

INTERNATIONAL

WATER & IRRIGATION

Vol. 27, No. 3, 2007



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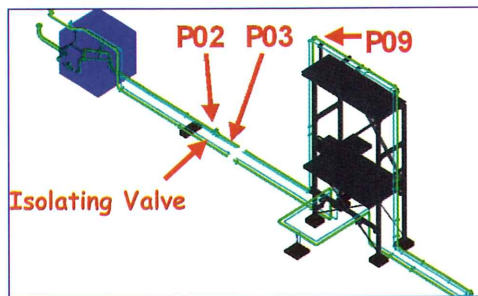


A.R.I. FLOW CONTROL ACCESSORIES

ARJ Air Valves and Pressure Surge

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Air valves are an important tool for surge dampening and suppression. Accurate air valve specification, location and sizing are vitally essential for effective, efficient liquid flow and for sufficient pressure surge dampening and suppression. In the scope of this short article, I will not go into details of the phenomena of pressure transients in liquid conveyance systems. But, I will describe several phenomena related to pressure surge events and will discuss some of the air valves that were designed for surge protection. Much has been written about the contribution of air valves to flow efficiency, therefore, I will not discuss this subject in this article.



Introduction

Air plays a very important role in liquid flow in pipelines and in liquid conveyance and treatment systems in general. Surge suppression is one of the primary purposes for airflow control in liquid conveyance systems.

Air valves are universally recognized as the most effective airflow control tools for liquid

conveyance systems. Their contribution to efficient liquid flow, to energy savings and to down-surge suppression is widely acknowledged, but their positive contribution to upsurge suppression is often challenged.

Recognition and confidence in air valves as surge suppressers have improved with the development of non-slam, and other specially designed, surge dampening and suppressing air valves, and with innovations in the design of user friendly, yet powerful software tools for analysis and design of air valve airflow control systems.

Water Column Separation and Surge

Most surge or water hammer episodes are accompanied by full or partial water column separation. Sometimes water column separation occurs at the start of the surge episode, prior to the first upsurge of the episode, and sometimes it occurs following the initial upsurge. When water column separation occurs in a pipeline, a cavity or void is formed. This phenomenon is sometimes called "cavitation". The level of "completeness" (full or partial) of the column separation can be expressed by the void fraction, where 1 (unity) expresses full separation and any value below 1 expresses partial separation. Full column separation usually occurs at pump stations, at in-line valve locations, and at peaks in the pipeline that are close to the hydraulic gradeline. Full separation can cause very substantial pressure drops, depending on the velocity change at the instant of occurrence. Partial separation can occur at almost any point along the pipeline, under certain conditions. For instance, when two negative pressure waves cross each other, and their combined negative head is higher than the system operating head prior to the surge episode, intermediate cavities can form.

When referring to "surge", people usually mean a sudden, very significant pressure **rise**.



Surge test rig

Suppression

If we define “surge” to be a sudden, very significant pressure **change**, the pressure drop at column separation can, also, be considered a surge, and be referred to as a down-surge. When the down-surge is extreme, and pressure drops to below vapor pressure, the tail end of the column changes phase to vapor. The void, or cavity, fills with vapor and is, thus, called a “vapor cavity”.

There are those who distinguish between “void” and “cavity”, and consider only vapor cavity to be a “cavity”, and “cavitation” to be an event where a vapor cavity is formed. Liquid transients are sometimes divided into two types of flow regimes, a “water hammer regime”, where pressure does not drop to the vapor pressure of the liquid, and no “cavitation” occurs (no vapor cavity formation), and a “cavitation regime”, where pressure is at or below vapor pressure (Anton Bergant et al. 2006).

When a surge episode is initiated by an upsurge caused by a water column slamming against a dead end or a closed valve (at pipe filling, for instance), the water column can bounce off the valve or the dead end (the point of impact), leaving a void behind it. This bouncing-off can be considered a column separation event, which induces a down-surge. This down-surge affects a deceleration in the water column flow away from the point of impact, causes a flow reversal, and accelerates the flow, back, in the direction of the point of impact. Due to increase in velocity brought about by the “pulling” (suction) forces of the down-surge, the subsequent second upsurge at the point of impact is often greater than the initial upsurge.

At the end of the nineteenth century, Joukowski, one of the fathers of twentieth century surge research, who developed the equation that carries his name: observed and understood the phenomenon of water column separation and recognized that the second impact (surge) is stronger than the first

(Anton Bergant et al. 2006).

If a returning pressure wave arrives at the point of impact at the instant of impact of the returning water column, the consequent upsurge can be very much greater. If the down-surge at column separation reaches vapor pressure, and a vapor cavity forms, the collapse of the vapor cavity greatly increases the upsurge. The size of the vapor cavity depends, both, on the intensity and the duration of the down-surge, and the intensity of the consequent upsurge is greatly influenced by the size of the vapor cavity. The second upsurge will be followed by a consequent down-surge, followed by recurring upsurges and down-surges, until the excess energy of the surge episode depletes.

Many surge episodes are initiated by a water column separation triggered down surge. These surge events can result from sudden pump shut-offs (at power failure, for instance), from fast, sudden valve closure (down-stream from the valve), from pipe burst, from pipe drainage, from sudden peak flow demands at times of low flow supply, etc'. If there is no water column return, such as at pipe drainage, there is, usually, no significant consequent upsurge, but damage can still be extremely intensive.

If the water column does return, there will be a consequent upsurge, followed by recurring down-surges and upsurges, just like surge episodes initiated by an upsurge.

All in all, what happens during water column separation and/or vapor cavity formation has a great effect on the intensity of both, the down-surge, and the upsurge. If we could control cavity formation at water column separation, we could control the otherwise consequent upsurges and down-surges. This is where air valves come to play.

Air Valves and Pressure Surges

When air valves are installed in the location along the pipeline where column separation

occurs, they act in two major ways to control the anticipated consequent down-surge. As the decreasing pressure in the column separation site reaches around atmospheric pressure, the air valves open, admitting air into the pipeline, and exposing the column separation site to the atmosphere. The admitted air replaces the departing water column, thus, preventing or controlling the formation of a void (vacuum cavity). By exposing the column separation site to the atmosphere, the air valves expose the site to atmospheric pressure, thus, halting the pressure drop, preventing its decrease to vapor pressure, and avoiding the formation of a destructive vapor cavity. These greatly limit the intensity of the initial pressure wave, halt the acceleration of the returning water column, prevent vapor cavity collapse (since there is no vapor cavity) and, thus, suppress, or even eliminate any consequent upsurges.

In the past, some surge experts, such as Dr. Don J. Wood of the University of Kentucky, were skeptical of air valves as tools for surge suppression. They were convinced that air valves caused local surges that often increased the intensity of the overall surges in the system. This was true, especially, for nominal air valves, as required by the AWWA Standard C-512 for air valves. Air/vacuum valves, are usually sized for vacuum protection, and have very large orifices to enable intake of air at high flowrates to control down-surges. When the same orifice serves for air discharge, the discharge flowrate is, also, very high. The velocity of the water column following the discharging air pocket is very high, and when the air valve slams shut, the water column comes to an abrupt stop, resulting in a high upsurge.

“Air Slam” and Non-Slam Air Valves

Dr. Don J. Wood and Dr. Srinivasa Lingireddy, the renowned surge experts who developed University of Kentucky’s KY Pipe

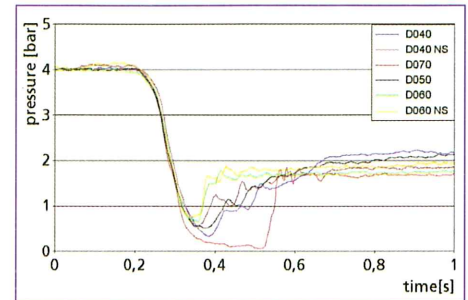
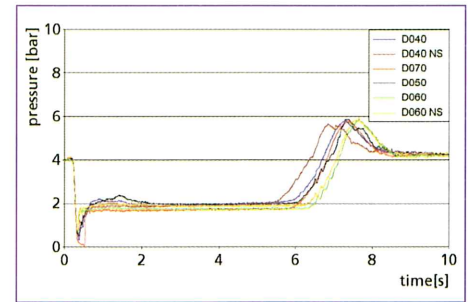
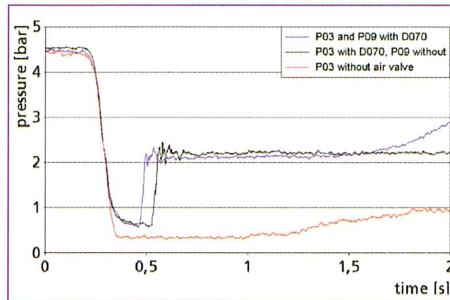
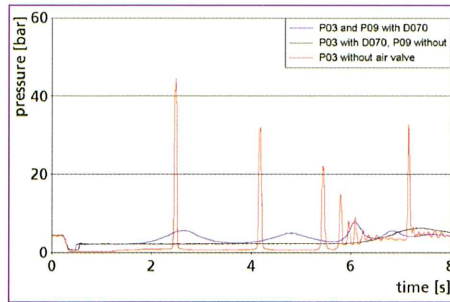
surge analysis software (today, Surge 2008), investigated this phenomenon, which they call "Air Slam". They published a comprehensive article (with some collaboration from this author), in the July 2004 issue of the American Water Works Association Journal (Srinivasa Lingireddy et al. 2004). In this article, it was shown that the larger the discharge orifice, the higher the surge, and that by throttling the discharge air flow through a smaller orifice, the surge at air valve closure can be eliminated. In this study, an A.R.I D-060 HF NS non slam combination air valve was used, and was shown to repress the "air slam", or surge, that occurred without the air valve's non-slam mechanism. This valve allows intake of air at very high flowrates, through its large, nominal orifice, but, when the water column returns, air discharge rushing through the air valve causes a disc with a much smaller orifice to rise and cover the large orifice, throttling the air through the small orifice.

Experimental Examination of Air Valves at Fraunhofer UMSICHT

The Fraunhofer-Institute for Environmental, Safety and Energy Technology UMSICHT (Fraunhofer UMSICHT) is a non-profit scientific / technical institute located in Oberhausen, Germany. Fraunhofer UMSICHT is highly recognized, throughout Europe, for its expertise in Surge research and its advanced surge research facilities. Dr.-Ing. Andreas Dudlik, the Head of the Division of Pipeline Technology of Fraunhofer UMSICHT did his doctoral thesis on the experimental and theoretical investigation on water hammer and cavitation in pipes, in 1999, and conducted research, and wrote a number of papers on surge, since then.

In November, 2004, Dr. Dudlik and his team conducted a set of experiments on air valves on Fraunhofer UMSICHT's special, advanced, Surge test rig in Oberhausen. They were assigned to investigate the dynamic behavior of six different air valve models manufactured by A.R.I. Flow Control Accessories.

Water was pumped through a 100mm pipeline at a steady state velocity of 4 m/s when an automatic shut-off valve was closed very rapidly. Tests were conducted without any surge protection, and with protection



Pressure at PO3 without and with air valve surge protection

provided by each of the six types of A.R.I. air valves. Three of the air valves tested were regular combination air valves, the D-040, the D-050, and the D-060 HF. Two of the air valves were float type non-slam combination air valves, one with a single stage kinetic discharge, the D-040 NS, and the second, with a two stage kinetic discharge, the D-060 HF NS. The sixth air valve tested was a new, revolutionary, non-float, diaphragm operated air valve, the D-070 dynamic, surge suppressing, combination air valve.

Some surge engineers are skeptical of air valves as surge control tools, and one of their claims is that the reaction time of air valves is too long, and serious down-surges can develop before the air valves open. The experiments conducted by Dr. Dudlik's team at Fraunhofer UMSICHT, in November, 2004, proved that the A.R.I. air valves tested were very fast acting, and were extremely effective and efficient in protecting pipelines "against cavitation hammer". Whereas without air valves surge reached above 42 bar (609 psi), the A.R.I. air valves eliminated the surge. Furthermore, Dr. Dudlik concluded that "A.R.I. air valves are also capable to reduce secondary water hammer if they are placed upstream a fast closing valve" (Dr.-Ing. A. Dudlik et al. September 2005).

Conclusion

A.R.I. air valves, especially the non-slam and the dynamic air valves, are very effective and

efficient tools for surge suppression. In many cases alone, and in systems with very large diameter pipes, in combination with other surge suppressing equipment, such as hydraulically controlled check valves, air vessels, surge tanks, surge control valves, etc., A.R.I. air valves are the most cost effective surge protectors.

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