Report
Experimental Examination of Air Valves

for:

AIRVALVE Flow Control GmbH

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1. Tasks and Objectives

Fraunhofer UMSICHT is assigned to investigate the dynamic behaviour of five different A.R.I air valve types at pressure surge conditions. The aim is to determine, if A.R.I air valves are capable of protecting a pipeline system against cavitational hammers, induced downstream of a fast closing valve. Therefore, several air valve types are installed in Fraunhofer UMSICHT's test rig in Oberhausen (see Fig. 1). In each run two valves are built within the system, driving one (at PO3 or at PO9), two (at PO3 and PO9) or none of them. After the steady state velocity of 4 m/s has been established, the valve at Pos.1 is shut rapidly and the pressure time history is recorded at various measuring positions.

Furthermore, some of the tests are driven with reversal flow in order to investigate the performance of air valves positioned on the upstream side of a fast closing valve. To underline the "hard" with "visual" data, videoclips are made during the experiments.

The objectives of the experiments are:

- to investigate the influence of airvalves on pressure time-history and maximum pressure

- to investigate several airvalve types on system pressure

- to find hints on how to improve airvalve construction

The configuration of the Fraunhofer UMSICHT test loop PPP (Pilot Plant Pipework) is shown below (figure 1). Demineralized tap water is pumped from the pressurized vessel B2 through the pipe and back to the vessel. At t = 0 sec the valve at Pos. 1 closes rapidly while the pump is still running. During the first phase of the transient, a rarefaction wave is travelling inside the pipe towards the downstream reservoir. As a consequence, cavitation occurs downstream the valve and a vapour bubble is formed. The generated pressure wave oscillates between the vessel and the vapour bubble until the cavitation condenses, inducing a cavitational hammer. The axial position of the pump, the valve, the fix points (FP), where the force measuring devices are mounted, as well as the position of the wire mesh sensor (GS) and the pressure sensors (P01 – P23) are denoted.
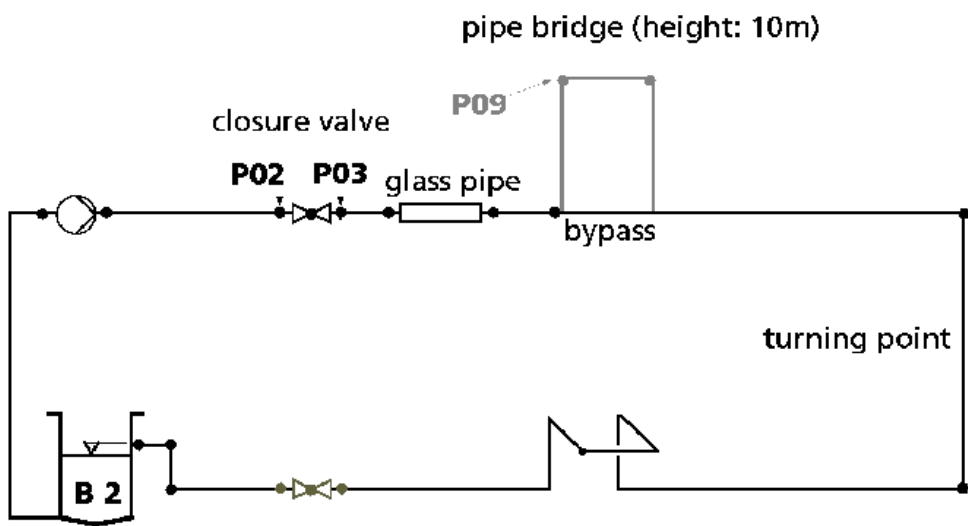
pipe bridge (height: 10m)

Fig. 1 P&I Sheet for the test rig and 3D scheme

2. General results

This study deals with the examination of A.R.I. air valves under pressure surge conditions. Thereby the tested air valves turn out to be effective means to protect pipelines against cavitational hammer very good. In addition, A.R.I. airvalves are also capable to reduce *secondary* water hammer if they are placed upstream a fast closing valve.

Type D070 shows the best performance (also seen in the video material) and is taken as a basis of comparison to show the effect of air valves under pressure surge conditions.

3. Experimental results with air valves downstream the closure valve

Figure 2 illustrates the pressure history at P03 performed with air valves positioned downstream the shut off valve. The red curve shows experimental results without air valves. Due to valve closure there is a pressure drop downstream. The picture below shows the same experiments for the period of 2 seconds.

As a result, a cavitational bubble is formed, which re-condensates abruptly when the backflow arrives. The re-condensation is accompanied by a cavitational hammer with a magnitude of nearly 45 bar.
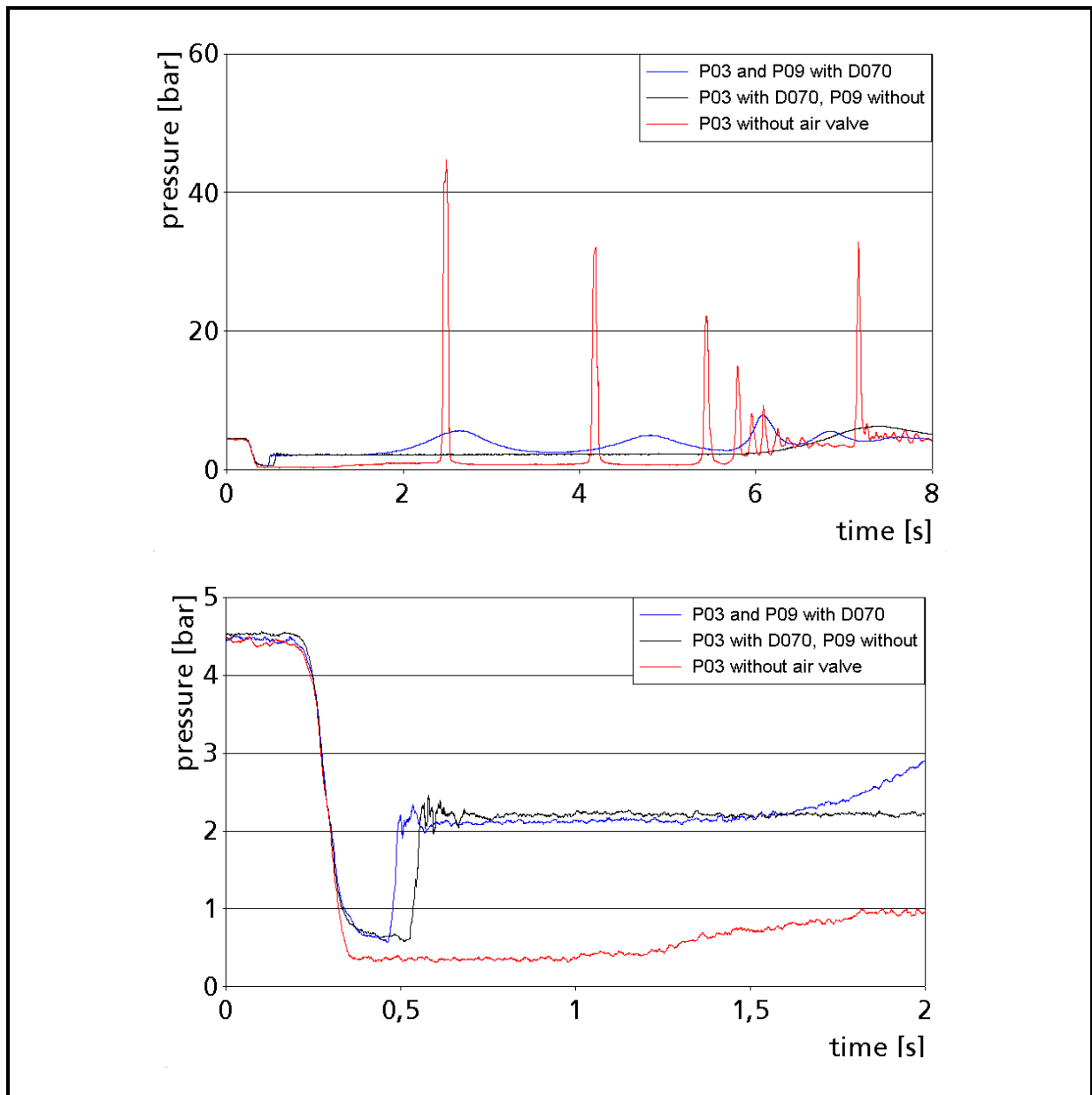

Fig. 2 Pressure at P03; air valves on the downstream side

With respect to the blue curve, one can see that no cavitational hammer occur if the airvalve type DO70 is activated at P03 and P09. Also the total time of low pressure is comparatively

small. Good results are also achieved by using a D070 only at position P09. As shown in the zoom figure, the level of the system pressure is higher when air valves are applied. Vapour pressure is not reached. For the experiments without air valve there is an increase in pressure after 1 sec. because air comes out of solution due to the low system pressure. This process is referred to as "degassing".

3.1 Comparison: Different activated air valves at P03; measured at P03

The following chart demonstrates the investigated pressure time histories using several air valve types, exclusively positioned at P03. All experiments are performed under the same experimental conditions. Figure 3 indicates that there are no big differences between the investigated valve types within this constellation. The pressure rise up to nearly 6 bar (t=7s) is caused by a re-opening of the shut-off valve.
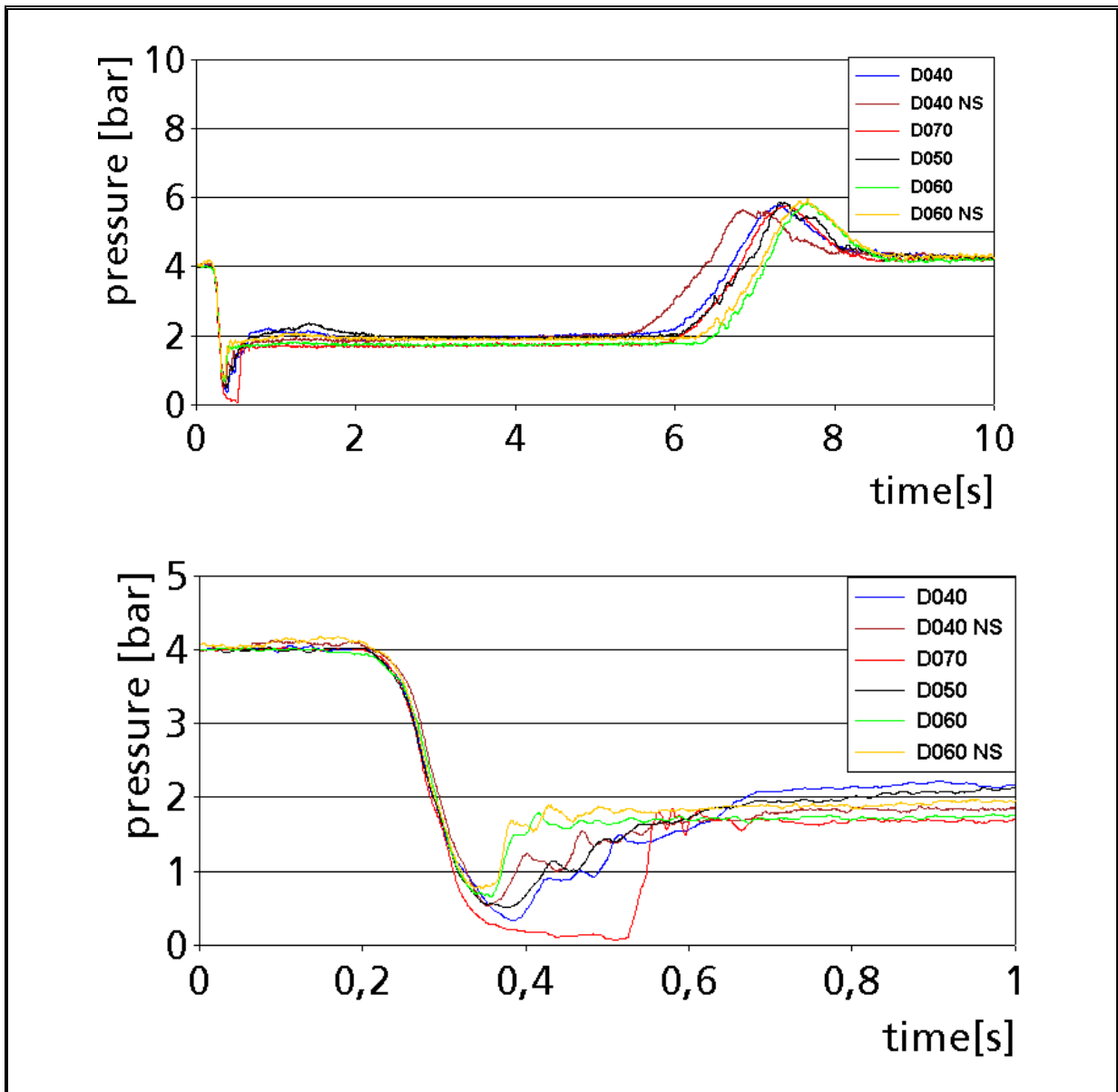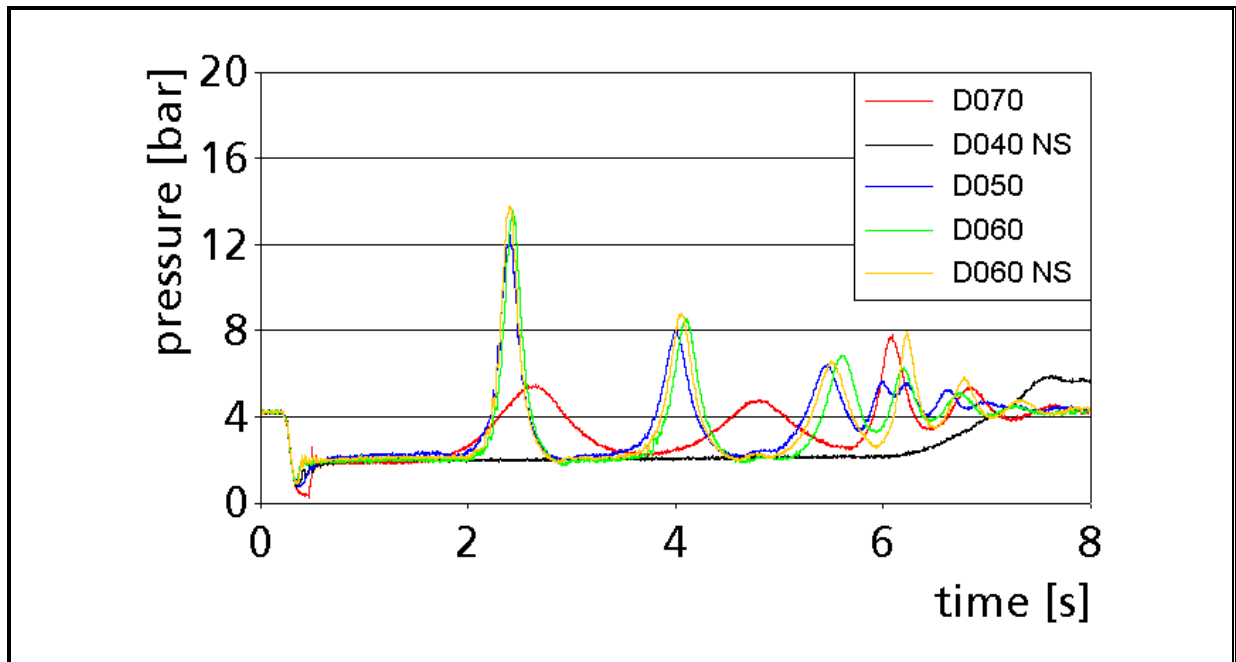
Fig. 3 Pressure at P03; air valves on the downstream side

The extension shows that both D060 an D060 NS have the lowest and shortest down-surges because they have the largest orifices, and thus, the largest capacity. Consequently they also have a quicker response time to air intake than the D070.

3.2   Comparison: Different activated air valves at P03 and P09; measured at P03

The use of an additional air valve at P09 is accompanied by supplementary slight water hammer which occur when the air valves close during a simultaneous water outflow. The air valve type D040 NS seems to give best over-all results, even better than the D070. That is because its response to air intake is quicker than that of the D-070 (even though the capacity is much lower), and its air discharge is throttled and controlled through a much smaller orifice, thus preventing the "air slam", resulting in the small upsurge.
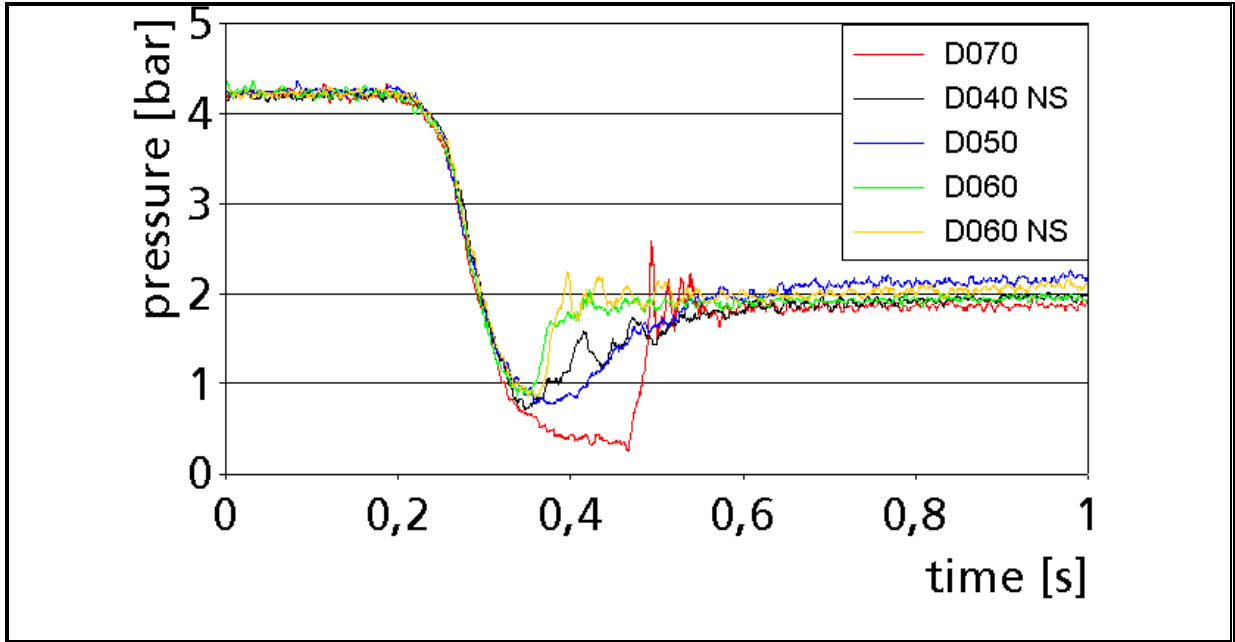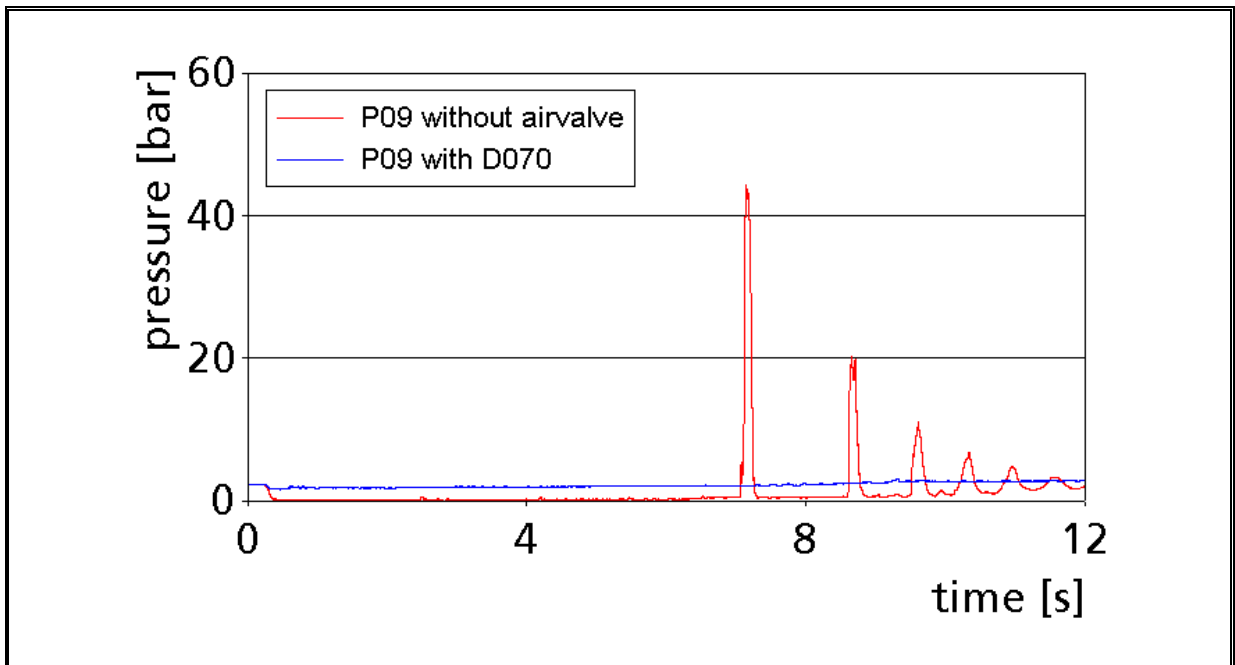
Fig. 4 Pressure at P03; air valves on the downstream side

These small additional water hammer (in comparison to the flat curves using only one air valve at PO3) occur because the air valve at P09 opens so that the pressure at the top of the bridge doesn`t reach vapour pressure. Therefore the liquid column may oscillate between the bridge and the closed valve much easier (see also Fig 5).

3.3   Comparison: with and without air valve; measured at Position P09

Because of an activated D070 at position P09, there is nearly no drop on vapour pressure and cavitational hammer do not appear in contrast to experiments without air valve.
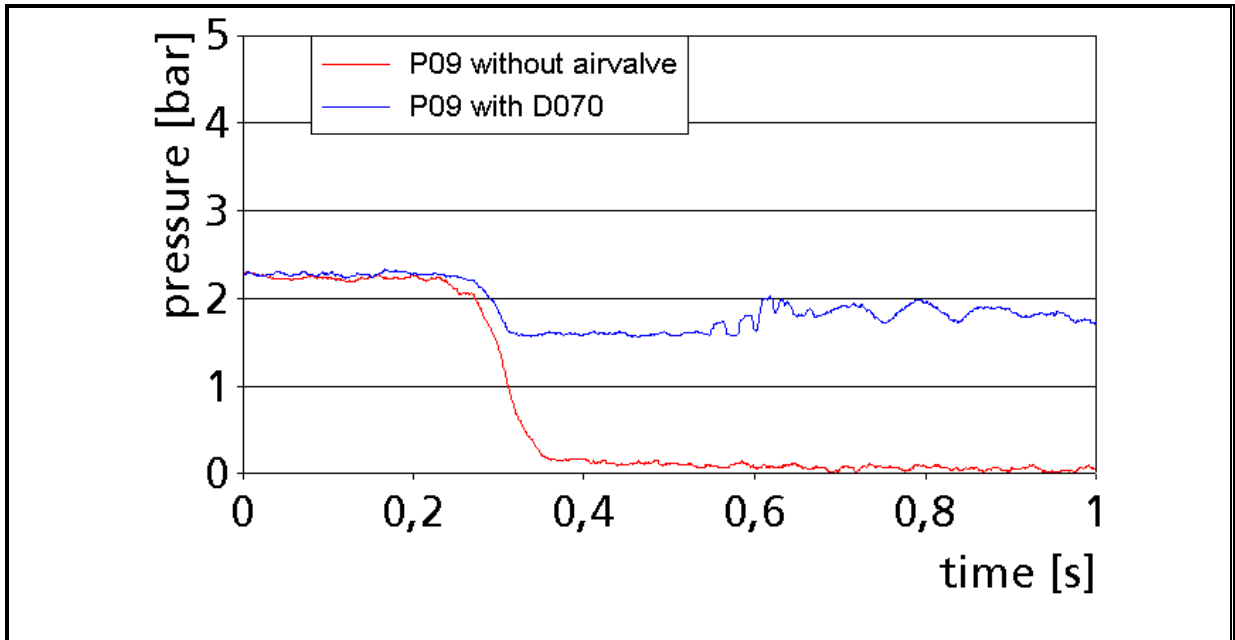
Fig. 5 Pressure at P09; air valves on the downstream side

For the experiment without air valve, there is a cavitational hammer of about 45 bar, which is caused by a re-opening of the shut-off valve at t=7s. In this case water flows from the upstream side into the cavitational bubble, which leads to an abrupt re-condensation.

3.4 Comparison: Different activated air valve types activated at P09; measured at P09

Figure 6 describes the performance of different air valve types at P09. Compared to the other valves, the D040 series yield the largest pressure drop, whereas D040 NS shows less good results (maybe due to a lower Kv-value?). Furthermore, there is no significant difference between the types D050, D060 and D070. The D-040 and the D-040 NS have the highest down-surges because they have by far the smallest orifice and, thus, the smallest air intake capacity.
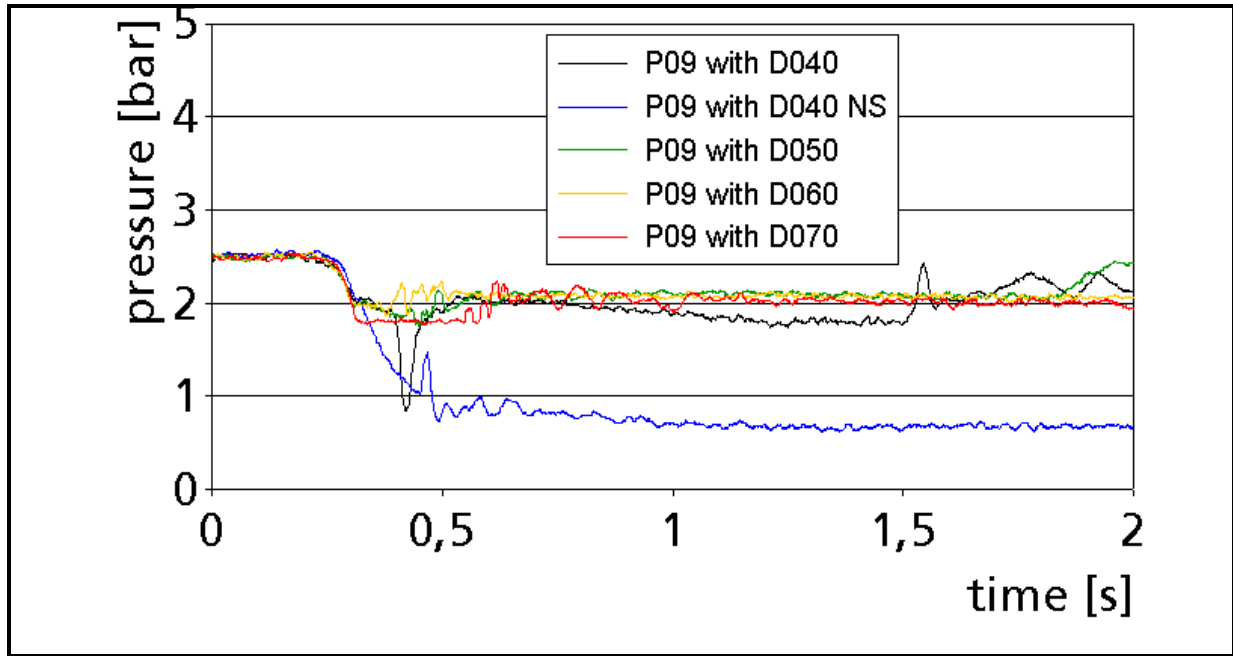
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Fig. 6 air valves only activated in P09; measured at P09

4. Experimental results with air valves upstream the closure valve (water hammer)

This scenario investigates the dynamic behaviour of air valves positioned on the upstream side of a fast closing valve. The flow direction is now in the reverse direction. The measuring position P03 is now *up*stream, P02 *down*stream the valve.

4.1   Air valves upstream the closure valve; measured at P03

The red curve makes obvious that several water hammer appear due to the fast valve closure when no air valves are used.

At the instant of valve closure the fluid nearest the valve is retarded and compressed. As soon as the first layer is stopped, the process is repeated for the next layer. Because of inertia, the fluid upstream the valve continues to move downstream with the steady state velocity until all layers are stopped successively. This process is accompanied by a pressure wave, which moves upstream and brings the flow to rest. When the pressure wave reaches the vessel, there is an unbalanced condition since the vessel pressure is constant. As a consequence fluid flows into the pipe and the flow is reversed. A negative pressure wave is generated, which is reflected at the shut off valve. Since the valve is closed no fluid is available to maintain the flow at the valve, the fluid evaporates an a cavitational bubble is formed on the upstream side.

By comparing the blue and black curve, one comes to the conclusion that two air valves - one immediately upstream the valve and the second located top of the pipe bridge- give best protection against water hammer. That is why the overpressure wave created at the valve is reflected as an underpressure wave at the vessel and propagates back to the valve where it is again reflected as an underpressure wave. This results in cavitation at P03 and P09.
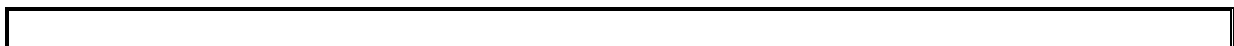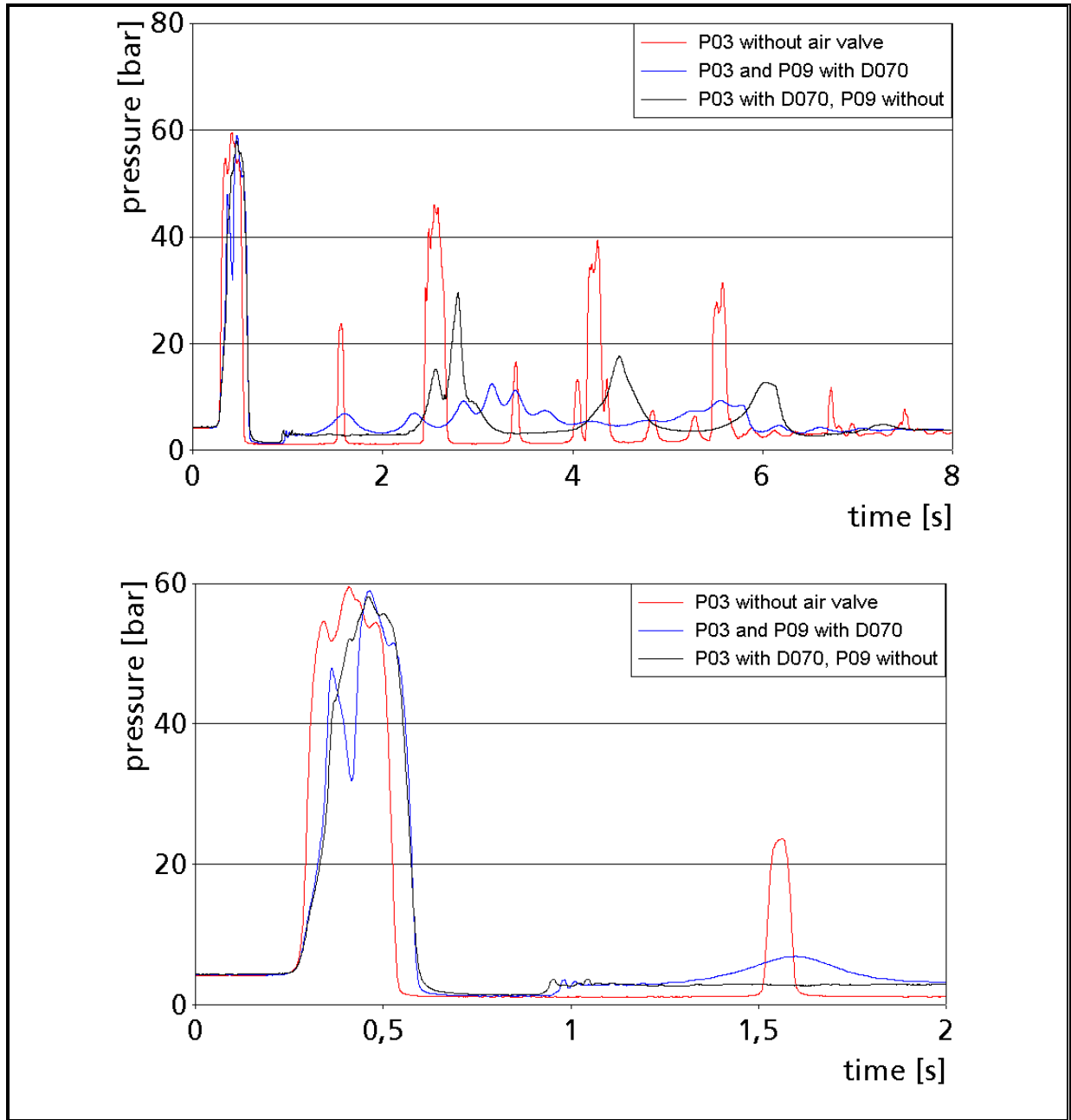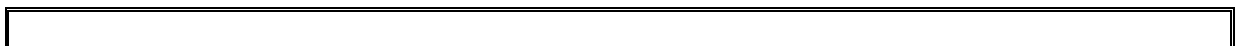
Fig. 7 Pressure at P03; air valves on the upstream side
(reverse flow, P03 is now *upstream* the valve)

4.2 Air valve upstream the closure valve; measured at P09

Figure 8 describes the pressure time history with and without air valve in P09. As expected, the use of an air valve in P09 reduces the exposure of water hammer.
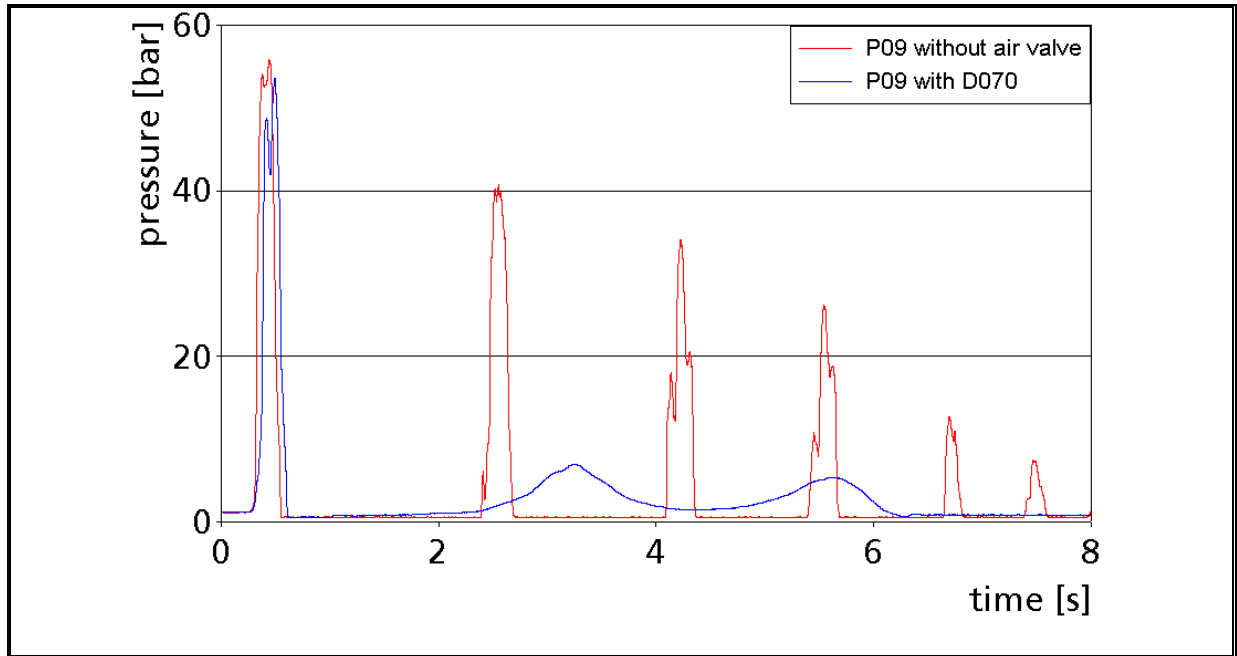
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Fig. 8 Pressure at P09; air valves on the upstream side

5. List of experiments

Experiment Number	Aaa P03[1]	Aaa P09[2]
132m010c01b00601d010	-	-
132m010c01b00608d010	D060	D060
132m010c01b00609d010	D060	-
132m010c01b00610d010	D060 NS	-
132m010c01b00611d010	D060 NS	D060
132m010c01b00612d010	D070	-
132m010c01b00613d010	D070	D060
132m010c01b00614d010	D070	D070
132m010c01b00615d010 (reverse flow)	D070	-
132m010c01b00616d010 (reverse flow)	D070	D070
132m010c01b00617d010 (reverse flow)	-	D070
132m010c01b00618d010 (reverse flow)	-	-
132m010c01b00619d010	D040	-
132m010c01b00620d010	-	D040
132m010c01b00621d010	D040 NS	-
132m010c01b00622d010	D040 NS	D040 NS
132m010c01b00623d010	D040 NS	D060
132m010c01b00624d010	D060	-
132m010c01b00625d010	D050	-
132m010c01b00626d010	D050	D050

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[1] Airvalve active at

[2] Airvalve active at