AVOID THE SQUEEZE ON YOUR WALLET & PIPELINE: ARV STRATEGIES

K. Rutherford, P.E., and K. LaBree, E.I.T.
Parkhill, Smith & Cooper
501 W. San Antonio
El Paso, TX 79901

ABSTRACT

Much like medical stents are to a heart patient, air valves to a pipeline can mean the difference between an emergency and peace of mind.

The results from a design strategy that saved a city in the Texas Panhandle almost a third of the total cost in air valves on a pipeline from a nearby well field is making Engineers and Owners take notice.

As parched Southwest communities struggle to add to their water sources, pipeline designers look to make their projects as efficient as possible. An interesting case study in Borger, Texas, focused on an innovative approach that used hydraulic modeling to protect pipelines and cut the number of air valves needed by 59 percent. This saved almost a third of the air valve cost.

Borger's pipeline crosses the Canadian River and traverses terrain that is 383 feet from the highest point to the lowest point. The pipeline transports 10 million gallons of water a day from the pump station to the city, which feeds major industrial customers and domestic users.

This design strategy isn't specific to this situation; it can save your clients money, too. If there is too much vacuum and no way to admit air, a pipe could crush like a Coke can being twisted. Hydraulic modeling allows you to run a surge analysis on the pipeline to find weaknesses so that you can place air release valves strategically to keep the pipeline healthy.

Three types of air valves can be used throughout a pipeline. Air release valves contain a small orifice that releases air continuously during operation. Air/vacuum valves contain a large orifice that releases air on startup and admits air on shutdown. These valves will not open until the pressure is very low or near zero. Combination air valves work as both an air release valve and an air/vacuum valve. Theoretically, air valves are placed at pump discharges, along sloping runs, when there are changes in slope, and at high points along the pipeline.

PSC engineers initially used an air valve manufacturer's program to get the manufacturer's recommendations for the pipeline. The manufacturer's software requires that you input all the high and low points of the pipeline and determine where air valves need to be placed. However, the Borger pipeline, a concrete steel cylinder transmission line, extends about 14 miles. The slide-rule calculations generally are for shorter distances. The manufacturer's program called for 117 air valves, which was not cost-effective. So PSC used hydraulic modeling, which showed through transient analysis that they would need 48 combination air valves ranging from 4 to 12 inches in size. The air release valve costs were originally going to be over $1.2 million; with hydraulic modeling, they ended up under $880,000.

The project piqued the interest of El Paso Water Utilities and the American Council of Engineering Companies, which requested a presentation in February 2015, comparing the costs of each type of work.

Using hydraulic modeling rather than manufacturers' recommendations for air valve placement can significantly reduce capital cost on your project while still protecting your pipeline.

KEYWORDS

Air lock, cavitation, surge, transient, wave speed, air valve, air release valve, vacuum valve.

INTRODUCTION

Pipelines are a necessity in the water community, whether it is transporting water from the water treatment plant to a household or if it is transporting water miles across the county from a well field. Either way, pipelines are important in transporting water. As you will read, all water pipelines will collect air in them, this air needs a way to escape and what better way to release this air than with an air valve?

What are air valves?

In the early 1900s, the water industry started to understand problems that were caused by air in the pipelines. This started the placement of manual valves at high points along the pipelines to bleed off accumulated air. Standpipes were then placed along pipelines to create high points for air to escape. The problem with these two approaches was that it was impossible to predict when the air needed to be vented and it required a lot of manpower to regularly operate the manual release valves in a large system. In the late 1960s, automatic air valves started to appear in the industry. Development of other types of air valves followed this. In 1992, the American Water Works Association (AWWA) published the first air valve standard.

Types of air valves

The three types of air valves are: air release valves, air/vacuum valves, and combination air valves. Air release valves contain a small orifice that releases air continuously during operation. Air/vacuum valves contain a large orifice that releases air on startup and admits air on shutdown. The orifices on this valve will not open until the pressure is very low or near zero. Combination air valves work as both air release valves and air/vacuum valves, allowing air release, releasing air on startup and admitting air on shutdown, and allowing air to be continuously released.

Why use air valves

It is important to use air valves to release and admit air when filling or draining pipes. Empty pipes are filled with air. When a pipeline is filled, this air gets trapped within the pipe. Using a manual relief such as a hydrant will only release a portion of the air. Since hydrants are typically connected to the side of the pipe, there is still air trapped along the top of the pipe that is not released. Water also typically has about 2 percent of air entrained in it, this air will also need to be released. Draining a pipeline can cause a vacuum if air is not admitted into the line. Creating a vacuum can damage and collapse the pipe.

Air that gets trapped at the high points along your pipeline can reduce the flow diameter in the line, which will cause a higher velocity and create a larger head loss throughout the line. Once air gets trapped at a high point, it can cause air lock. Air lock is when air completely fills a high point and the flow velocity is too low to move the air downstream, restricting flow through the pipe.

Using air release valves can also help with transient suppression and control. If a pipe cannot admit air when it is under vacuum conditions, it can cause the pipe to cavitate. A sudden change in flow rates can produce water hammer, which can cause damage to your pipe. This can create negative pressure along your pipeline. Adding combination air valves will prevent this negative pressure and prevent pipe collapse.

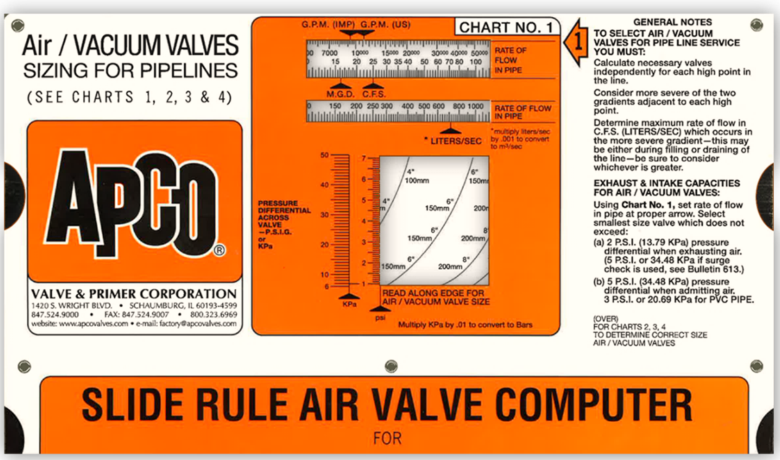
DISCUSSION

How to Place and Size Air Valves

Theoretically, air valves are to be placed at pump discharge locations, along long sloping runs, along changes in pipe slope and at high points along the pipeline.

There are many different ways to size air valves for your pipeline, with manufacturer's tools or the engineered approach of using transient analysis. Valve manufacturers have different tools, such as slide rule calculators, graphs, tables, and proprietary software. These tools will allow you to calculate the size of one valve at a time using the flow being pumped through the pipe, the size of the pipe and the slope of the pipe. Figure 1 shows a slide rule calculator from APCO. This slide rule calculator is used by matching the pipe diameter with the slope of the pipe on the back of the calculator. From this you will get a corresponding flow. The flow is then used on the front side of the calculator, and from this you will get corresponding valve sizes on the chart.

Figure 1. Slide Rule Calculator.



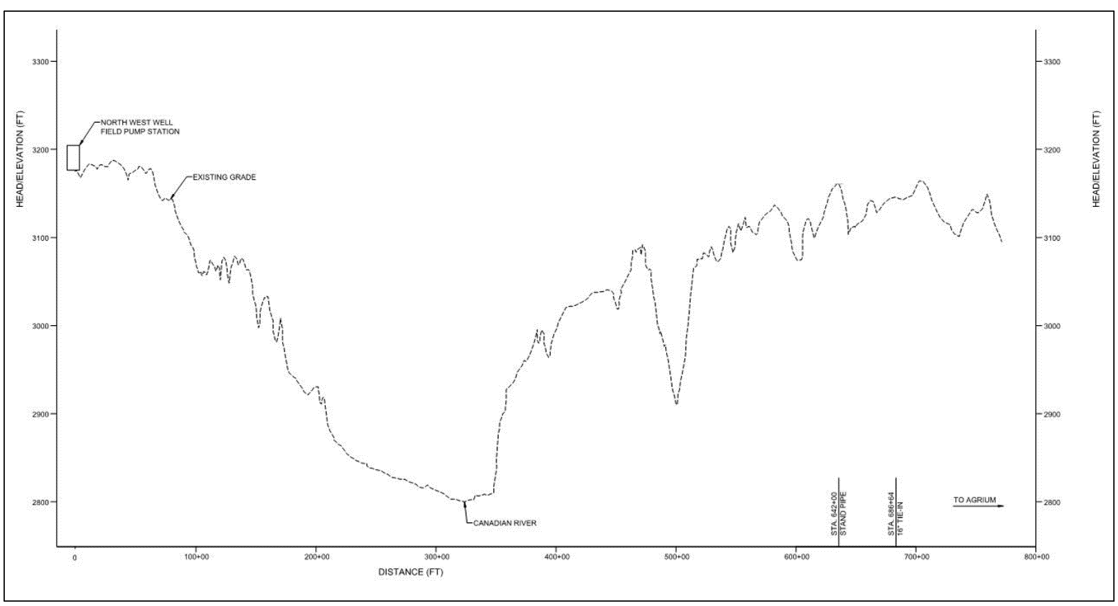
The manufacturer's proprietary software will analyze the entire pipeline at once, while calculating collapse pressure, flow and the valve size at each location identified. The software will allow you to save and modify your profile if needed.

Using the engineered method of transient analysis, we can use various software such as H2O Map, KY Surge or Bentley Hammer. The transient analysis approach allows you to analyze the entire pipeline, including pipe appurtenances and system features. In the software you can model pipe breaks, valve closures and pump trips. Running this analysis using modeling allows you to optimize the placement and sizing of the air valves. The results of this analysis will also output a pressure envelope to help with pipe design.

Case Study: Placement and Sizing Based On Manufactured Tables/Charts Vs. Engineered Solution Using Transient Analysis

An interesting case study in Borger, Texas, focused on an innovative approach that used hydraulic modeling to protect pipelines and cut the number of air valves needed by 59 percent. This saved almost a third of the air valve cost. Borger's pipeline crosses the Canadian River and traverses terrain that is 383 feet from the highest point to the lowest point as shown in Figure 2. The pipeline transports 10 million gallons of water a day from the pump station to the city, which feeds major industrial customers. The Borger pipeline is a 24-inch concrete steel cylinder transmission line that extends about 14 miles.

Figure 2. Borger Pipeline Profile.



This design strategy isn't specific to this situation; it can save your clients money, too. As stated before, it is important that pipelines release and admit air so that they do not collapse. For the Borger pipeline, hydraulic modeling was used to analyze the pipeline and run surge conditions. The hydraulic modeling was compared to the manufacturer's software analysis.

A manufacturer's proprietary air valve software was used to analyze the entire pipeline. This software allows you to input the type of liquid being carried in the pipe, the material of the pipe, the size of the pipe, valve rating, safety factor and the flow rate through the pipe. Along with these variables, you are required to input the high and low spots along the line. This will include station number and elevation. The analysis is performed off these high and low point elevations that are entered into the program. The results of the analysis will show at which stations an air release valve is required and the size of the valve, as shown in Figure 3.

Figure 3. Borger Results from Air Valve Software.

PIPELINE AIR VALVE SCHEDULE:

Station No	ELEV ft	Excav ft	Description	Recommended Valve Size/Model	Max Slope	Flow Rate CFS
0	3,164.92	0.00	Beginning	No valve necessary	-0.0044	0.00
81	3,164.56	0.00	Low Point	No valve necessary	0.0097	0.00
350	3,167.17	0.00	High Point	4 IN #104SS/22.9 Surge-Suppression	-0.0195	27.66
715	3,160.07	0.00	Low Point	No valve necessary	0.0234	0.00
1,350	3,174.92	0.00	High Point	4 IN #104SS/22.9 Surge-Suppression	0.0234	34.20
2,000	3,170.48	0.00	Low Point	No valve necessary	0.0167	0.00
2,200	3,173.82	0.00	Decr in Up-Slope	3 IN #103SS Air/Vac Reg-Ex	0.0167	18.69
2,800	3,173.92	0.00	Incr in Up-Slope	No valve necessary	0.0143	0.00
3,150	3,178.92	0.00	High Point	3 IN #103SS/22.9 Surge-Suppression	0.0143	23.45
4,083	3,171.46	0.00	Incr in Down-Slope	3 IN #103SS/22.9 Surge-Suppression	-0.0566	23.20
4,375	3,154.92	0.00	Low Point	No valve necessary	0.0928	0.00
4,472	3,163.92	0.00	Decr in Up-Slope	3 IN #103SS Air/Vac Reg-Ex	0.0928	23.02
5,000	3,166.85	0.00	Incr in Up-Slope	No valve necessary	0.0354	0.00
5,200	3,173.92	0.00	High Point	4 IN #104SS/22.9 Surge-Suppression	0.0354	31.35
5,550	3,169.83	0.00	Incr in Down-Slope	2 IN #102SS/22.9 Surge-Suppression	-0.0455	11.05
5,700	3,163.00	0.00	Low Point	No valve necessary	-0.0455	0.00
5,950	3,163.89	0.00	Incr in Up-Slope	No valve necessary	0.0466	0.00
6,050	3,168.55	0.00	Decr in Up-Slope	2 IN #102SS Air/Vac Reg-Ex	0.0466	9.89
6,250	3,170.92	0.00	High Point	6 IN #106SS/38 Surge-Suppression	-0.0800	50.55
6,500	3,150.92	0.00	Decr in Down-Slope	No valve necessary	-0.0800	0.00
6,900	3,135.95	0.00	Decr in Down-Slope	No valve necessary	-0.0374	0.00
7,800	3,133.92	0.00	Incr in Down-Slope	4 IN #104SS/22.9 Surge-Suppression	-0.0520	33.61
8,153	3,115.55	0.00	Decr in Down-Slope	No valve necessary	-0.0520	0.00
8,850	3,097.92	0.00	Decr in Down-Slope	No valve necessary	-0.0253	0.00

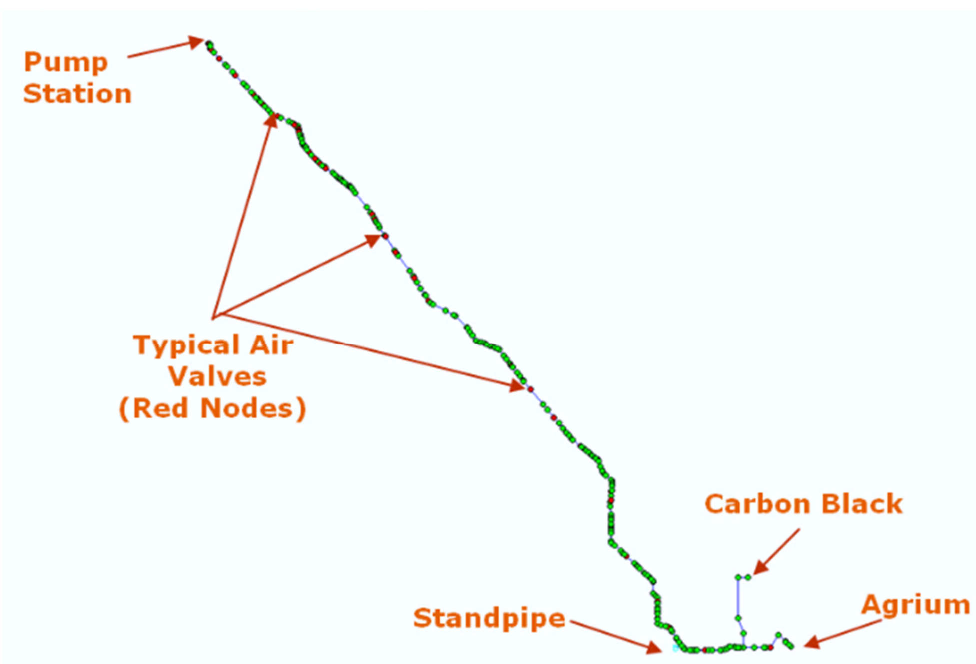
The results also show the max slope and the flow rate at that location. The results of the pipeline can also be presented on a graph that shows the profile of the pipeline and the locations of the valves along with the type of valve. Table 1 is a summary of the valve results using the manufacturer's software.

Table 1 – Air Valve Software – Borger Results.

Size of Valve	Number of Valves
2-inch	23
3-inch	33
4-inch	32
6-inch	29
Total	117

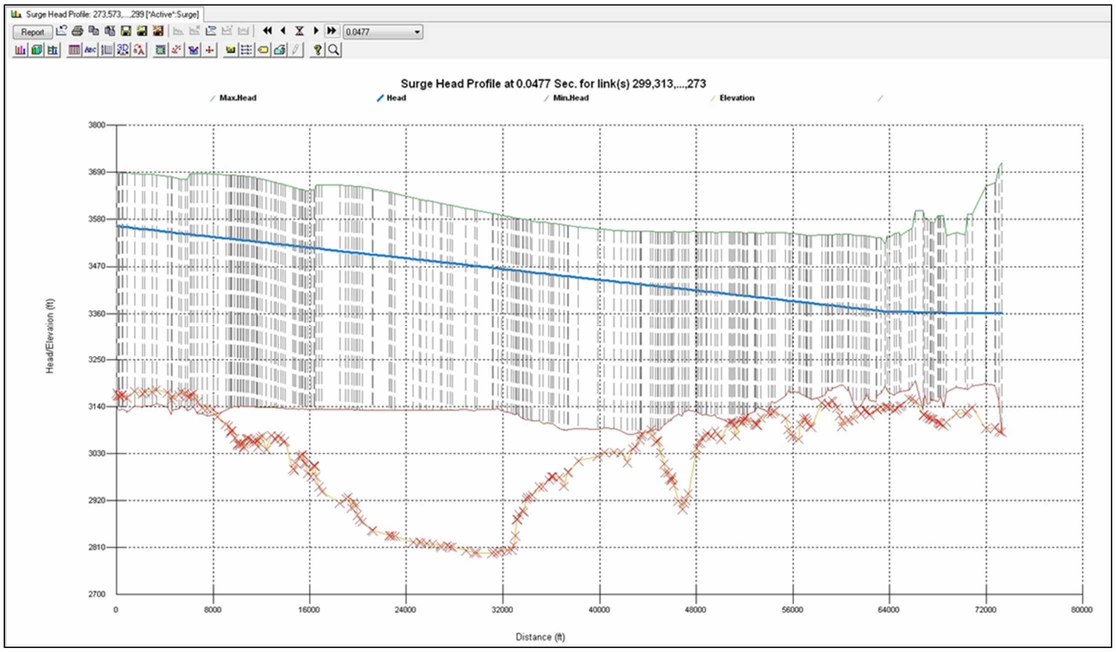
Using the engineered approach of transient analysis, we applied a software called H2OMAP to analyze the pipeline for Borger. This software allowed us to input the proposed alignment of the pipeline using ground elevations and pipe cover. To model the Borger alignment, we input all of the high points, low points and major points of intersection along the alignment. The model of the alignment is shown in Figure 4.

Figure 4. Model of Borger Pipeline.



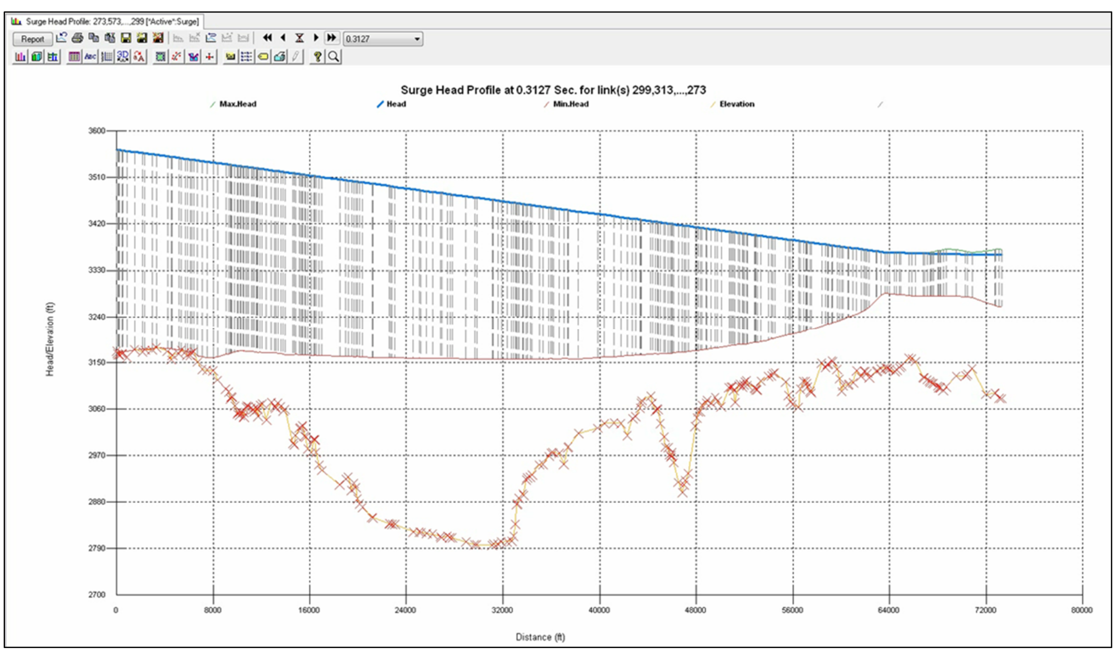
Air release valves were placed at all high points and every 2,500 feet throughout the alignment. These valves sizes were estimated using the slope and the diameter of the pipe. A pump and a tank were placed at the beginning of the line and a stand pipe was modeled toward the end of the alignment. The system was modeled so that after a certain amount of time, the pump would suddenly shut off, creating a surge through the system. The surge analysis was run and the results were viewed in graphical form to look for cavitation throughout the line. Figure 1 shows the surge analysis results of the model run with no air valves.

Figure 1. Surge Results without Air Valves.



On the sections of line that showed cavitation, if no release valve was present, then one would be added. If there was a release valve in place, the size of the valve was changed until there was no cavitation. After a few iterations of running the surge analysis, the pipeline had no cavitation, as shown in Figure 2.

Figure 2. Surge Results with Air Valves.



The results from H2OMAP can be presented in graphical form and tabular form. Table 2 is the valve results using transient analysis.

Table 2 – H2OMAP – Borger Results.

Size of Valve	**Number of Valves**
4-inch	1
6-inch	15
8-inch	27
10-inch	4
12-inch	1
Total	48

Comparing the results from the engineered approach to the approach of using the manufacturer’s software, we can see that the engineered approach has reduced the amount of valves dramatically. The manufacturer’s software recommended using two different types of air valves ranging in size from two inch to six inch. The manufacturer’s software is based on slope and does not consider tie-ins of other lines. For the H2OMAP modeling we modeled all air valves as combination air release valves. This was done to avoid confusion during construction when installing the valves. The combination air valves ranged in size from 4 inches to 12 inches. When modeling in H2OMAP, the model considers the entire pipeline, including additional lines and tanks that are on the main line.

Cost is always important to a project, and saving your client money is always a good thing. By using the engineered method over the manufacturer’s results we were able to save the client 30 percent in air valve costs. Table 3 compares the cost of the valves for each method.

Table 3. Comparison of Valve Cost.

Manufacturer’s Software				**Engineered Modeling**				
Size of Valve	Unit Cost	QTY	Item Cost	Valve Size	Unit Cost	QTY	Item Cost	
2-inch	$7,353	23	$169,119	4-inch	$9,488	1	$9,488	
3-inch	$8,421	33	$277,893	6-inch	$16,980	15	$254,700	
4-inch	$9,488	32	$303,616	8-inch	$18,862	27	$509,274	
6-inch	$16,980	29	$492,420	10-inch	$20,530	4	$82,120	
				12-inch	$23,560	1	$23,560	
Total		117	$1,243,048	Total			$897,142	Δ= $345,906

CONCLUSION

Now we know how important air valves are to protect our pipeline and the different tools that are used to effectively place these valves along the line. The key to protecting your pipeline is to effectively place air valves so that your line has no cavitation. Using hydraulic modeling rather than manufacturers' recommendations for the air valve placement can significantly reduce capital cost on your project, while still protecting your pipeline.