AIR VALVES AND ENERGY SAVINGS

D. Kim Sorensen, P.E.
TOPICS

• Properties of Air and Water
  – Volume
  – Viscosity
  – Solubility
  – Vapor Pressure
• How Air Travels in Pipelines
• How Air Enters Pipelines
• Air Valves and Energy Savings
• Efficient Air Valve System Design
PROPERTIES OF AIR AND WATER
For ideal gasses:

\[ PV = nRT \]

For air:

\[ V = \frac{T}{P} \]

Where \( T \) (temperature) is in Rankine (absolute)

<table>
<thead>
<tr>
<th>Temp. °F</th>
<th>Temp. °R</th>
<th>Specific Volume Water Ft³/lb</th>
<th>Specific Volume Air Ft³/lb</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>491.67</td>
<td>0.01602</td>
<td>12.392</td>
</tr>
<tr>
<td>50</td>
<td>509.67</td>
<td>0.01602</td>
<td>12.837</td>
</tr>
<tr>
<td>70</td>
<td>529.67</td>
<td>0.01605</td>
<td>13,351</td>
</tr>
<tr>
<td>90</td>
<td>549.67</td>
<td>0.01610</td>
<td>13.850</td>
</tr>
<tr>
<td>110</td>
<td>569.67</td>
<td>0.01617</td>
<td>14.368</td>
</tr>
<tr>
<td>130</td>
<td>589.67</td>
<td>0.01625</td>
<td>14.859</td>
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<tr>
<td>150</td>
<td>609.67</td>
<td>0.01634</td>
<td>15.361</td>
</tr>
<tr>
<td>170</td>
<td>629.67</td>
<td>0.01645</td>
<td>15.873</td>
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<tr>
<td>190</td>
<td>649.67</td>
<td>0.01657</td>
<td>16.393</td>
</tr>
<tr>
<td>210</td>
<td>669.67</td>
<td>0.01670</td>
<td>16.892</td>
</tr>
<tr>
<td>212</td>
<td>671.67</td>
<td>0.01671</td>
<td>16.938</td>
</tr>
</tbody>
</table>

\( P \) = Pressure  
\( V \) = Volume  
\( n \) = Number of moles  
\( R \) = Universal gas constant
Air pocket possesses a great amount of dangerous potential energy

147 PSI
Viscosity

**WATER** has about 1000 times the viscosity of **AIR**

Viscosity effects resistance and, thus,

**Velocity**
SOLUBILITY of Air in Water

Volumetric Concentration

The capacity of water to hold dissolved air in solution
## Vapor Pressure

<table>
<thead>
<tr>
<th>Temp. °F</th>
<th>Vapor Pressure psi</th>
<th>Temp. °F</th>
<th>Vapor Pressure psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>0.09</td>
<td>130</td>
<td>2.22</td>
</tr>
<tr>
<td>40</td>
<td>0.12</td>
<td>140</td>
<td>2.89</td>
</tr>
<tr>
<td>50</td>
<td>0.18</td>
<td>150</td>
<td>3.72</td>
</tr>
<tr>
<td>60</td>
<td>0.26</td>
<td>160</td>
<td>4.74</td>
</tr>
<tr>
<td>70</td>
<td>0.36</td>
<td>170</td>
<td>5.99</td>
</tr>
<tr>
<td>80</td>
<td>0.51</td>
<td>180</td>
<td>7.51</td>
</tr>
<tr>
<td>90</td>
<td>0.70</td>
<td>190</td>
<td>9.34</td>
</tr>
<tr>
<td>100</td>
<td>0.95</td>
<td>200</td>
<td>11.52</td>
</tr>
<tr>
<td>110</td>
<td>1.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>1.69</td>
<td>212</td>
<td>14.70</td>
</tr>
</tbody>
</table>

Source: Wastewater Engineering: Collection and Pumping of Wastewater by George Tchobanoglous
Vapor Pressure
A PIPELINE IS NEVER EMPTY
Air Pocket Formation
Air Pocket Formation

Air pockets form at peaks along the pipeline.
If there are no peaks for long stretches of pipe, air pockets form at the crown of pipeline.
As the cross section of flow decreases, velocity increases
Air Pocket Formation

Though velocity may rise above critical velocity for bubble transport,
there is not enough energy to move a large air pocket
Air Pocket Formation

The air pocket is smeared downstream, forming an elongated air pocket.
Dissolved air is not the only source of air in water/wastewater transmission systems. There are numerous ways for atmospheric air to enter the system.
Air Entrainment

Vortex
Air Entrainment

Entrainment by a plunging jet

In wet wells
Dynamic Air Bubble/Pocket Behavior

Real air pocket behavior is much more complicated than described before.

Behavior is affected by Buoyancy, Drag and Surface Tensions (water / air / walls).

Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005
Dynamic Air Bubble/Pocket Behavior

Small bubbles move with the water stream

Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005
Larger air pockets move against the water stream.

Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005
Dynamic Air Bubble/Pocket Behavior

Very large pockets break up, large parts of the pocket move against the water stream, while small air bubbles move with the water flow.

Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005
Dynamic Air Bubble/Pocket Behavior

Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005
Dynamic Air Bubble/Pocket Behavior

Air pocket building up at a small bend

Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005
Air Valves and Energy Savings
The Energy Star Program of the EPA estimates that about $4 billion are spent annually for energy costs to run drinking water and wastewater utilities. If the sector could reduce energy use by just 10% through investment in energy efficiency collectively, it would save about $400 million annually.
EFFECTS of TRAPPED AIR on HYDRAULIC GRADE LINE
Pump records for a wastewater lift station in Denton County, Texas, with 5 conventional wastewater air valves on its force main.

**Wednesday**

Flow rate in gpm

**Thursday**

Flow rate in gpm

- **Low flow rates**
- **Long pump runs**
2 of the 5 conventional Air Valves were replaced by 2 *new innovative* wastewater Air Valves.

Long pump runs

Change of flow rate scale

Flow rates rise off the chart!

Short pump runs
A Month Later

Friday

A slight drop in flowrates
<table>
<thead>
<tr>
<th>Option 1: Without A.R.I. Air Valves</th>
<th>Option 2: With A.R.I. Air Valves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Years of operation</strong></td>
<td>20 years</td>
</tr>
<tr>
<td><strong>Days of operation (lifetime)</strong></td>
<td>7300 days</td>
</tr>
<tr>
<td><strong>Daily operating time</strong></td>
<td>7.36 hours</td>
</tr>
<tr>
<td><strong>Operating time (annual)</strong></td>
<td>2,686 hours per year</td>
</tr>
<tr>
<td><strong>Operating time (lifetime)</strong></td>
<td>53,728 hours</td>
</tr>
<tr>
<td><strong>Flow</strong></td>
<td>100 gpm</td>
</tr>
<tr>
<td><strong>Flow</strong></td>
<td>44,160 gallons per day</td>
</tr>
<tr>
<td><strong>Flow</strong></td>
<td>16,118,400 gallons per year</td>
</tr>
<tr>
<td><strong>Electricity cost</strong></td>
<td>$0.1120 per kilowatt-hour</td>
</tr>
<tr>
<td><strong>TDH</strong></td>
<td>56 feet</td>
</tr>
<tr>
<td><strong>Pump efficiency</strong></td>
<td>19%</td>
</tr>
<tr>
<td><strong>Motor efficiency</strong></td>
<td>85%</td>
</tr>
<tr>
<td><strong>Cost per thousand gallons</strong></td>
<td>$0.1223</td>
</tr>
<tr>
<td><strong>Cost per year</strong></td>
<td>$1,971.81</td>
</tr>
<tr>
<td><strong>Lifetime cost</strong></td>
<td>$39,436.29</td>
</tr>
<tr>
<td><strong>Cost per hour</strong></td>
<td>$0.7340</td>
</tr>
<tr>
<td><strong>Cost per year</strong></td>
<td>$1,971.81</td>
</tr>
<tr>
<td><strong>Lifetime cost</strong></td>
<td>$39,436.29</td>
</tr>
</tbody>
</table>

Option one cost per year: $1,971.81
Option two cost per year: $580.67
Option two will save: $1,391.15 per year

Option one 20-year cost: $39,436.29
Option two 20-year cost: $11,613.31
Option two will save: $27,822.98 over the 20-year life cycle

Assuming pump in use is similar to EBARA 100DLMF67.5 (10HP - 7.5kW),
Synchronous speed: 1800 RPM, 3" discharge
Rule of thumb – Air valve specification and location

Figure 3-1. Sample piping system profile illustrating typical valve locations.
Where:

\[ Q = \text{flow-rate in scfm} \]

\[ C = \text{Chezy Coefficient (110 for iron, 120 for concrete, 130 for steel, 190 for PVC)} \]

\[ S = \text{pipeline slope in ft/ft} \]

\[ ID = \text{pipeline inside diameter in inches} \]

\[ Q = 0.0472C\sqrt{SID^5} \]

BASED ON CHEZY
Very Long,

Very Complicated Projects
The pipeline profile should not follow overly undulating ground surfaces
Recommended air valve setup in a vault

\[ d_s = \text{Diameter of the air/vacuum orifice of the air valve} \]

\[ h = \geq 1.0D^*, \quad h \geq 6" \]

\[ d = D \text{ for } D \leq 12", \]
\[ d = 0.6D \text{ for } 12" < D \leq 60" \]
\[ d = 0.35D \text{ for } D > 60" \]

\[ \frac{\pi d^2}{4} \geq \frac{\pi d_s^2}{4} \]

* If there is not enough head room in the manhole, \( h \) could be reduced to 0.5D
Venting air valves in flooding vaults
A.R.I. Recommended Offset Design for Wastewater Applications

Minimum rising slope of 2% - Higher slope strongly recommended

Minimum diameter 3" - preferable 4" and greater

Air trap riser minimum half of pipe diameter and half diameter above the crown of the pipe

If the offset pipe is longer than 5', air valve should be Non-Slam type

Always – minimum offset diameter will be greater than the air valve inlet diameter and air/vacuum orifice diameter!
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Thank You