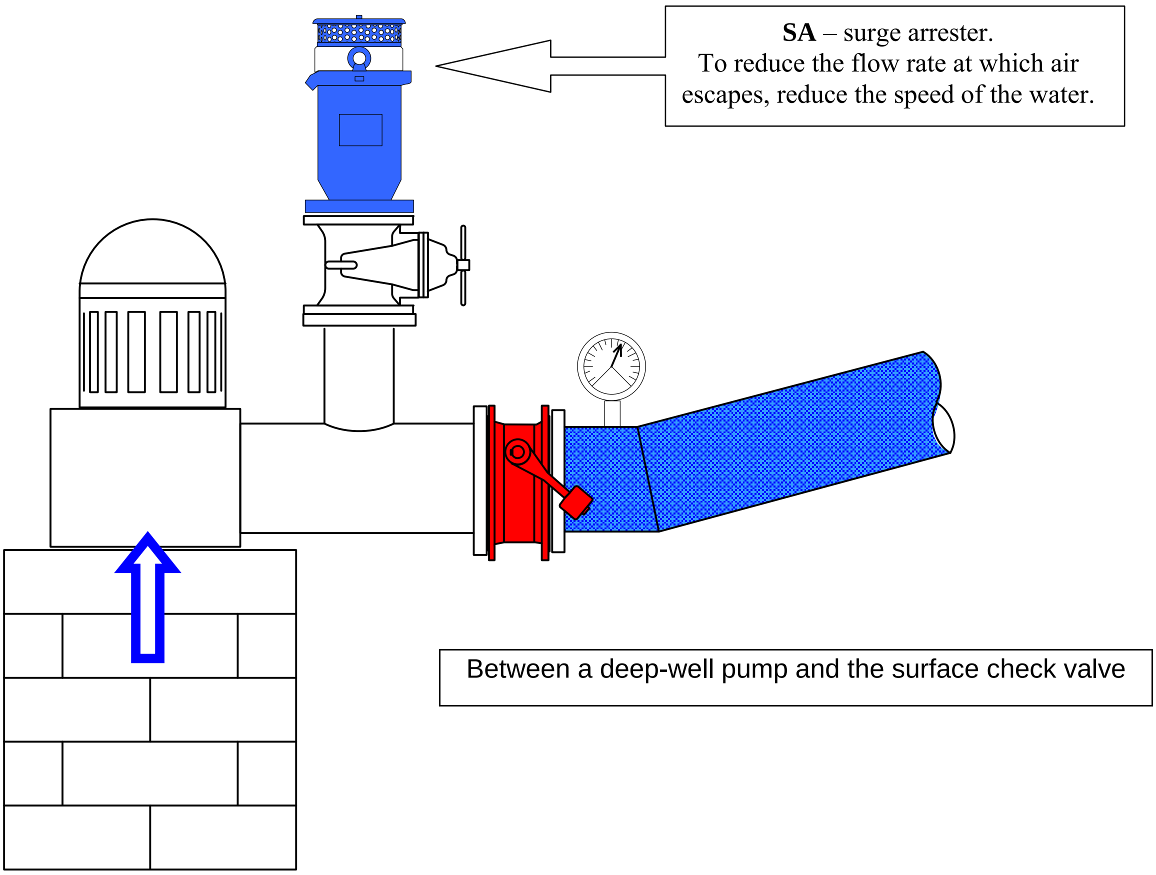
THE VELOCITY OF THE WATER IS LIMITED BY THE

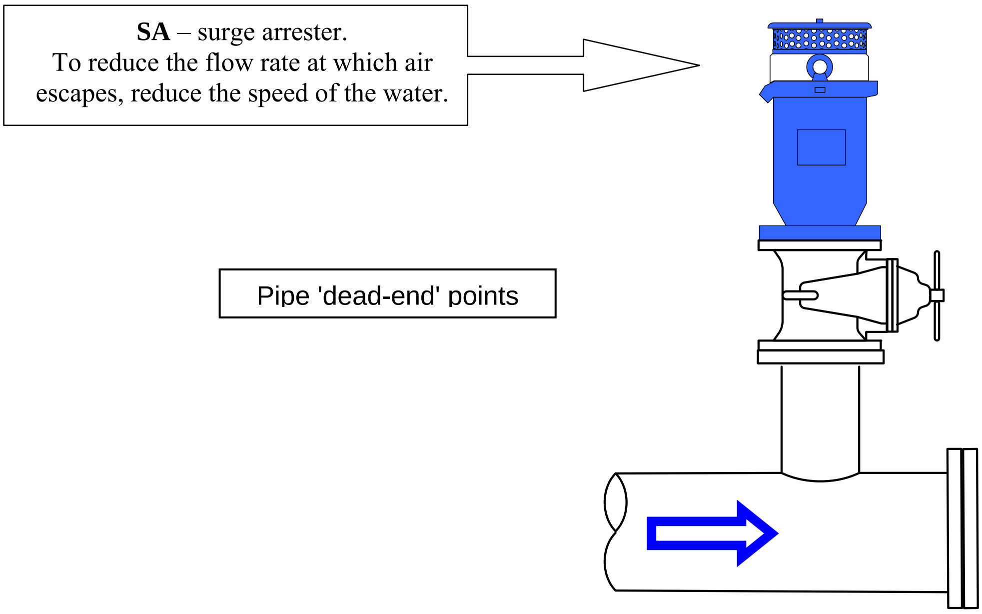
AIR RESISTANCE

Where should air valves with SA devices be positioned?

SA – surge arrester?






SA – surge arrester.
To reduce the flow rate at which air escapes, reduce the speed of the water.
Pipe 'dead-end' points

AirCAD, the Dorot software for sizing in positioning of the air valves in piping systems.

AirCAD is a tool that helps engineers to locate and size air-valves in pipelines.

What information does AirCAD need to operate?

- Topographic profile of the piping system. Based on a multiline AutoCAD drawing or a 2-column Excel spreadsheet: progressive/altimetry **(*)**
- Information on the pipe: material, diameter, thickness.
- Designed Flow.
- Presence of pumps, check valves, cisterns, etc.

What parameters does AirCAD allow the engineer to modify?

- The maximum and minimum distance between each air valve.
- Types of air-valves upstream and downstream of devices such as separation valves, non-return valves etc.

What results does AirCAD produce?

- Number and type of air valves.
- Position of air valves.

How are results shown in AirCAD:

- As an AutoCAD .dxf file **(*)**.
- Tabulated result in an Excel file.

(*) AirCAD is not only an excellent tool for sizing in positioning air valves; as an added benefit, if the original data comes from an Excel file, it is transformed into an AutoCAD multi-layer drawing.

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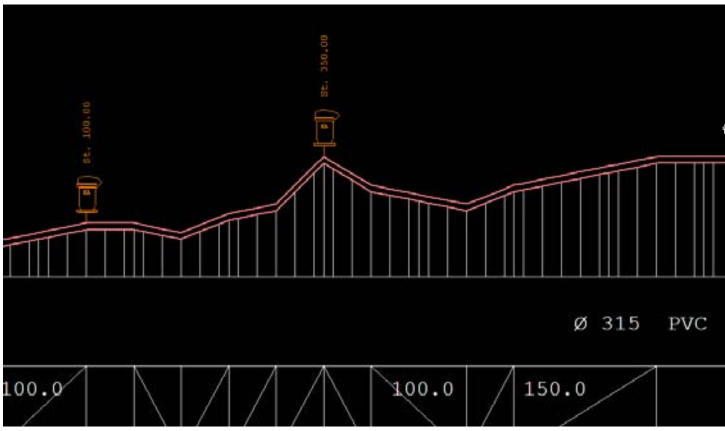
Sample AirCAD Results:



Air valves report

Pipe name is 1.

#	Station	Elevation	Type	Recommended valves: Option A	Recommended valves: Option B
1	0.00	820.30	KA	DAV-MH-2-KA	DAV-P-2-KA
2	205.00	818.31	KA	DAV-MH-2-KA	DAV-P-2-KA
3	409.64	819.30	KA/SA	DAV-MH-2-KA/SA	
4	635.00	817.34	KA	DAV-MH-2-KA	DAV-P-2-KA
5	860.16	818.30	KA/SA	DAV-MH-2-KA/SA	

Summing air valves report

Type	Amount
DAV-MH-2-KA	3
DAV-MH-2-KA/SA	2

AirCAD Engineering: Some aspects the software takes into consideration:

- Air valves must drain the air from the piping while it is filling; for every m3 of water that enters, a cu.m of air must be discharged.
- Air valves must allow air to be reintroduced during emptying, and for every cu.m of water that drains out of the system, a cu.m of air must be introduced into it.
- Air valves must automatically drain air pockets that accumulate at high points when the piping system is pressurized.
- The Bernoulli equation is used to calculate the air that is flowing through the valve orifice

$$V=\text{sqrt}\ (2g*k/(k-1)*P1/\rho*\text{sqrt}\ \{[(P2/P1)^{\wedge}(2/k)]-[(P2/P1)^{\wedge}[(k+1)/k]\}$$

V= velocity of compressed airflow
K = Gas expansion coefficient (air = 1.4)
ρ = compressed air density (depends on the pressure)
P2/P1= pressure ratio before and after the orifice

- The results obtained will be affected by the valve’s efficiency coefficient. Although Dorot has performed testing to determine that the efficiency coefficient for its valves is 0.73, a factor of 0.60 is adopted for use with AirCAD .
- The airflow obtained by Bernoulli and affected by the valve’s efficiency is bases for sizing the air valve orifice.
- The orifice must be sized so that is allows air to enter and escape at a rate equivalent to the flow of water, generating a **dh** of up to 2 mwc. This creates airflow through the orifice at a velocity of 35 m/sec.