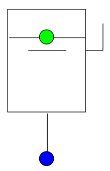
1 Airvessel Vertical Hybrid

1.1 Airvessel Vertical Hybrid (class)



Airvessel vertical hybrid

Supplier type

type label	description	active
Airvessel vertical hybrid	Vertically orientated air vessel with an air valve	No

1.1.1 Mathematical model

The Hybrid airvessel is a combination of a non-vented airvessel and an air valve at a strategic elevation. When the fluid level is above the air valve level, the component is governed by the same equations as the non-vented air vessel (see “AIRVvn (class)” on page 3-198). However, when the fluid reaches the air valve level, the air is expelled via the air valve. The user specifies the initial fluid level/air volume/constant C in steady state, which means that the air valve level can be reached when the air pressure is still greater than the atmospheric pressure. The capacity of the air valve is modelled by the discharge coefficient and in/outflow area. The hybrid air vessel is especially useful in long distance pipelines, in which the initial stage of the transient is the most critical stage. The initial wavefront is much flatter, because of the large air volume. The air valve prevents the air expanding into system in the later stages of the transient scenario.

As long as the fluid is above the air valve level, the governing equations are:

$$PV^{k} = C \tag{1}$$

in which:

P	=	absolute air pressure	[N/m^2]
V	=	air volume	[m^3]
k	=	Laplace coefficient	[-]
C	=	constant	[Nm] if k = 1

The Laplace coefficient depends on the thermodynamic behaviour of the air. Isothermal expansion is described by k = 1. Adiabatic expansion is described by k = 1.4.

The second equation governs the amount of supplying discharge Q:

$$Q = -A_{av} \frac{dx_f}{dt} \tag{2}$$

in which A_{av} denotes the storage surface and x_f the fluid level in the air chamber with respect to the global coordinate system. The minus sign indicates that the chamber supplies fluid to the system when the fluid level is decreasing in time.

When the fluid level is below the air valve level the change of air volume in time is dependent of two phenomena. First, the compression/expansion of the air, secondly the amount of air leaving/entering the system. This state is modelled as the air valve with a certain residual volume (see “VENT (class)” on page 3-360). The residual volume equals the volume between the air valve elevation and the top of the air vessel. The air leaving/entering the system is determined by equations (3) to (6).

1. Subsonic air flow in: $0,53 < \frac{P}{P_0} < 1,0$

$$Q_{air} = C \cdot A \cdot \sqrt{7RT_0} \sqrt{\left(\frac{P}{P_0}\right)^{1,4286} - \left(\frac{P}{P_0}\right)^{1,714}} \tag{3}$$

in which:

A	=	air discharge area	[m^2]
C	=	air discharge coefficient	[-]
P	=	abs. internal pressure on fluid level	[Pa]
P_0	=	atmospheric pressure	[Pa]
R	=	gas constant	[J/kg·K]
T_0	=	ambient air temperature	[K]
Q_{air}	=	air flow (positive if into system: supplier!)	[m^3/s]

2. Critical flow in: $\frac{P}{P_0} < 0,53$

$$Q_{air} = C \cdot A \cdot \sqrt{7RT_0} \cdot 0,259 \tag{4}$$

3. Subsonic air flow out: $1,0 < \frac{P}{P_0} < \frac{1}{0,53}$

$$Q_{air} = C \cdot A \cdot \sqrt{7RT_0} \cdot \left(\frac{P_0}{P}\right)^{\frac{k+1}{2k}} \sqrt{\left(\frac{P_0}{P}\right)^{1,4286} - \left(\frac{P_0}{P}\right)^{1,714}} \tag{5}$$

in which:

k	=	Laplace coefficient (ratio of specific heats)	[-]

4. Critical flow out: $\frac{P}{P_0} > \frac{1}{0,53}$

$$Q_{air} = -C \cdot A \cdot \sqrt{7RT_0} \cdot \left(\frac{P_0}{P}\right)^{\frac{k+1}{2k}} \cdot 0,259 \qquad (6)$$

For steady state calculations the air vessel does not supply fluid and hence the equation for steady state is simply:

$$Q = 0 \qquad (4)$$

1.2 Airvessel vertical hybrid

1.2.1 Hydraulic specifications

description	Input	unit	range	default	remarks
Top level	real	[m]			
Bottom level	real	[m]	(0 100)		
Air inlet level	real	[m]	(0-100)		
Chamber area	real	[-]	(0-100)		
Air quantity by	Fluid Level/ Air volume/ Constant C				See remarks
Initial fluid level	real	[m]			If “air quantity by” = Fluid Level
Initial air volume	real	[m^3]			If “air quantity by” = Air volume
Initial C in P*V = C**Error! Bookmark not defined.**	real	[J]			If “air quantity by” = Constant C
Laplace coefficient	real	[-]	[1-1.4]		
Ambient air temperature	real	[°C]			
Air discharge coeff.	real	[-]			
Air discharge area	real	[m^2]			

See also help on using the Property Window.

Remarks

“Top level”, “Bottom level”, “Air inlet level” and “initial fluid level” are related to the horizontal reference plane.

The air volume and the fluid level in the air vessel are determined by the initial fluid level, the initial air volume or the initial constant C. The user specifies either one of these properties. The other two quantities are calculated by WANDA.

If the user specifies the initial fluid level/air volume/constant C such that the air inlet level is reached when the pressure inside the air chamber is higher than the atmospheric pressure, the air will be expelled via the air inlet. This results in a decreasing C (see equation 1).

1.2.2 Component specific output

Fluid level	[m]	(relative to datum!)
Air volume	[m^3]	-
Air temperature	[°C]	-
Air pressure	[Pa]	-

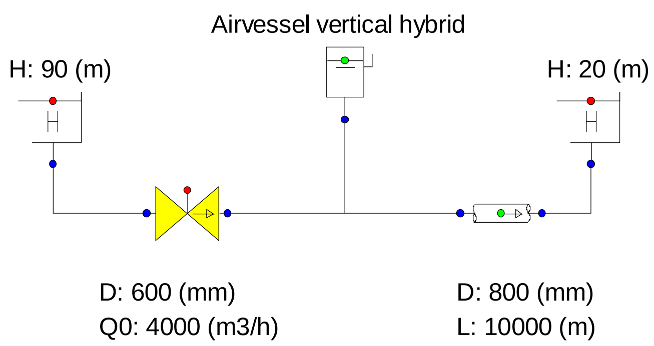
1.2.3 H-actions

None

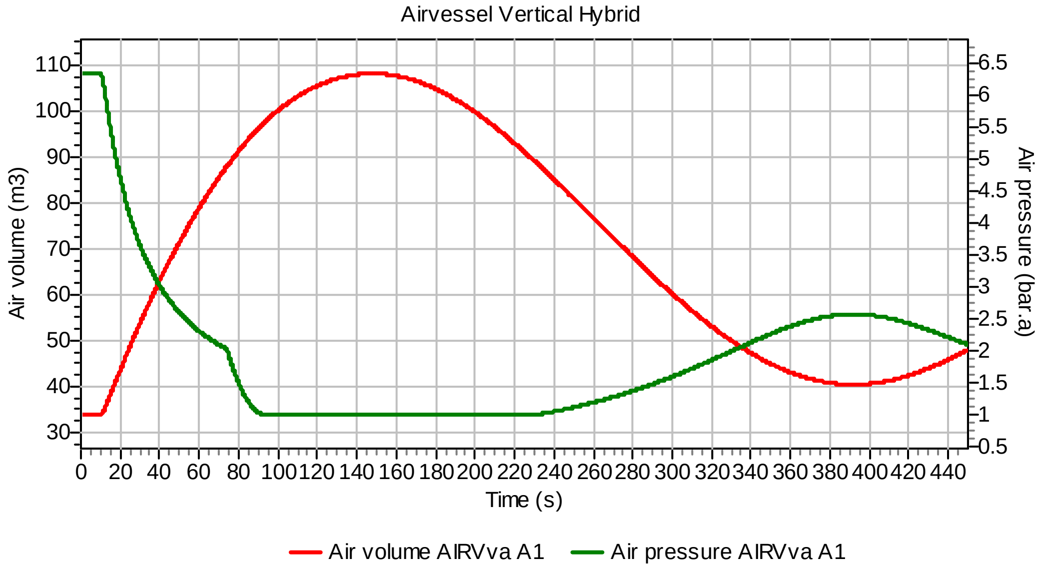
1.2.4 Example

The hybrid airvessel in the example below has the following specifications:

Proppperty	**Value**
Top level	20 m
Bottom level	6 m
Air inlet level	9 m
Chamber area	8 m^2
Air quantity by:	Constant C. C = 21600 kJ
Laplace coefficient	1.20
Ambient temperature	15 °C
Air discharge coeff.	0.9
Air discharge area	0.01770 m^2



The valve closes in 3 seconds.



The air vessel dampens the initial pressure wave, such that the air pressure drops from 6.4 bara to 2.0 bara in 65 s. After 75 s of simulation the air valve level is reached and air is being expelled from the vessel to prevent draining of the air vessel. The graph shows that the air pressure reaches atmospheric pressure at t = 95 s. The downstream boundary condition is large enough to smoothly shut the air valve after 340 s.

1.2.5 Component messages

message	explanation
ERROR: Initial fluid level not in between top and bottom level of air chamber	Input error. Keep in mind that the air vessel is inclined and that the fluid level is still relative to the horizontal reference plane.
ERROR: Initial fluid level inconsistent with steady head	The initial fluid level is below the air inlet level and inconsistent with the pressure head.
WARNING: empty air chamber	The fluid level has dropped below the bottom. The storage area becomes zero and further calculations can not be carried out.
WARNING: Accuracy not obtained in computing fluid level as function of volume with bisection method	This warning should not normally occur and is intended to warn the programmer.
WARNING: Initial fluid level below air valve level. Air pressure is atmospheric.	
INFO: Air inlet is closed	
INFO: Air inlet is open	
INFO: Air inlet opens	
INFO: Air inlet closes	