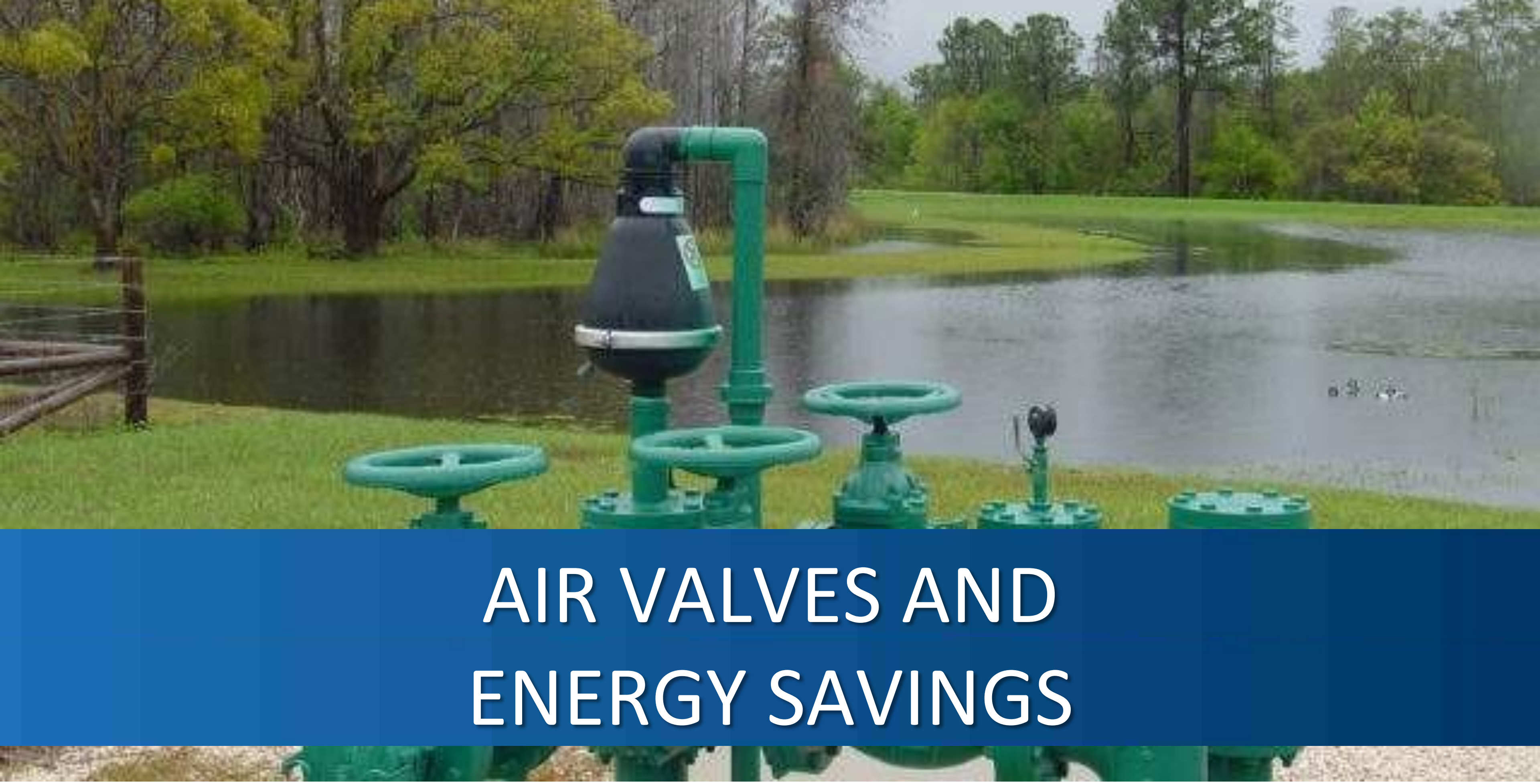


AIR VALVES AND ENERGY SAVINGS

D. Kim Sorensen, P.E.

Where Knowledge & Experience join with Innovation

A.R.I. USA Inc.

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

Volume

For ideal gasses:

$$PV = nRT$$

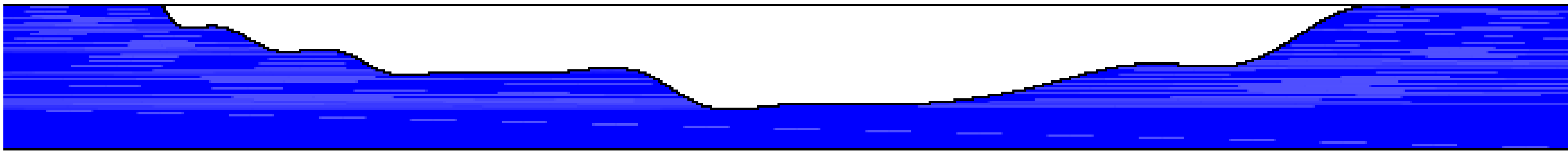
For air:

$$V = T / P$$

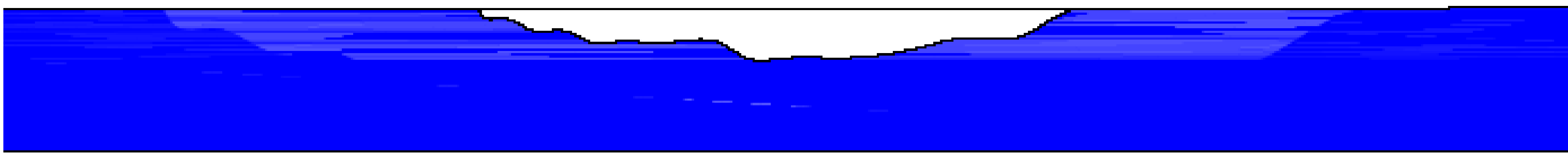
Where T (temperature) is in Rankine (absolute)

P = Pressure
V = Volume
n = Number of moles
R = Universal gas constant

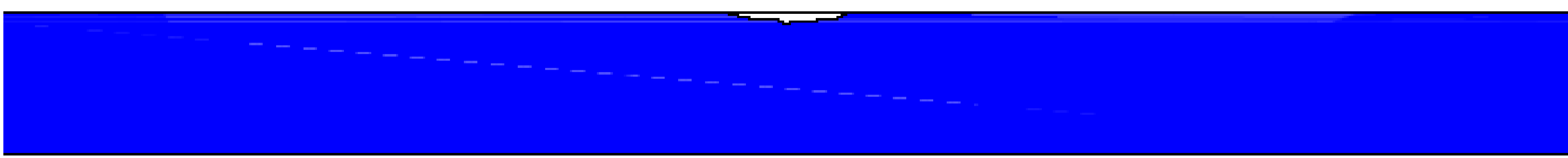
Temp. °F	Temp. °R	Specific Volume **Water** Ft^3/lb	Specific Volume **Air** Ft^3/lb
32	491.67	0.01602	12.392
50	509.67	0.01602	12.837
70	529.67	0.01605	**13.351**
90	549.67	0.01610	13.850
110	569.67	0.01617	14.368
130	589.67	0.01625	14.859
150	609.67	0.01634	15.361
170	629.67	0.01645	15.873
190	649.67	0.01657	16.393
210	669.67	0.01670	16.892
212	671.67	0.01671	16.938



14.7 PSI



29.4 PSI



147 PSI

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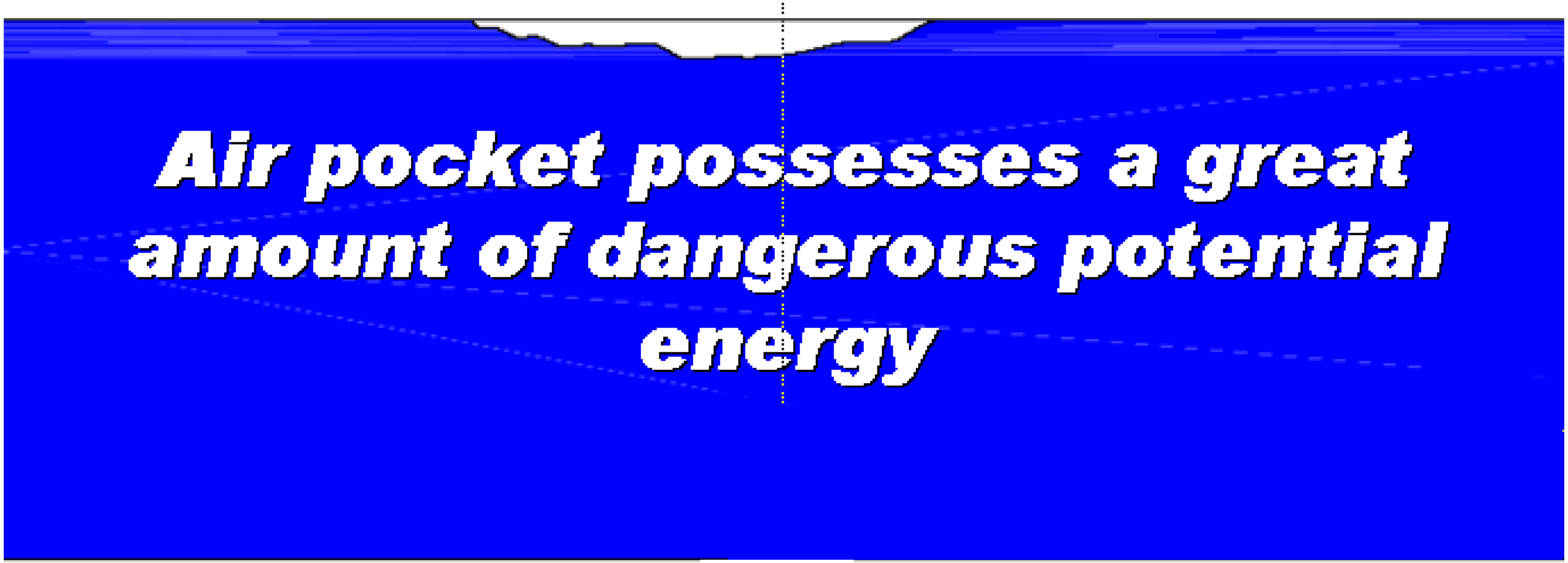

147 PSI

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

Temperature (°F)	Gauge Pressure (psig)					
	0	20	40	60	80	100
40	0.0258	0.0613	0.0967	0.1321	0.1676	0.2030
50	0.0223	0.0529	0.0836	0.1143	0.1449	0.1756
60	0.0197	0.0469	0.0742	0.1014	0.1296	0.1559
70	0.0177	0.0423	0.0669	0.0916	0.1162	0.1408
80	0.0161	0.0387	0.0614	0.0840	0.1067	0.1293
90	0.0147	0.0358	0.0589	0.0750	0.0990	0.1201
100	0.0136	0.0334	0.0536	0.0730	0.0928	0.1126
110	0.0126	0.0314	0.0501	0.0699	0.0877	0.1065
120	0.0117	0.0296	0.0475	0.0654	0.0833	0.1012
130	0.0107	0.0280	0.0452	0.0624	0.0796	0.0968
140	0.0098	0.0265	0.0432	0.0598	0.0765	0.0931
150	0.0089	0.0251	0.0413	0.0574	0.0736	0.0898
160	0.0079	0.0237	0.0395	0.0553	0.0711	0.0869
170	0.0068	0.0223	0.0378	0.0534	0.0689	0.0844
180	0.0055	0.0208	0.0361	0.0514	0.0667	0.0820
190	0.0041	0.0192	0.0344	0.0496	0.0647	0.0799
200	0.0024	0.0175	0.0326	0.0477	0.0628	0.0779
210	0.0004	0.0155	0.0306	0.0457	0.0607	0.0758

Vapor Pressure

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

Source: Wastewater Engineering: Collection and Pumping of Wastewater by George Tchobanoglous

Vapor Pressure

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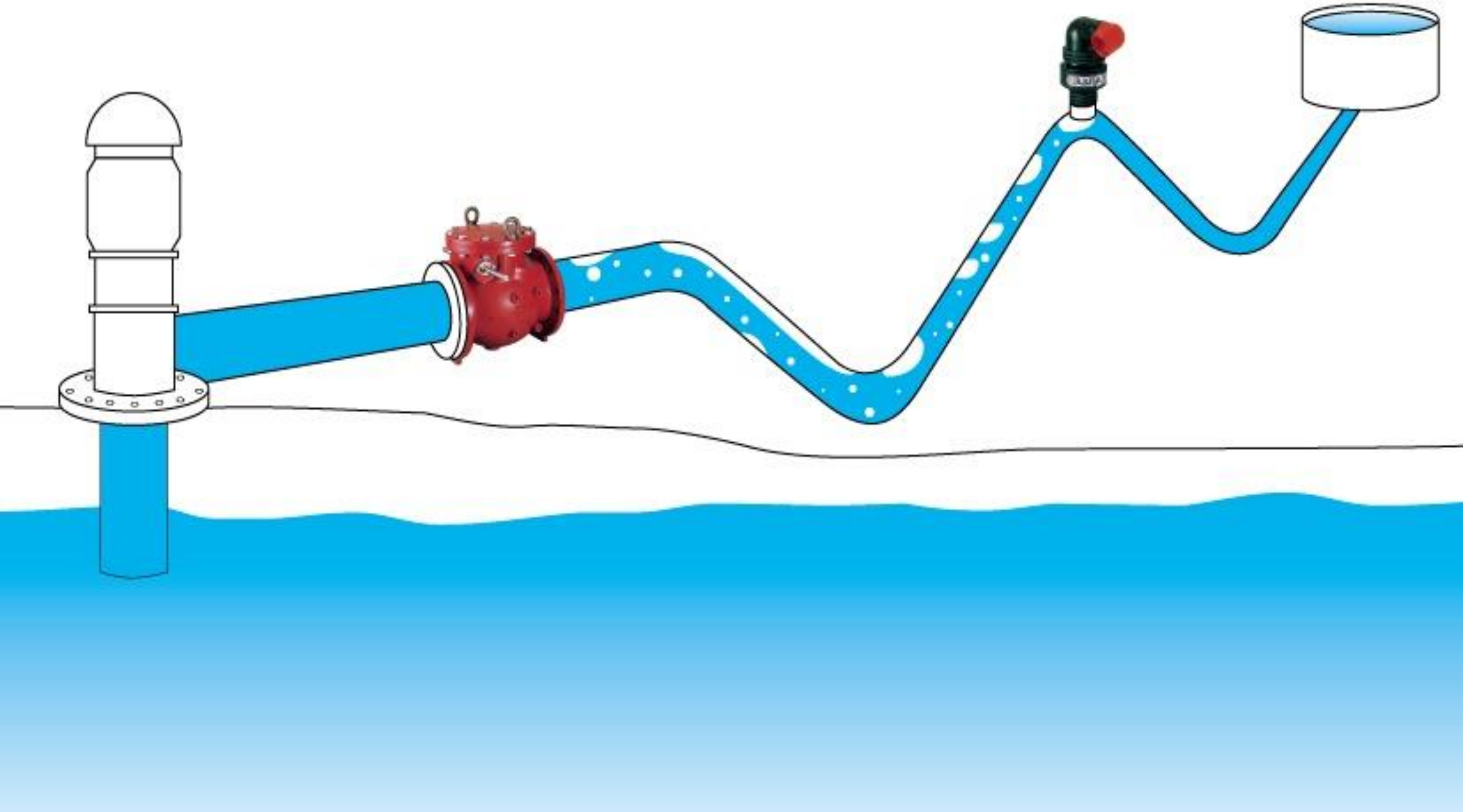
A PIPELINE IS NEVER EMPTY



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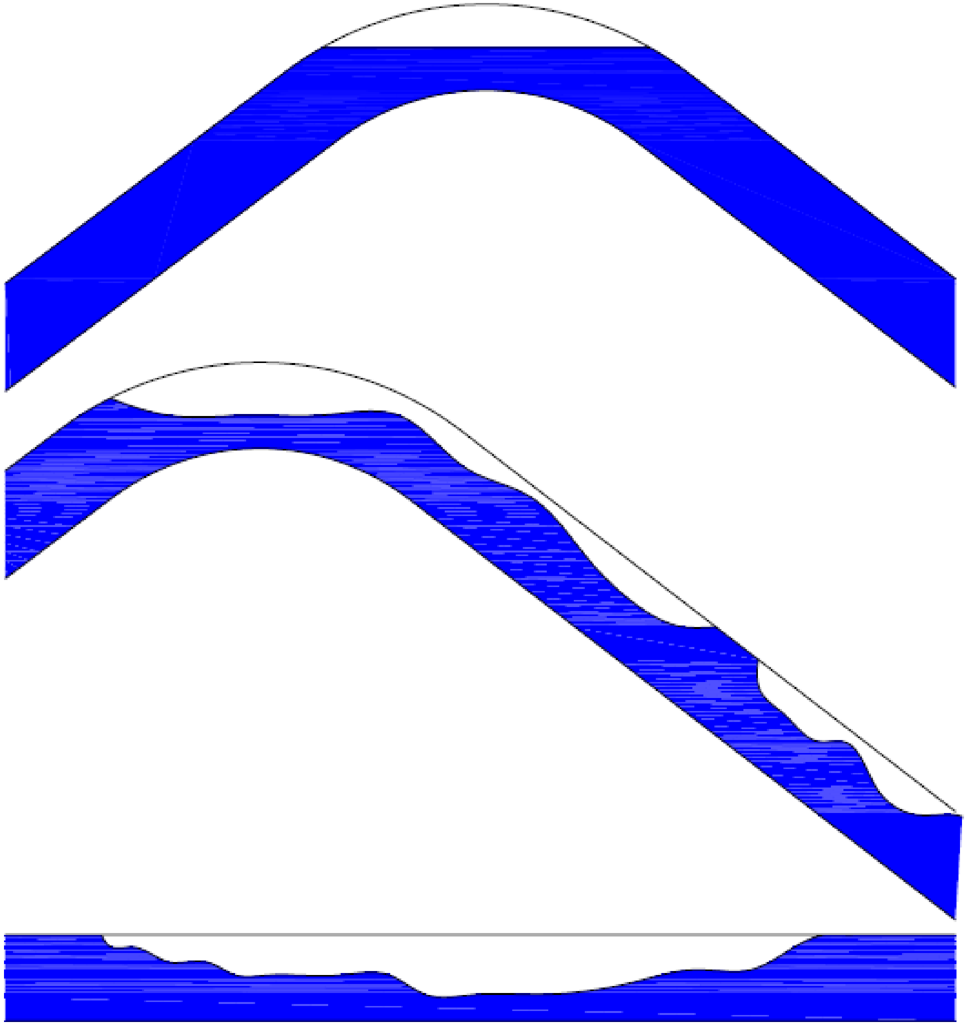
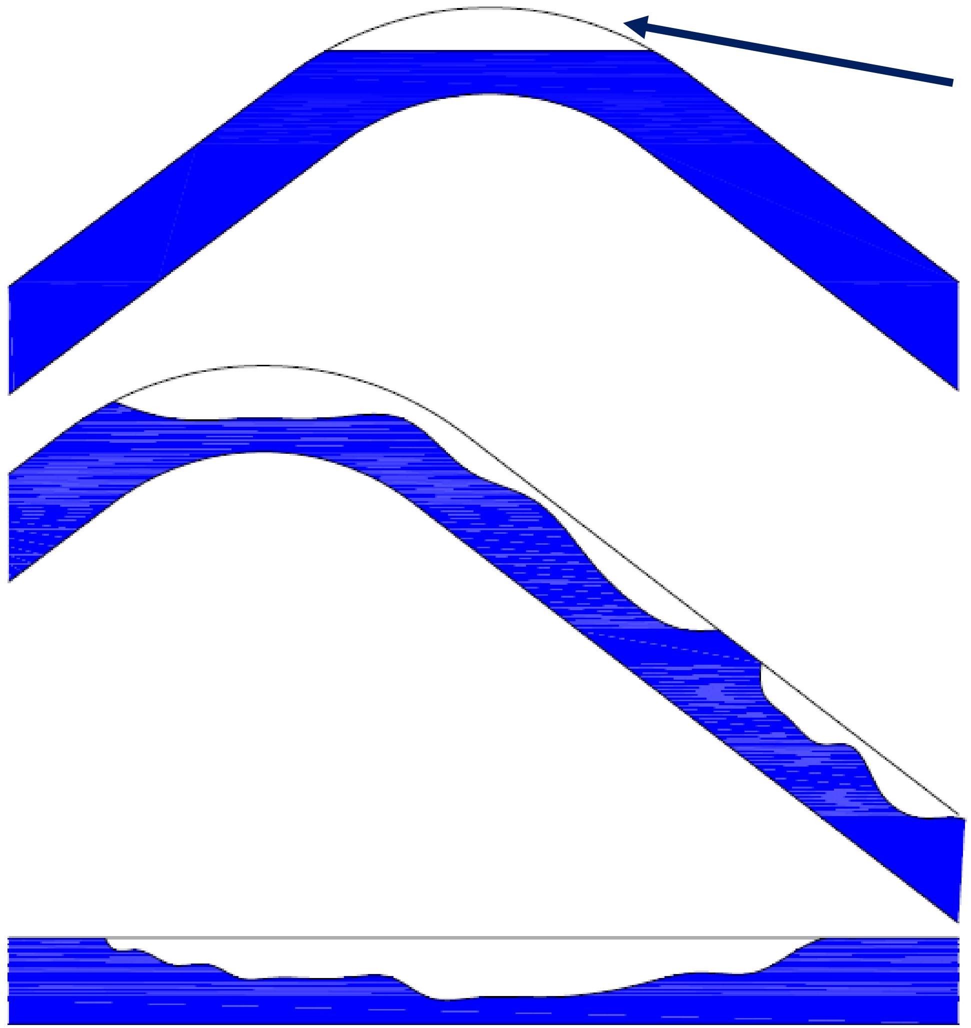
Air Pocket Formation

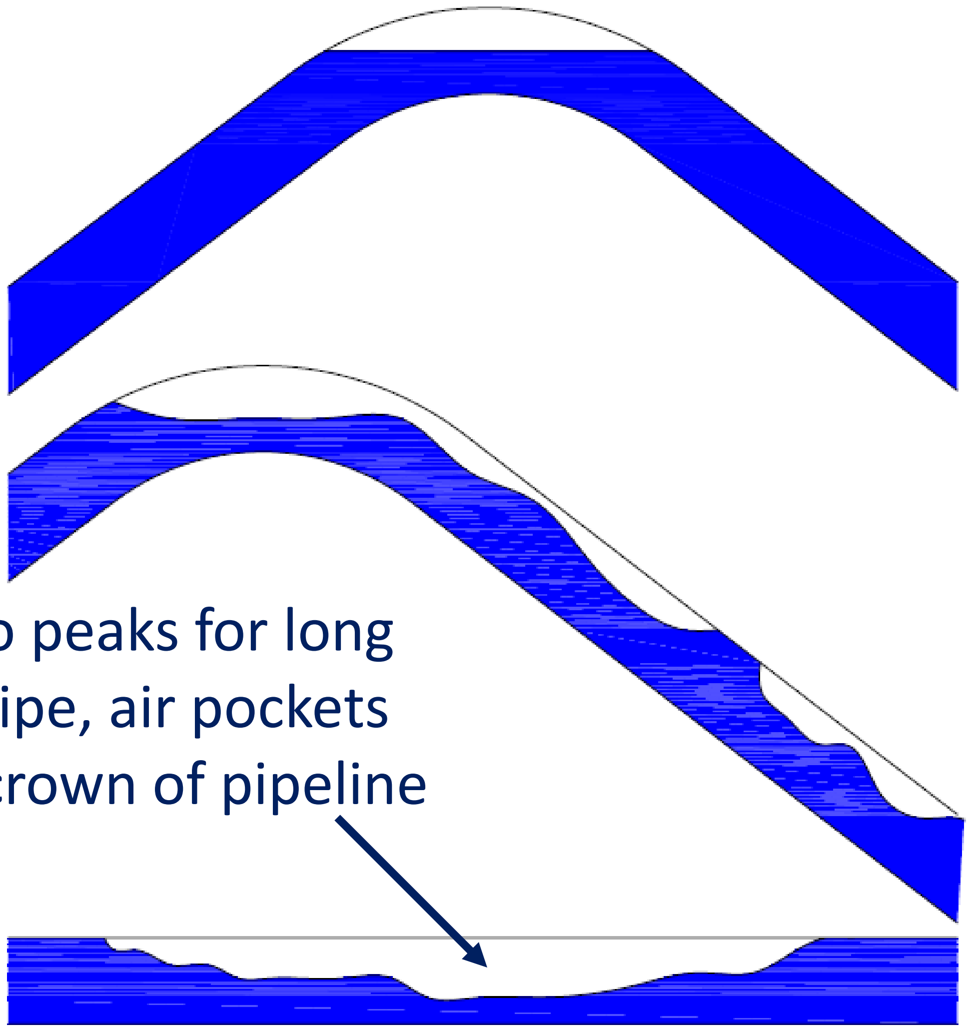


Air Pocket Formation



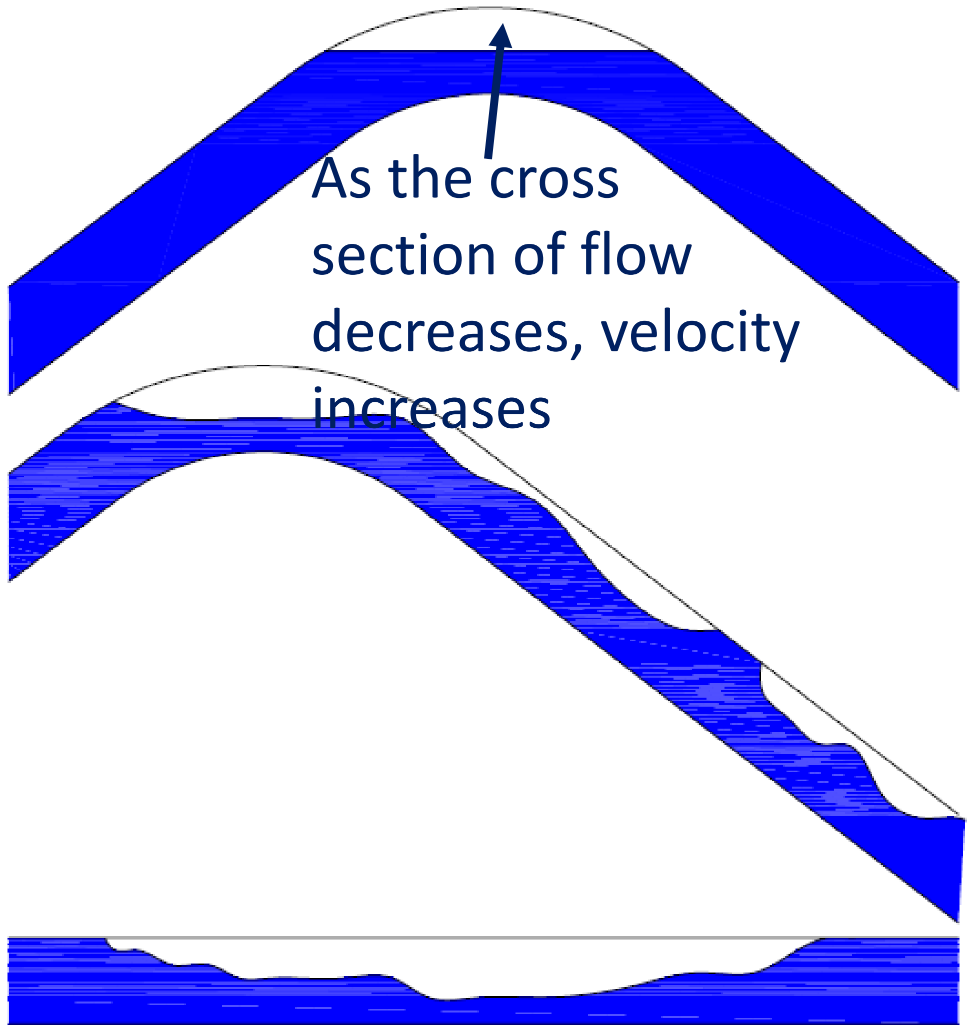
Air pockets forms at peaks along the pipeline

Air Pocket Formation



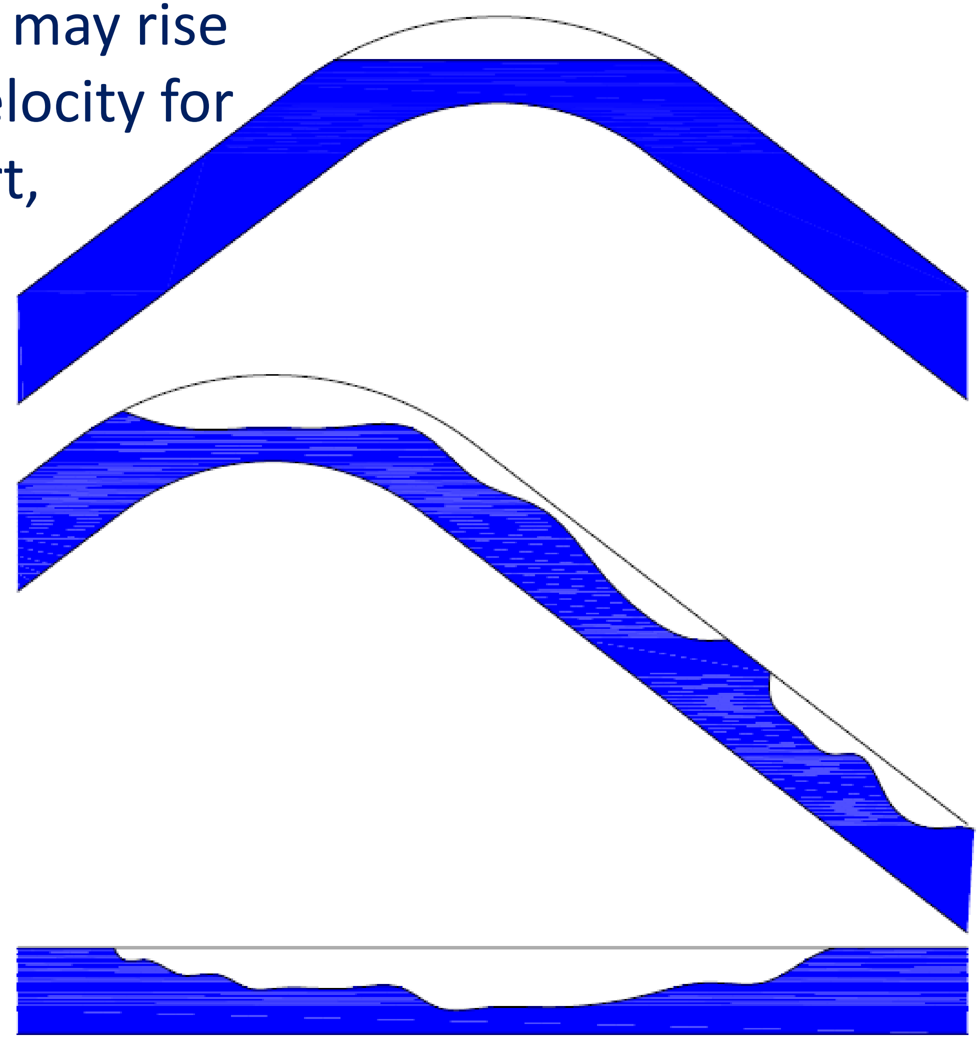
If there are no peaks for long stretches of pipe, air pockets forms at the crown of pipeline

Air Pocket Formation



Air Pocket Formation

Though velocity may rise above critical velocity for bubble transport,



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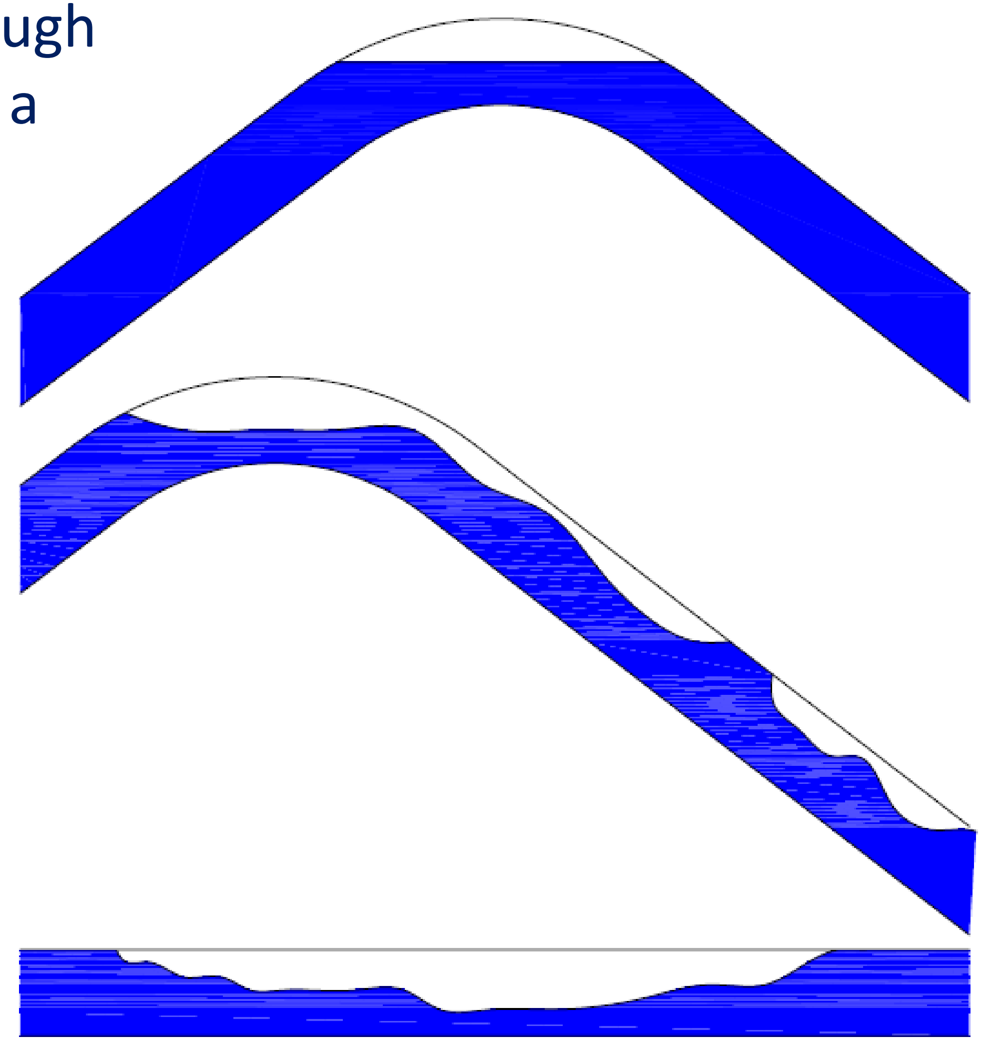
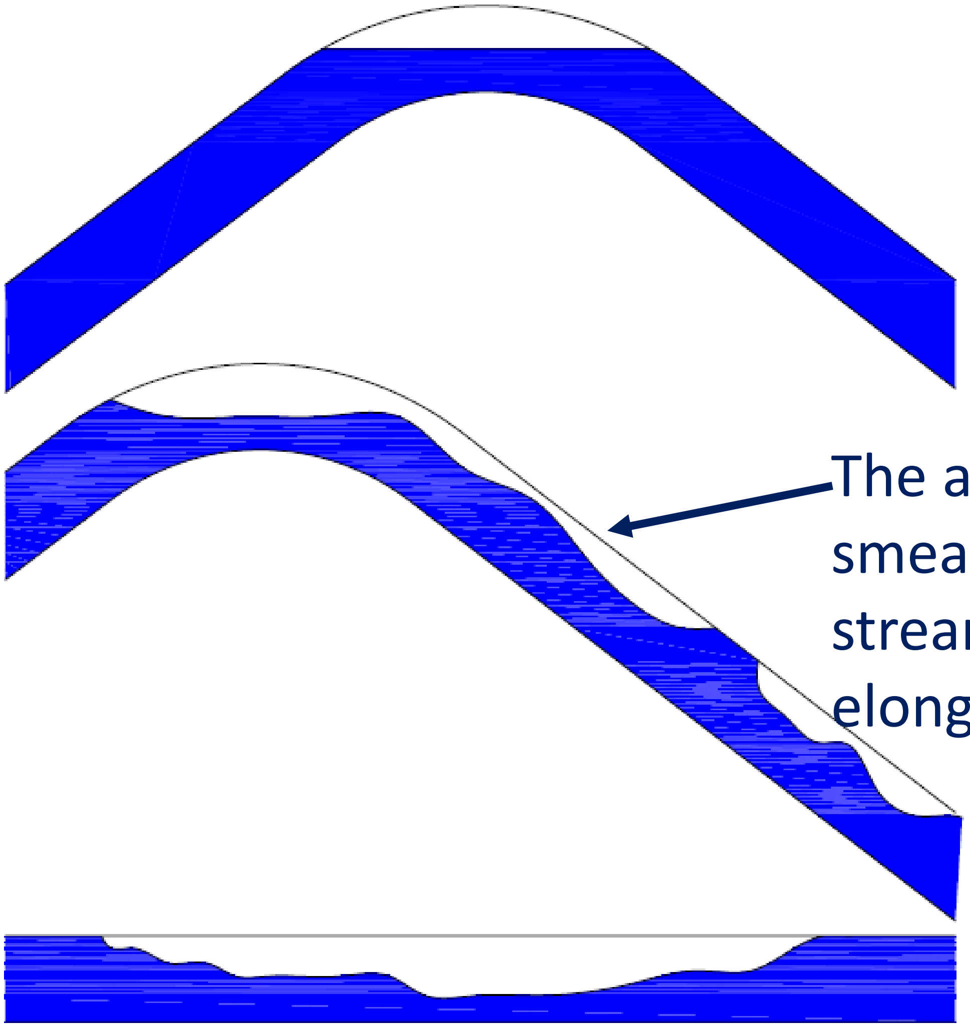
Air Pocket Formation

there is not enough energy to move a large air pocket



Air Pocket Formation



The air pocket is smeared down-stream, forming an elongated air pocket

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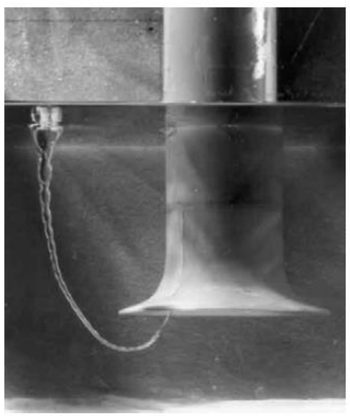
Air Entrainment

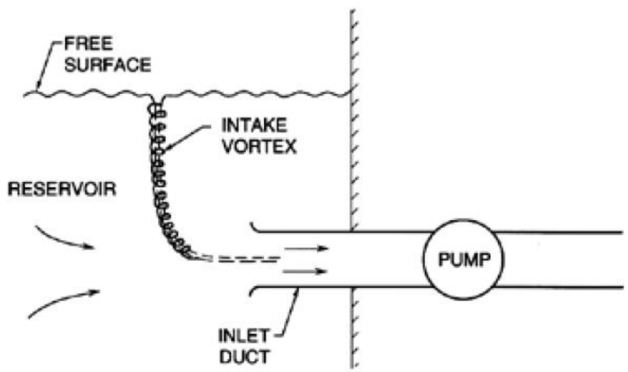
Dissolved air is not the only source of air in water/wastewater transmission systems.

There are numerous ways for atmospheric air to enter the system

Air Entrainment

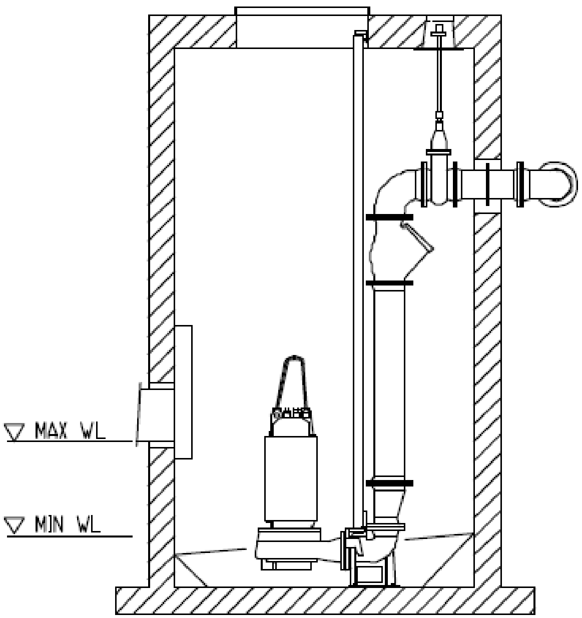
Vortex



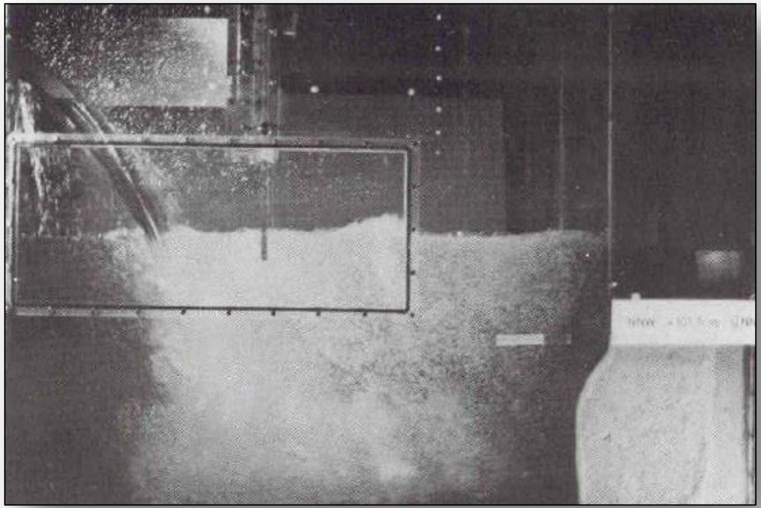


Air Entrainment

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

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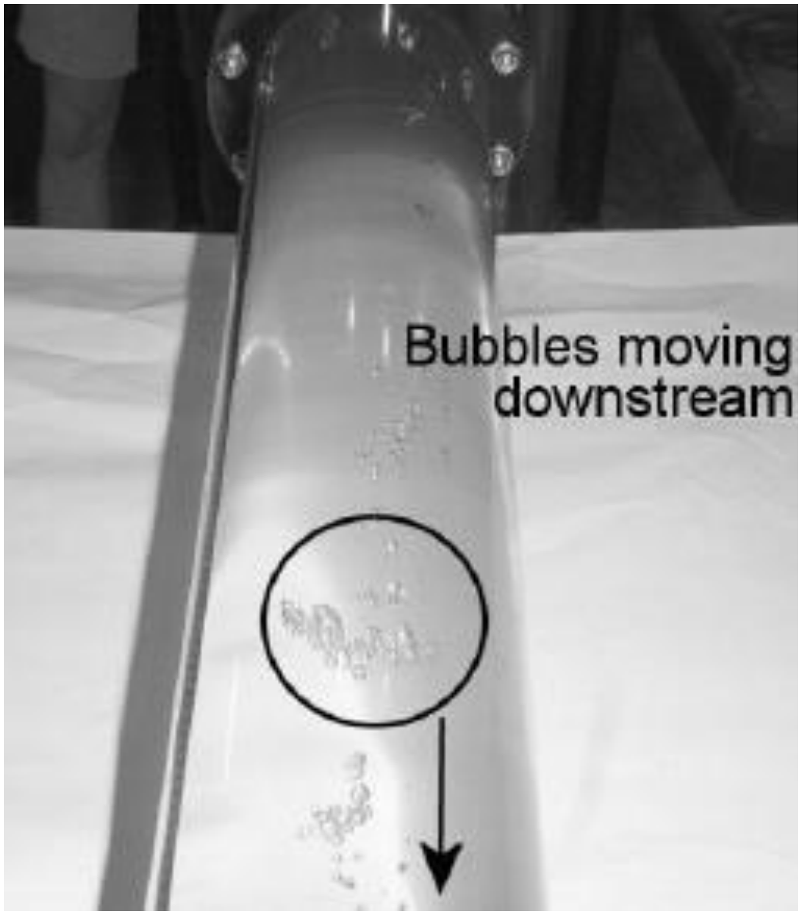
Dynamic Air Bubble/Pocket Behavior



Small bubbles move with the water stream

Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005

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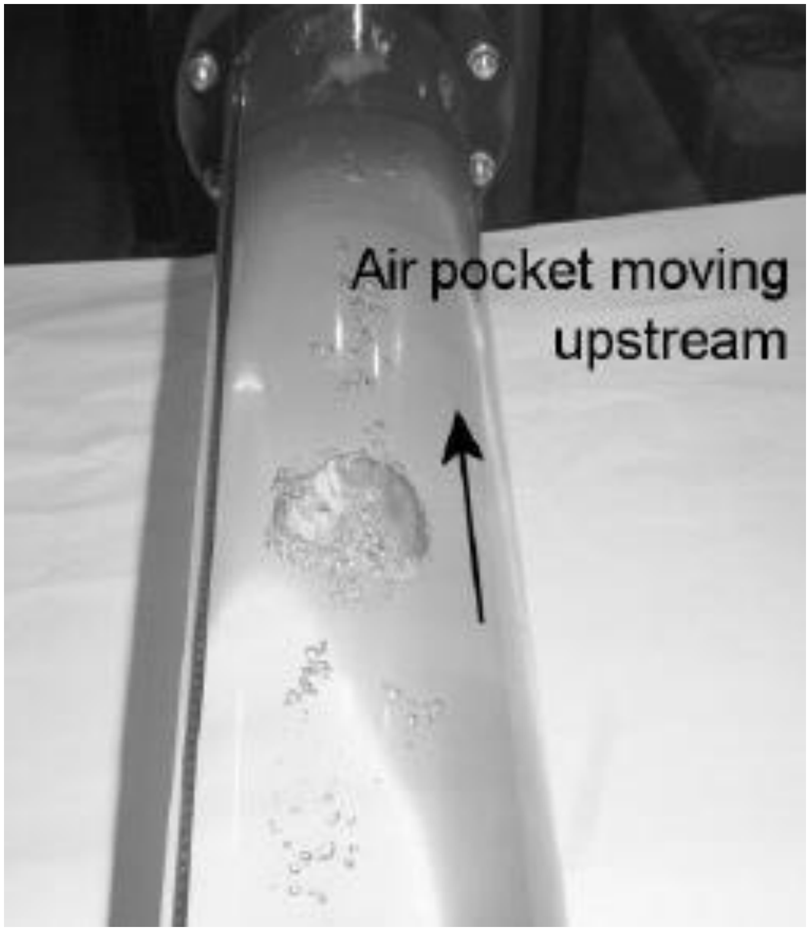
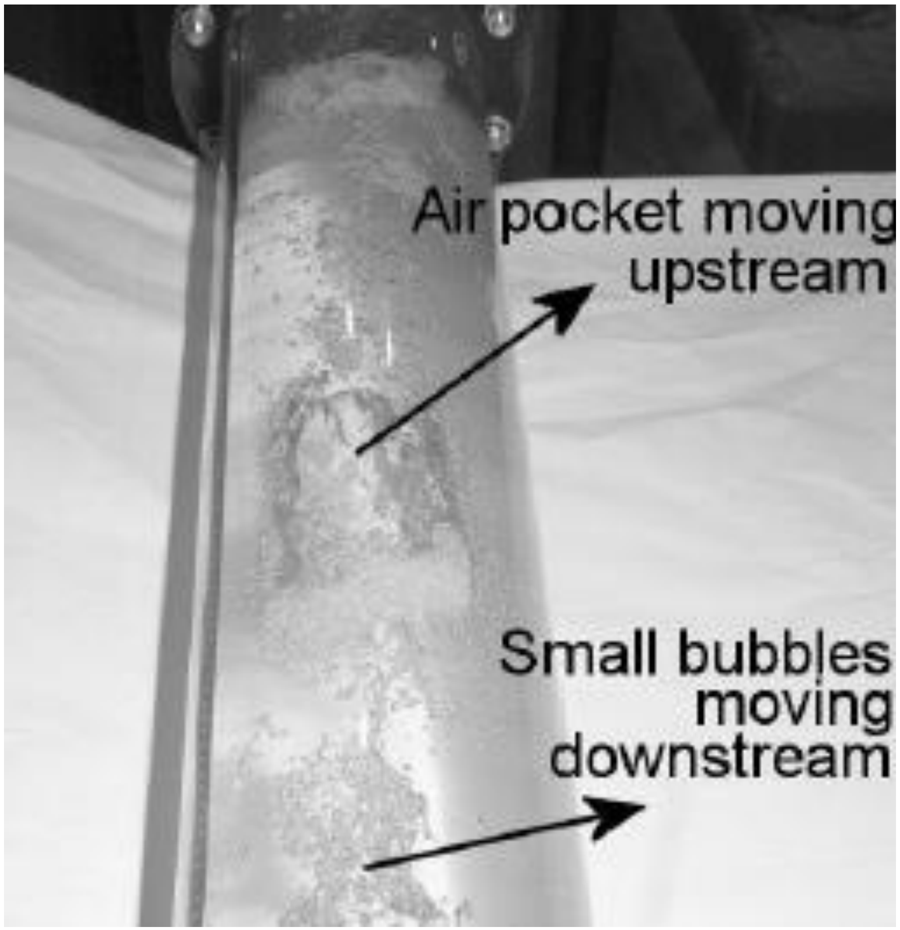
Dynamic Air Bubble/Pocket Behavior



Larger air pockets move against the water stream

Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005

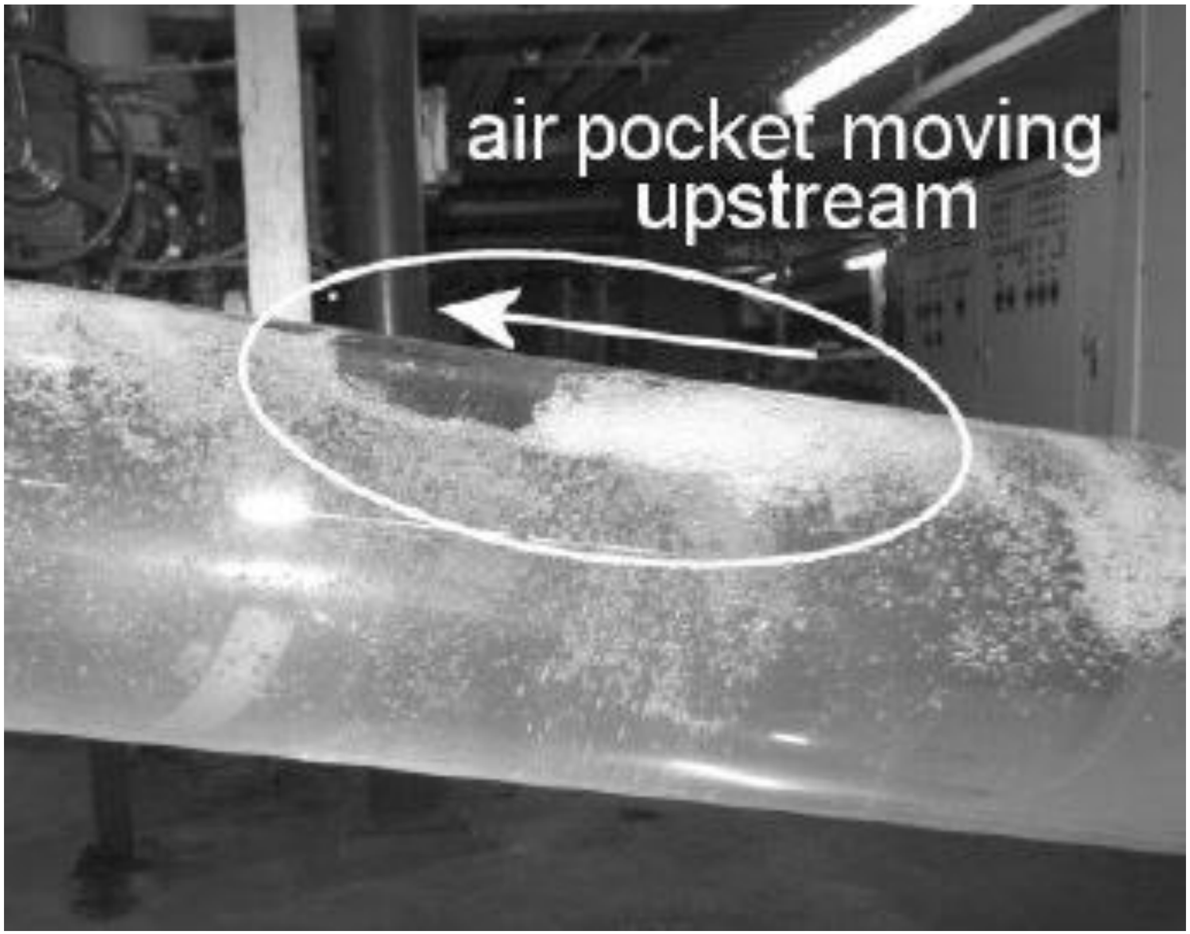
Dynamic Air Bubble/Pocket Behavior



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



Side view of air pocket breaking up

Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005

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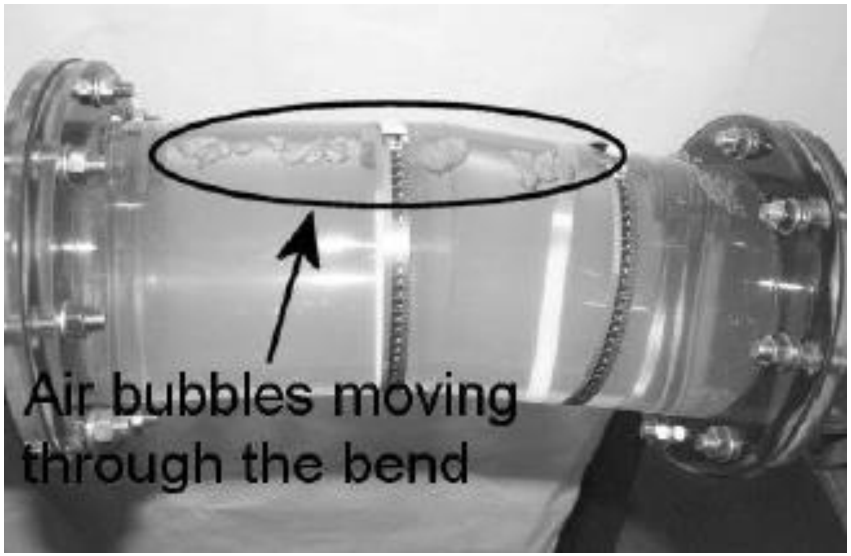
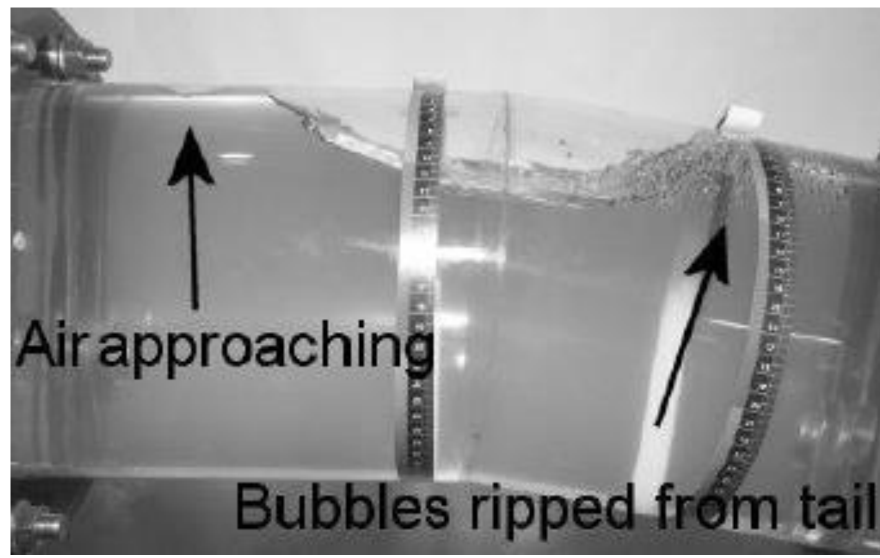
Dynamic Air Bubble/Pocket Behavior



Air pocket building up at a small bend



Lubbers, Christof L. and Clemens, Francois H.L.R, April 2005

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Air Valves and Energy Savings

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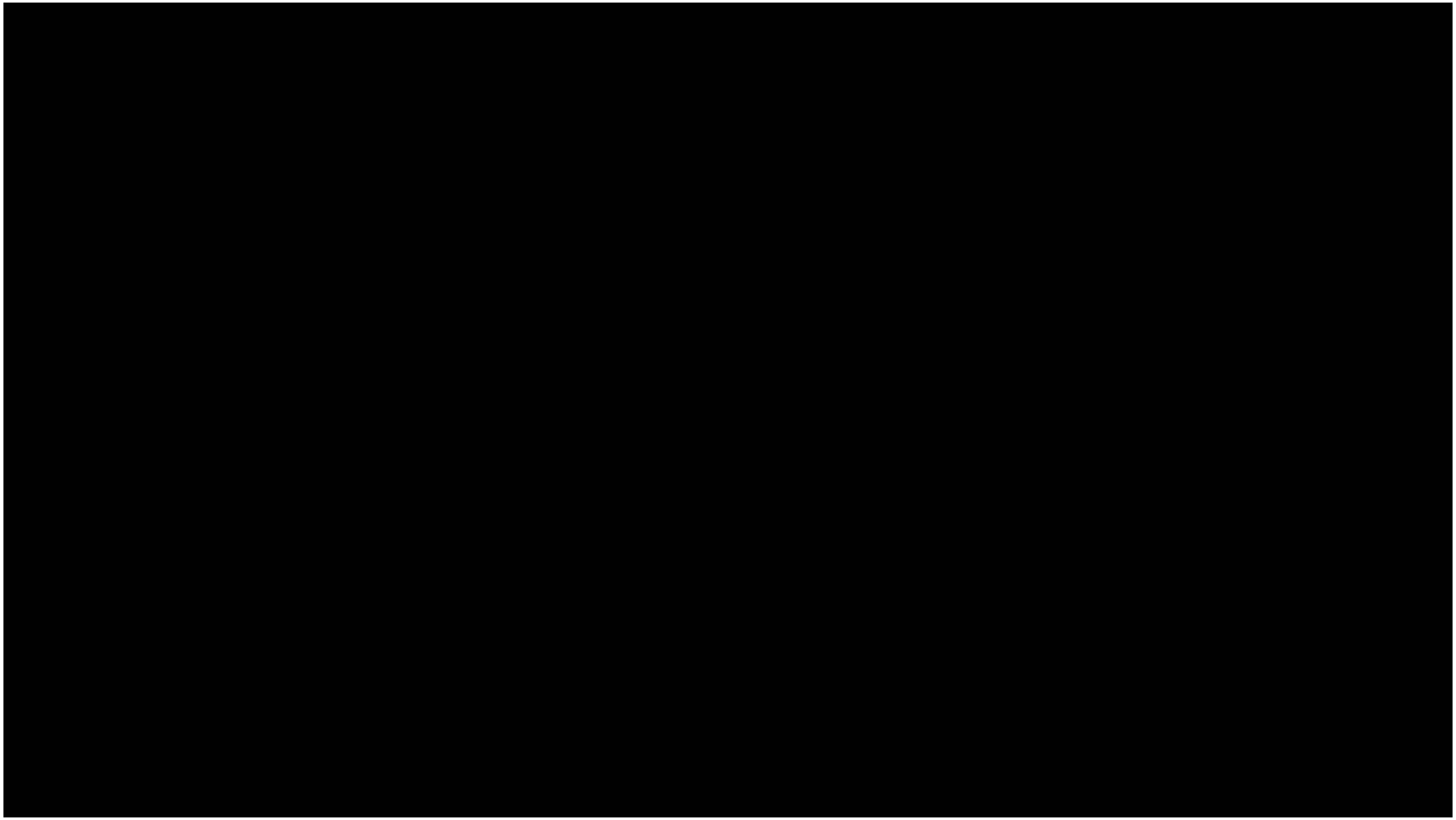
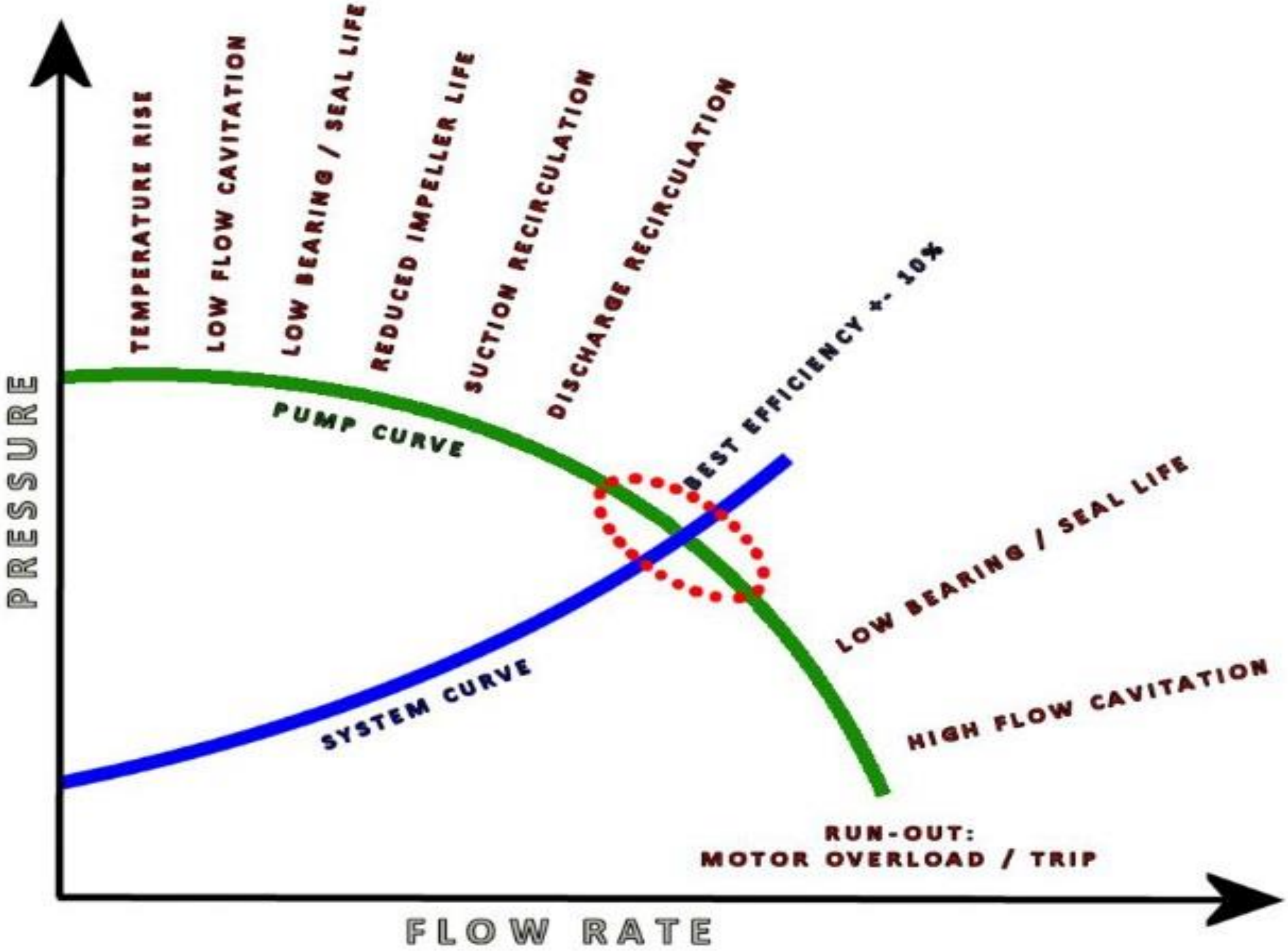
The Energy Star Program of the **EPA estimates that about $4 billion are spent annually for energy costs to run drinking water and wastewater utilities.** If the sector could reduce energy use by just 10% through investment in energy efficiency collectively, it would **save about $ 400 million annually.**




TEMPERATURE RISE
LOW FLOW CAVITATION
LOW BEARING / SEAL LIFE
REDUCED IMPELLER LIFE
SUCTION RECIRCULATION
DISCHARGE RECIRCULATION
BEST EFFICIENCY +- 10%
PUMP CURVE
SYSTEM CURVE
LOW BEARING / SEAL LIFE
HIGH FLOW CAVITATION
RUN-OUT:
MOTOR OVERLOAD / TRIP
PRESSURE
FLOW RATE

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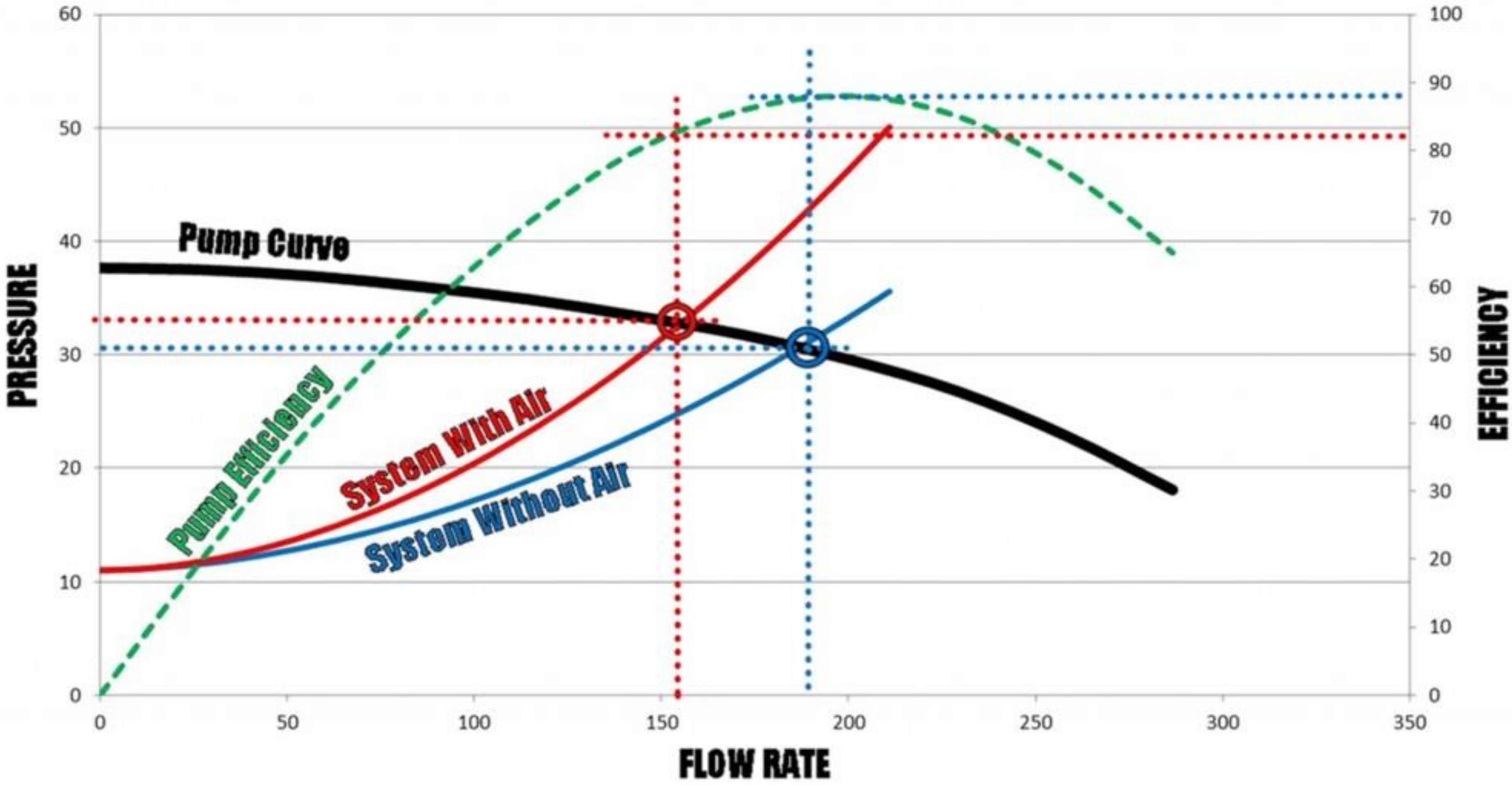
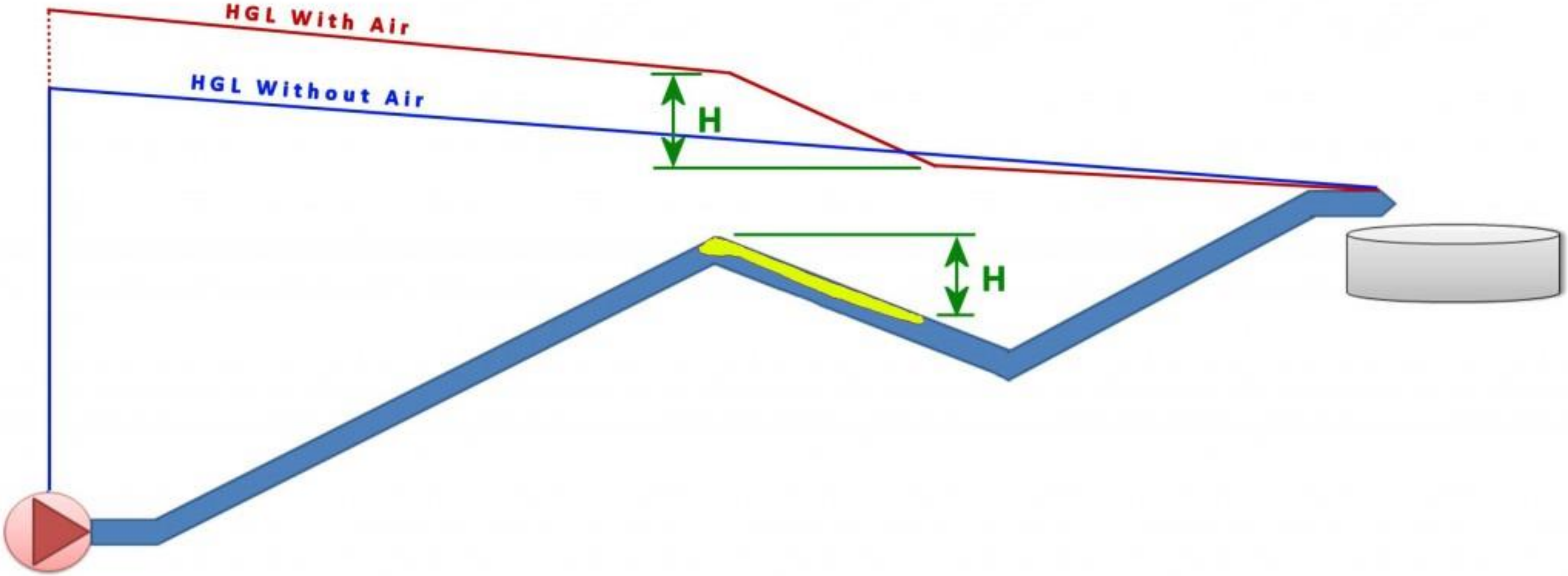
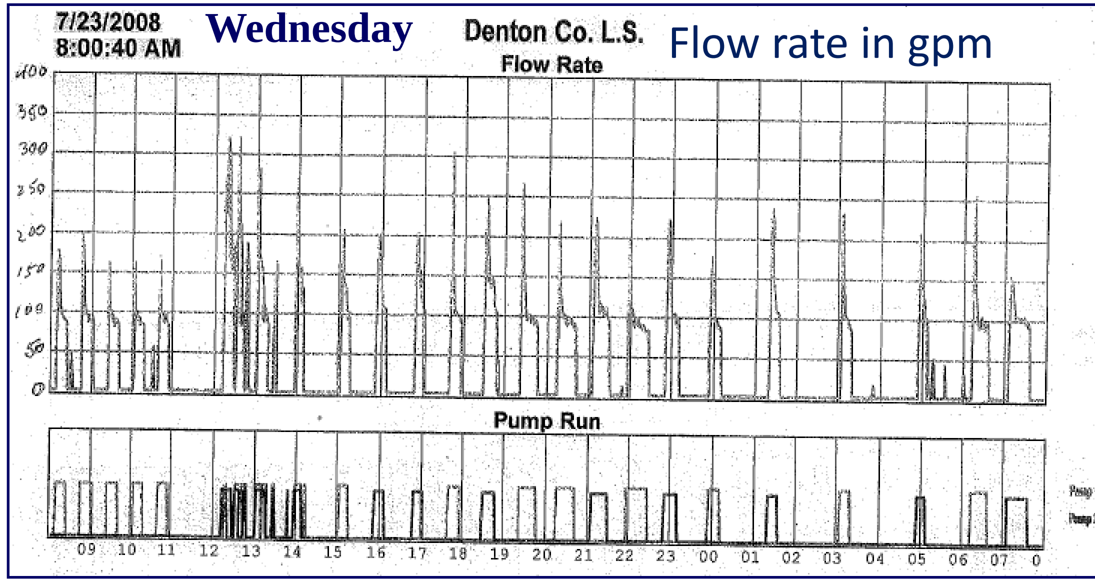


Pump Curve
Pump Efficiency
System With Air
System Without Air
PRESSURE
EFFICIENCY
FLOW RATE
0
10
20
30
40
50
60
70
80
90
100
50
100
150
200
250
300
350

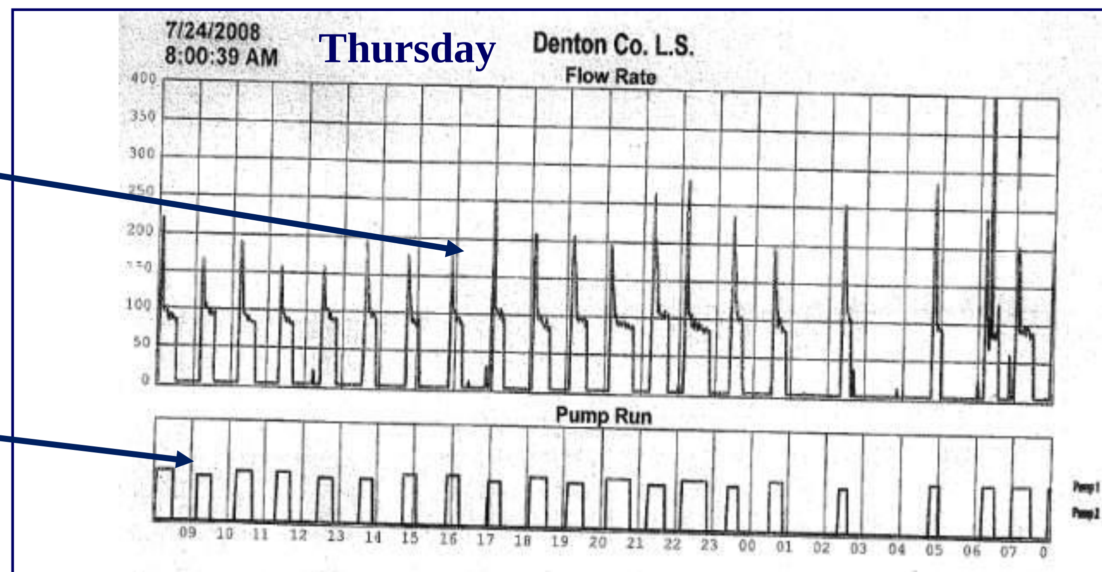


EFFECTS of TRAPPED AIR on HYDRAULIC GRADE LINE

Pump records for a wastewater lift station in Denton County, Texas, with 5 conventional wastewater air valves on its force main.



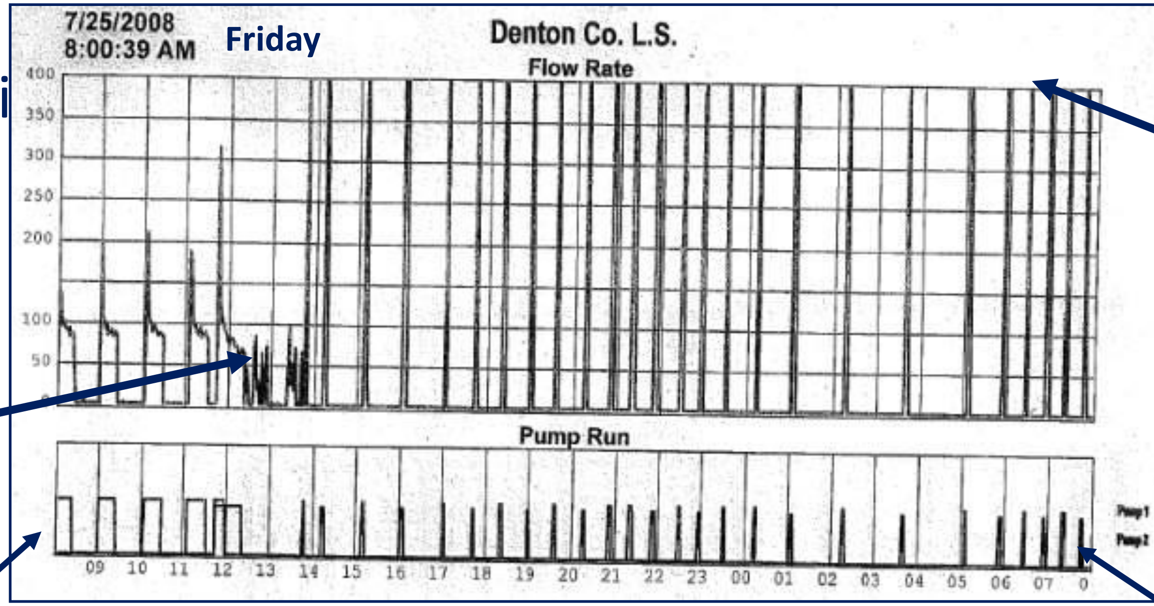
Pump run



Low flow rates

Long pump runs

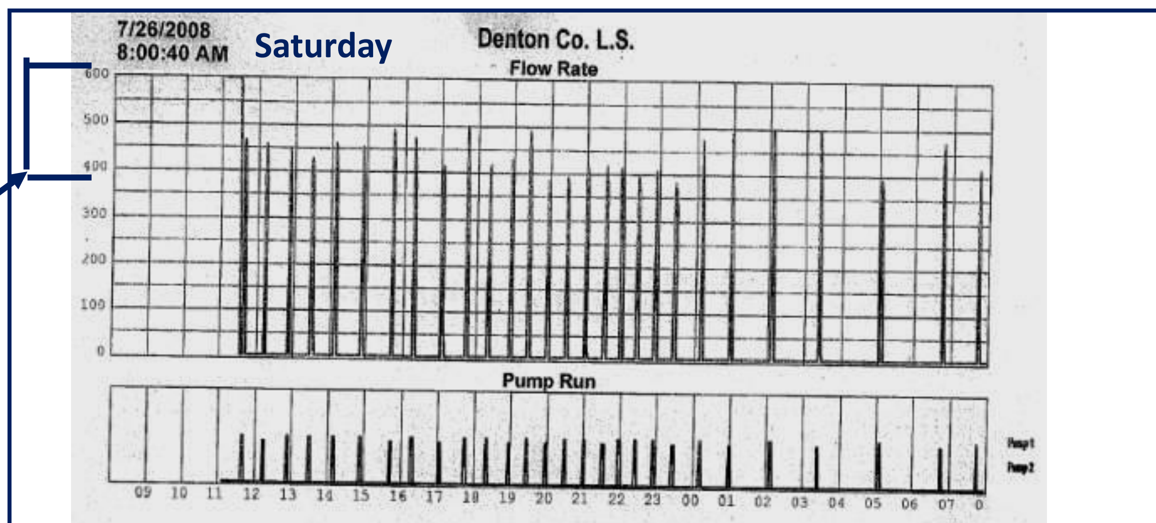
2 of the 5 conventional Ai Valves were replaced by 2 ***new innovative*** wastewater Air Valves



Flow rates rises off the chart!

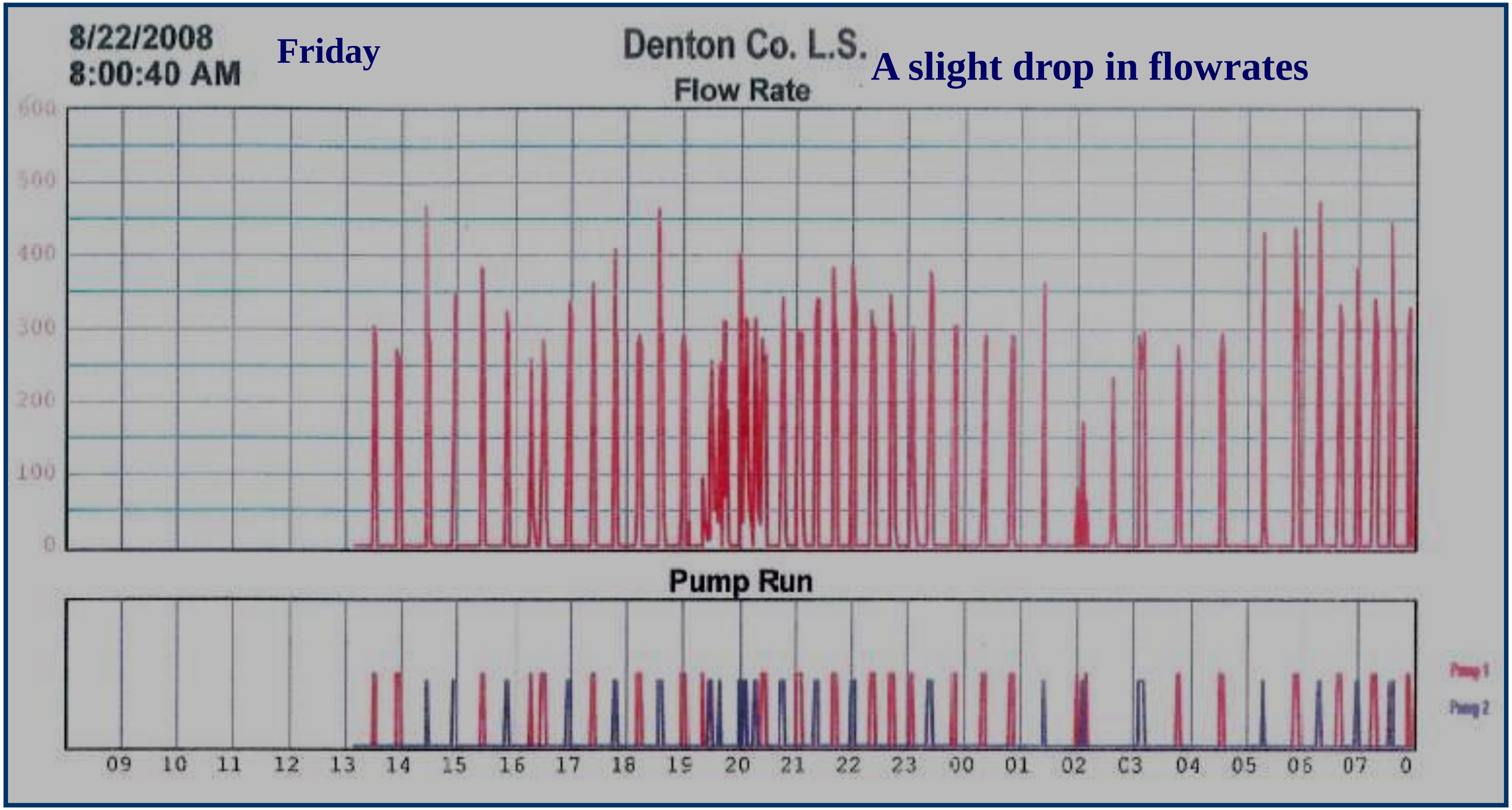
Long pump runs

Short pump runs



Change of flow rate scale

A Month Later



Option 1: Without A.R.I. Air Valves			Option 2: With A.R.I. Air Valves		
Years of operation	20	years	Years of operation	20	years
Days of operation (lifetime)	7300	days	Days of operation (lifetime)	7300	days
Daily operating time	7.36	hours	Daily operating time	2.65	hours
Operating time (annual)	2,686	hours per year	Operating time (annual)	967	hours per year
Operating time (lifetime)	53,728	hours	Operating time (lifetime)	19,345	hours
Flow	100	gpm	Flow	430	gpm
Flow	44,160	gallons per day	Flow	68,370	gallons per day
Flow	16,118,400	gallons per year	Flow	24,955,050	gallons per year
Electricity cost	$ 0.1120	per kilowatt-hour	Electricity cost	$ 0.1120	per kilowatt-hour
TDH	56	feet	TDH	37	feet
Pump efficiency	19%		Pump efficiency	66%	
Motor efficiency	85%		Motor efficiency	85%	
Cost per thousand gallons	$ 0.1223		Cost per thousand gallons	$ 0.0233	
Cost per year	$ 1,971.81		Cost per year	$ 580.67	
Lifetime cost	$ 39,436.29		Lifetime cost	$ 11,613.31	
Cost per hour	$ 0.7340		Cost per hour	$ 0.6003	
Cost per year	$ 1,971.81		Cost per year	$ 580.67	
Lifetime cost	$ 39,436.29		Lifetime cost	$ 11,613.31	

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

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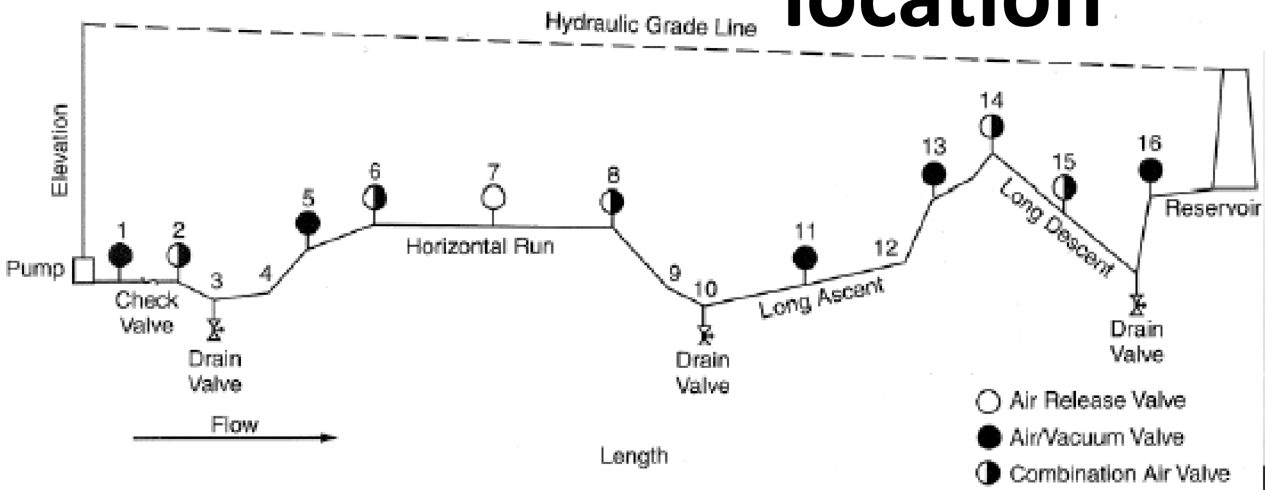
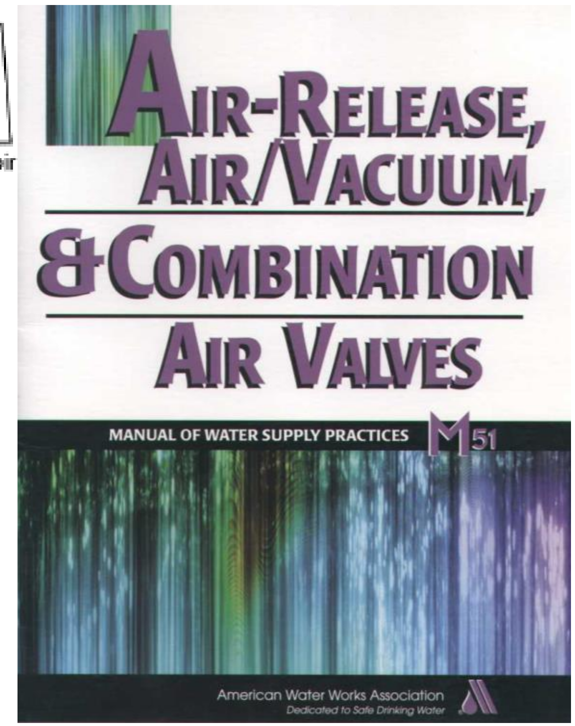
Rule of thumb – Air valve specification and location



No.	Description	Recommended Types
1	Pump Discharge	Air/Vacuum for Pumps
2	Incr. Downslope	Combination
3	Low Point	No Valve Required
4	Incr. Upslope	No Valve Required
5	Decr. Upslope	Air/Vac or Combination
6	Beg. Horizontal	Combination
7	Horizontal	Air Rel or Combination
8	End Horizontal	Combination

No.	Description	Recommended Types
9	Decr. Downslope	No Valve Required
10	Low Point	No Valve Required
11	Long Ascent	Air/Vac or Combination
12	Incr. Upslope	No Valve Required
13	Decr. Upslope	Air/Vac or Combination
14	High Point	Combination
15	Long Descent	Air Rel or Combination
16	Decr. Upslope	Air/Vac or Combination

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



AWWA

AWWA

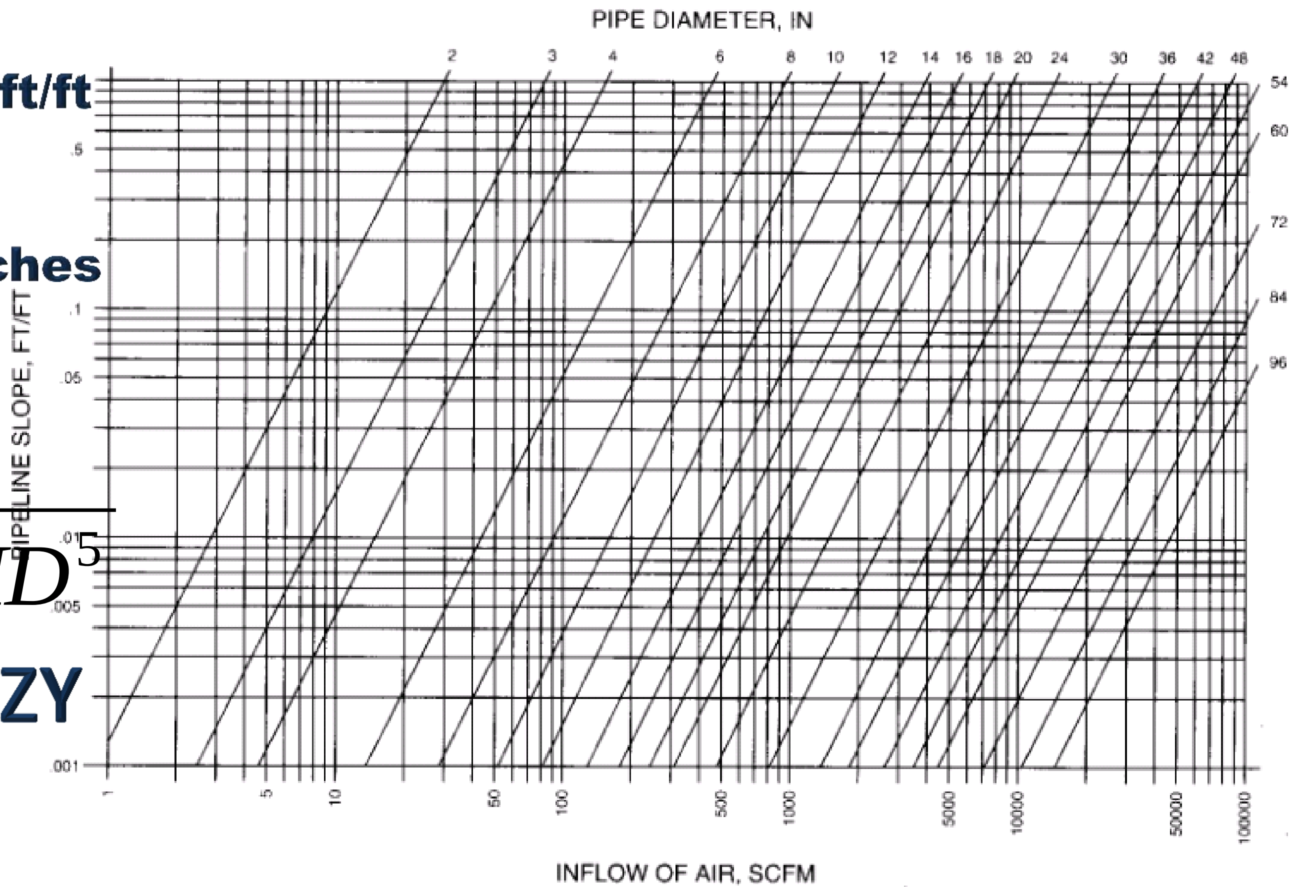
Where:

Q = flow-rate in scfm

C = Chezy Coefficient (110 for iron, 120 for concrete, 130 for steel, 190 for PVC)

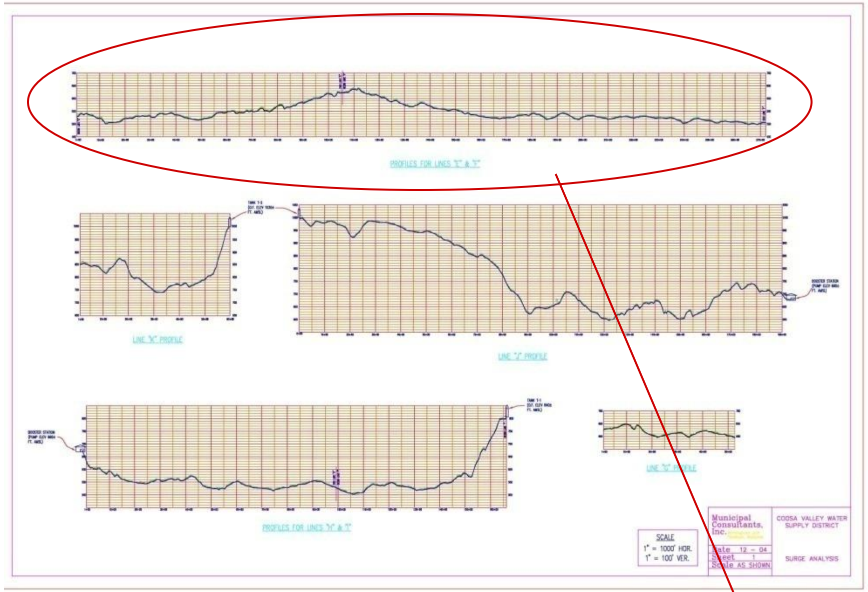
S = pipeline slope in ft/ft

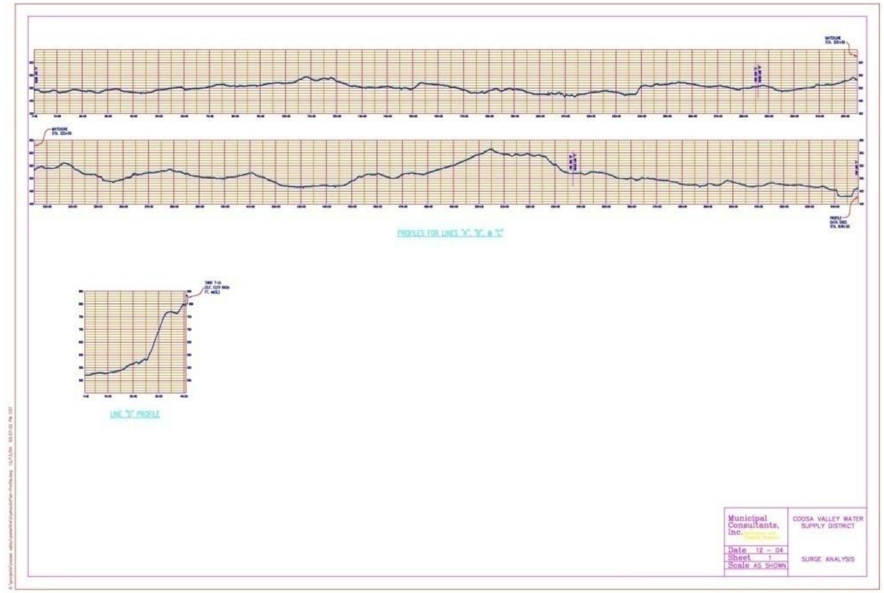
ID = pipeline inside diameter in inches



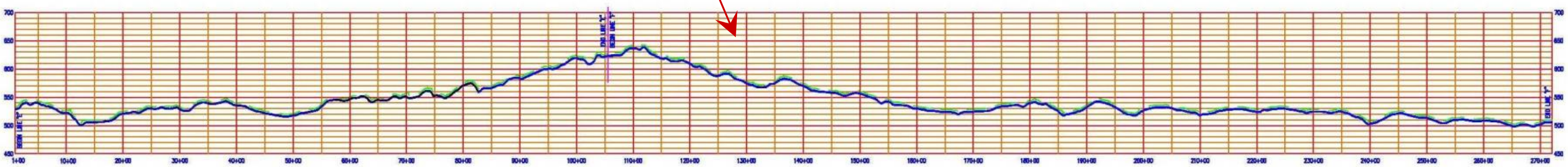
$$Q = 0.0472C\sqrt{SID^5}$$

BASED ON CHEZY





Very Long,



PROFILES FOR LINES "E" & "F"

Very Complicated Projects

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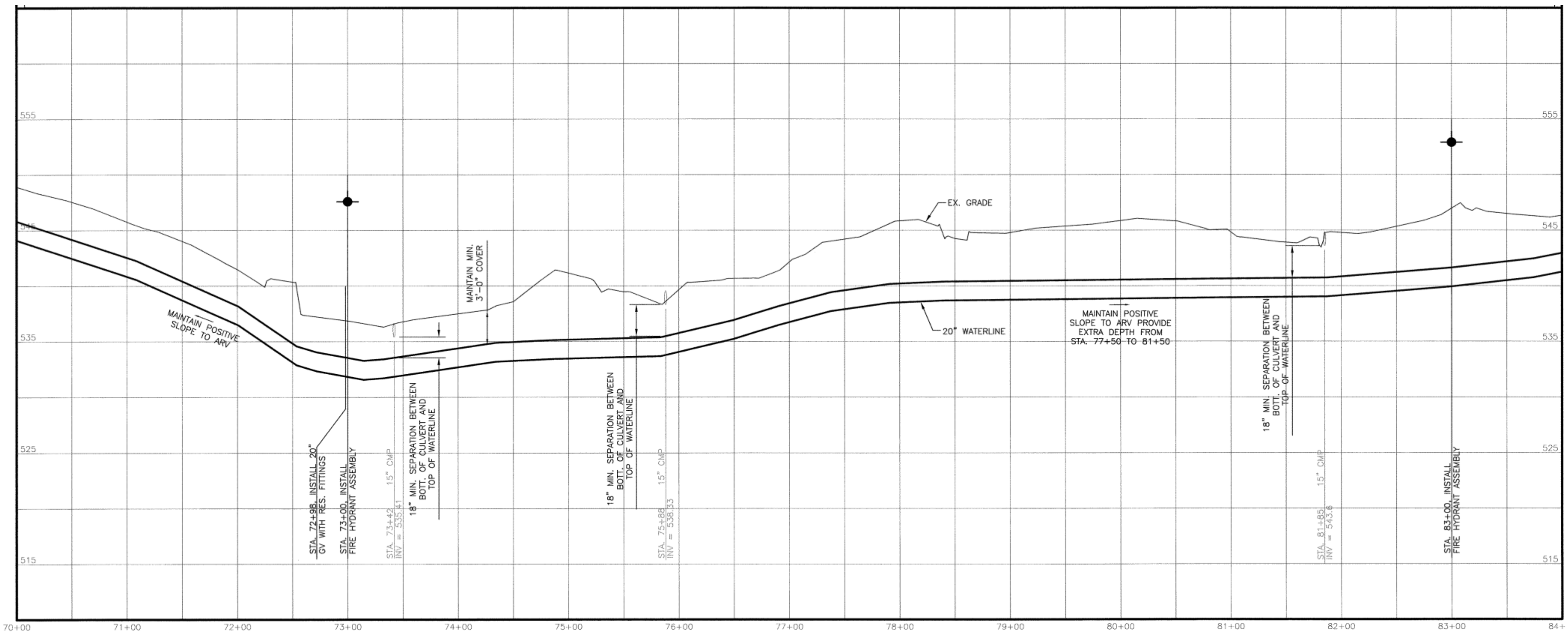
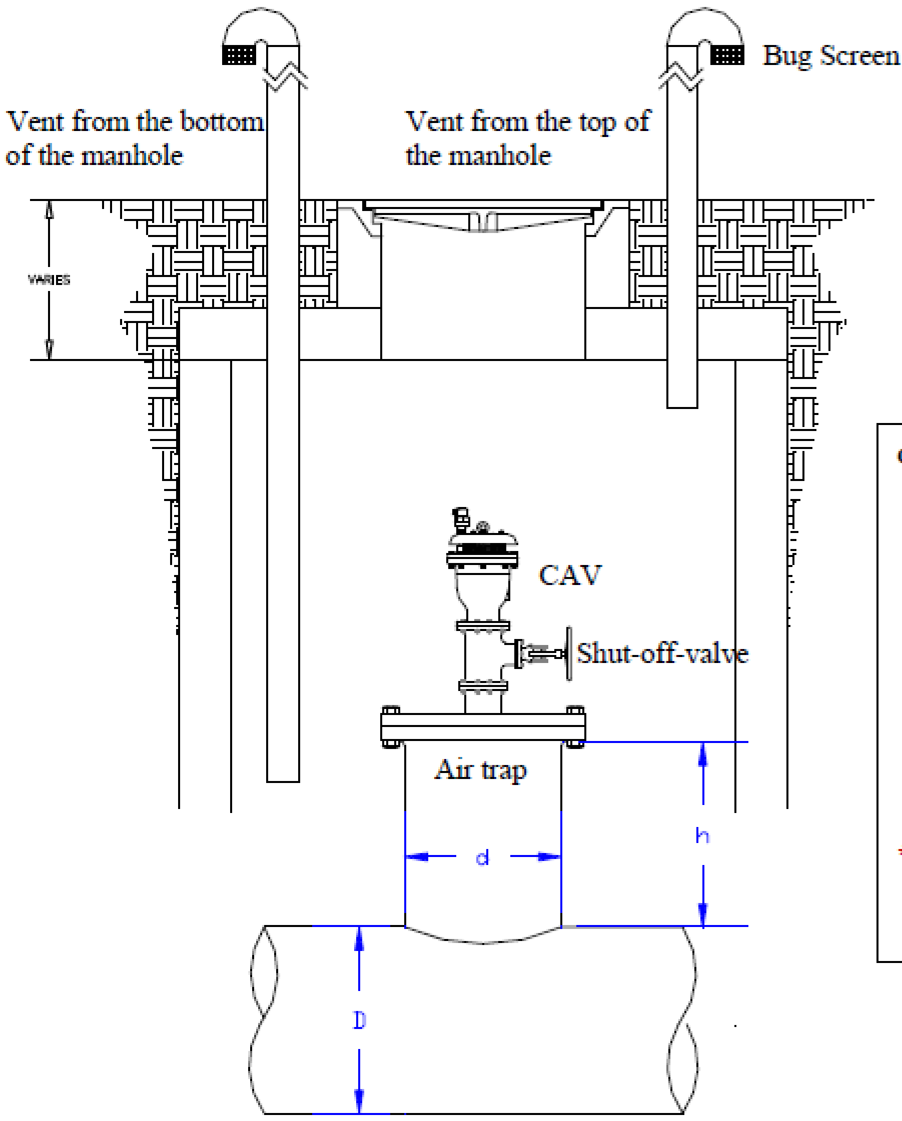


The pipeline profile should not follow overly undulating ground surfaces

Recommended air valve setup in a vault



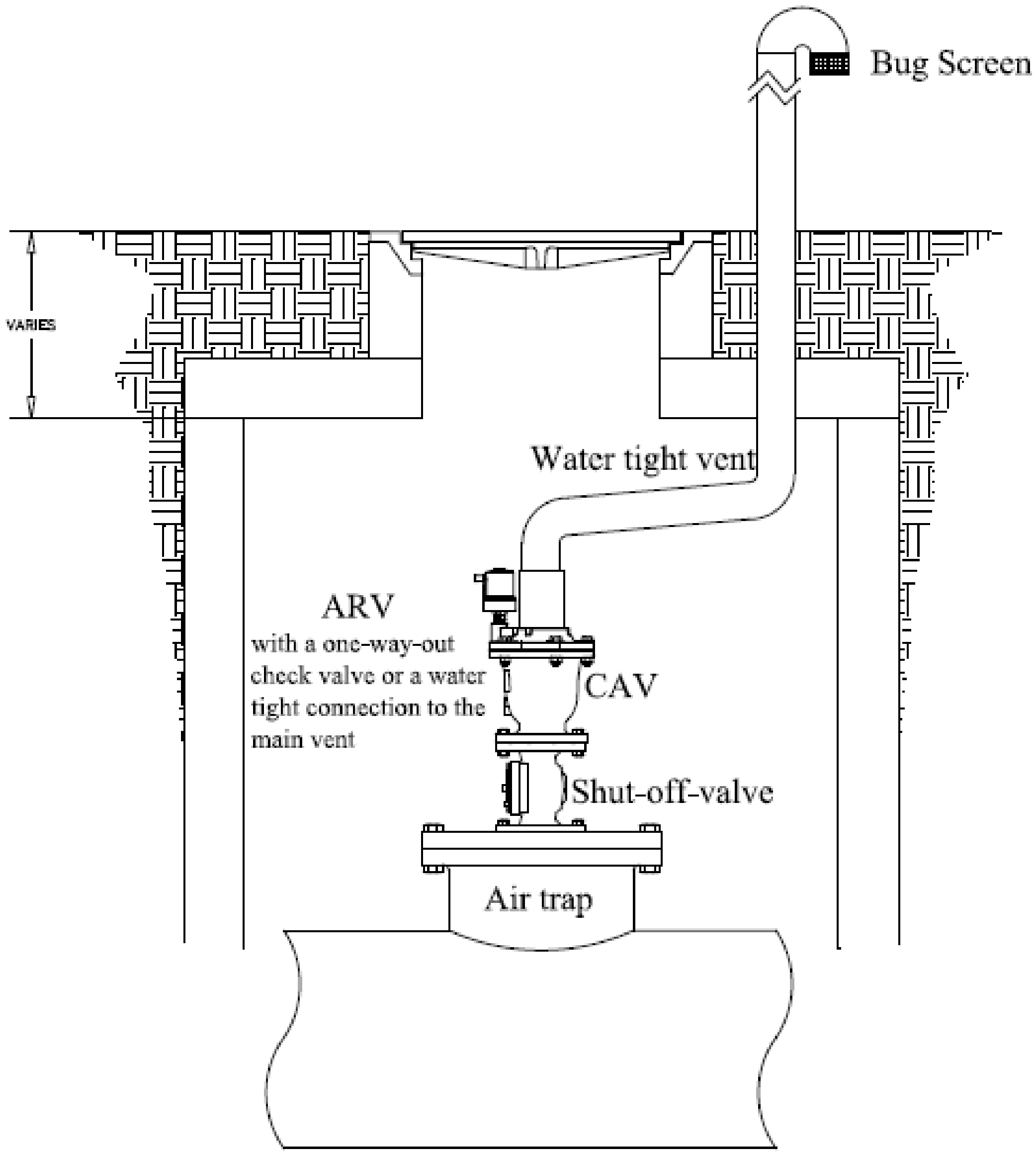
d_a= Diameter of the air/vacuum orifice of the air valve

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

$$d = D \text{ for } D \leq 12",$$
$$d = 0.6D \text{ for } 12" < D \leq 60"$$
$$d = 0.35D \text{ for } D > 60"$$
$$\frac{\pi d^2}{4} \geq \frac{\pi d_a{}^2}{4}$$

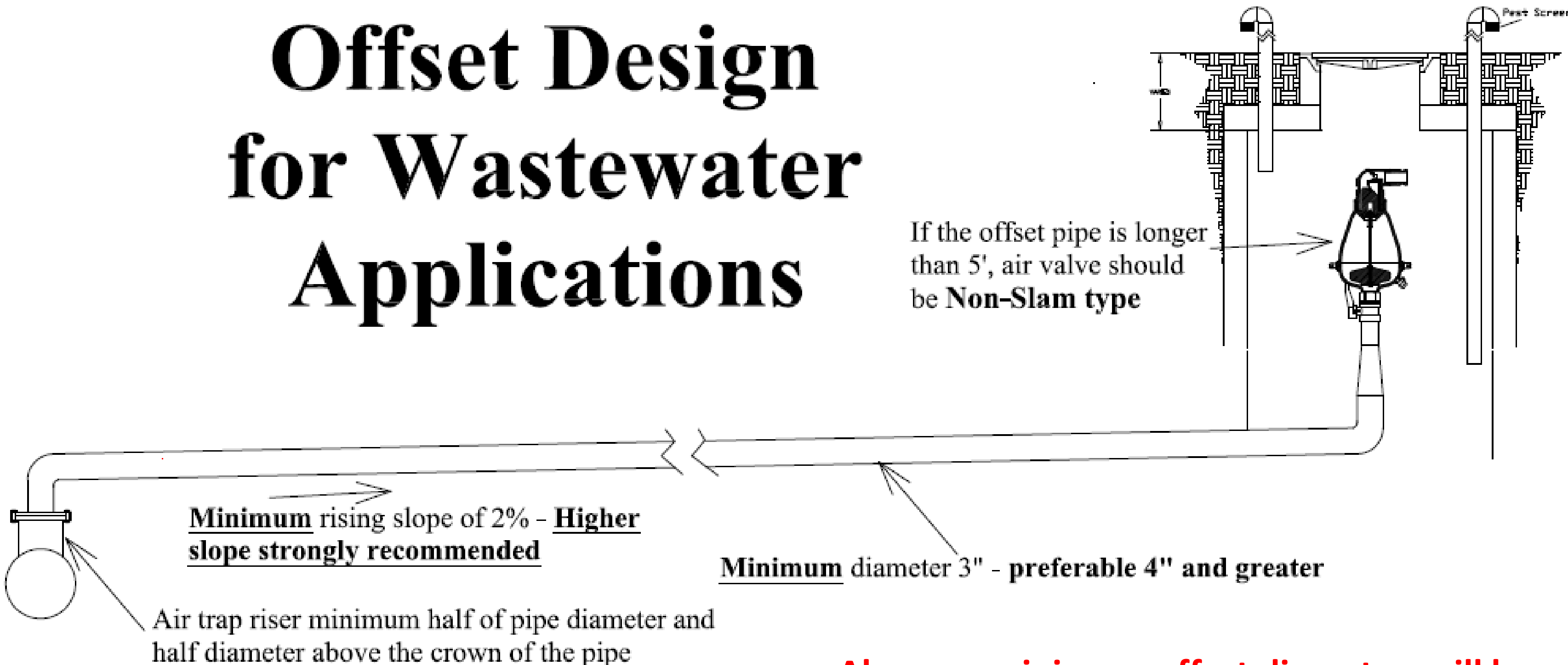
* If there is not enough head room in the manhole, h could be reduced to 0.5D

Venting air valves in flooding vaults



A VENTED CAV IN A MANHOLE SUSCEPTIBLE TO FLOODING

A.R.I. Recommended Offset Design for Wastewater Applications



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

A.R.I. USA Inc.

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Cell 801-875-9155
kim@ariusa.com
www.ariusa.com

D. Kim Sorensen, P.E.

Applications Engineer

Thank You