Irrigation Hydraulics

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Water Fundamentals: *Variables and Units*

- Cross sectional area of a pipe
  - $A = \pi * r^2$
  - $A = \pi * d^2/4$

Water Fundamentals: *Weight, Pressure, and Volume*

- Water…..
  - 8.34 lbs/gallon
  - 7.48 g/ft^3
  - 62.4 lbs/ft^3
  - 1000 kg/m^3

Water Fundamentals: *Weight and Pressure*

- Water exerts a force on it's surrounding
- Pressure: psi (lbs/in2), kPa, bars
  - 2.31 ft of water provides 1psi
  - 23.1 ft of water provides 10 psi
  - 1ft of water provides 0.433 psi
- Elevation (ft) = pressure (2.31 ft/psi)
- *Metric: 1m of water = 9.81 kPa*

Water Fundamentals: *Weight and Pressure*

- Static Pressure
  - *Pressure in a system when water is motionless*
  - *Will vary at different locations in system due to differences in elevation*
- Dynamic Pressure
  - *"Operating" or "Working" pressure*
  - *Pressure exiting any point in a system when it is operating*
  - *DP < SP due to resistance and friction losses*

Water Fundamentals: *Flow*

- *Velocity* is the speed of water as it moves through a pipe system. We use "average" velocity (feet per second, fps, ft/s, m/s).
  1 ft/s = 0.305 m/s
- *Flow* (flowrate) is a measure of the amount of water moved during a period of time (gallons per minute, gpm, ft^3/s, m^3/s).
  1ft^3/s = 449/gpm

Water Fundamentals: *Flow*

- Relationship between velocity, flow, cross-sectional area of a pipe:

$q = va$

$q = 2.448 * v * D^2$

q = gpm ; v = ft/sec; D= in

Water Fundamentals: *Flow*

- *Example:* Schedule 40 pipe, 2" nominal pipe size (NPS), 3 feet per second. What is the flowrate in gpm?

$q = va$

$q = 3\ ft/s * 60\ s/min * \pi * (2/2)^2\text{-}in^2 * 1ft^2/144in^2$

$q = 3 * 60 * 3.14 * 1^2 * 0.00694$

$q = 3.92\ ft^3/min$

$q = 3.92\ ft^3/min * 7.48\ gal/ft^3$

$q = 29.3\ gpm$

Water Fundamentals: *Flow*

- *Class Problem:* Schedule 40 pipe, 4 feet per second. What is the flowrate in gpm at the following pipe sizes?
  - 1" =
  - 1¼" =
  - 1½" =
  - 2" =

Water Fundamentals: *Energy*

- Energy Head = the amount of energy associated with the combination of elevation, pressure, and velocity
- Neglecting velocity head (small contribution):

H (energy head) = p (pressure) + E (elevation)

H(ft) = p (psi) * 2.31 ft/(1 lb/sq.in.) + E (ft)

Water Fundamentals: *Friction Loss*

- Water flowing in pipes looses energy
- Any change in flow, restriction, causes of additional turbulence, etc., will result in a decrease in energy
- Factors affecting friction loss
  - velocity
  - pipe diameter
  - pipe roughness (type)
  - length

Water Fundamentals: *Friction Loss*

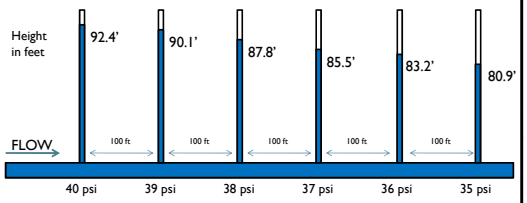
- Velocity Affects
  - Maximum?
  - Minimum?
- Recommended ranges of velocities in plastic pipe?
- Costs?

1 in. diameter PVC

Schedule 40 (450 psi)	$7.00/20 ft
Thin wall (315 psi)	$3.60 /20 ft

~ 49 % reduction in cost

Pressure loss due to pipe length



What's the effect of 1 psi loss per 100 feet?

Friction & Velocity Charts

Every shape and style!!!

PVC Schedule 40 IPS Plastic Pipe

PSI loss per 100 feet of pipe
Size 1/2" through 2 1/2"
Flow GPM 1 through 75
Shading indicates that the 5 ft/sec maximum velocity has been exceeded.

size (in)	1/2		3/4		1		1 1/4		1 1/2		2		2 1/2	
ID (in)	0.622		0.824		1.049		1.380		1.610		2.067		2.469	
Flow (gpm)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)
1	1.05	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.15	0.00				
2	2.11	1.55	1.20	0.38	0.74	0.12	0.42	0.03	0.31	0.02	0.19	0.00		
3	3.16	3.28	1.80	0.84	1.11	0.26	0.64	0.07	0.47	0.03	0.28	0.01	0.20	0.00
4	4.22	5.60	2.40	1.42	1.48	0.44	0.85	0.12	0.62	0.05	0.38	0.02	0.26	0.01
5	5.27	8.46	3.00	2.15	1.85	0.66	1.07	0.18	0.78	0.08	0.47	0.02	0.33	0.01
6			3.60	3.02	2.22	0.93	1.28	0.25	0.94	0.12	0.57	0.03	0.40	0.01
7			4.20	4.01	2.59	1.24	1.49	0.33	1.10	0.15	0.66	0.05	0.46	0.02
8			4.80	5.14	2.96	1.59	1.71	0.42	1.25	0.20	0.76	0.06	0.53	0.02
9			5.40	6.39	3.33	1.97	1.92	0.52	1.41	0.25	0.85	0.07	0.60	0.03
10					3.70	2.40	2.14	0.63	1.57	0.30	0.95	0.09	0.66	0.04
11					4.07	2.86	2.35	0.75	1.73	0.36	1.05	0.11	0.73	0.04
12					4.44	3.36	2.57	0.89	1.88	0.42	1.14	0.12	0.80	0.05
14					5.19	4.47	2.99	1.18	2.20	0.56	1.33	0.17	0.93	0.07
16							3.42	1.51	2.51	0.71	1.52	0.21	1.07	0.09
18							3.85	1.88	2.83	0.89	1.71	0.26	1.20	0.11
20							4.28	2.28	3.14	1.08	1.90	0.32	1.33	0.13
22							4.71	2.72	3.46	1.29	2.10	0.38	1.47	0.16
24							5.14	3.20	3.77	1.51	2.29	0.45	1.60	0.19
26									4.09	1.75	2.48	0.52	1.74	0.22
28									4.40	2.01	2.67	0.60	1.87	0.25
30									4.72	2.29	2.86	0.68	2.00	0.29
35									5.50	3.04	3.34	0.90	2.34	0.38
40											3.81	1.15	2.67	0.49
45											4.29	1.43	3.01	0.60
50											4.77	1.74	3.34	0.73
55											5.25	2.08	3.68	0.88
60													4.01	1.03
65													4.35	1.19
70													4.68	1.37
75													5.01	1.56

Friction & Velocity Charts (Choate, Page 388)

1-1/2 Sch 40 at 15 gpm = 0.669 psi loss/100 ft

Table Losses same for all Controlled OD Schedule 40 thermoplastic pipe. For PE pipe, convert losses to equivalent of C=140.

TABLE 8
PRESSURE LOSS
SCHEDULE 40 PVC PIPE

C = 150

Pipe Sizes: Nominal													Loss per 100 ft: lb/in²
gpm	1/2 in	3/4 in	1 in	1-1/4 in	1-1/2 in	2 in	gpm	2 in	2-1/2 in	3 in	4 in	6 in	8 in
1	0.503	0.123	0.037	0.010	0.004	0.001	105	7.16	3.02	1.04	0.276	0.037	0.010
2	1.81	.444	.134	.034	.016	.005	110		3.29	1.14	.300	.041	.011
3	3.84	0.940	.283	.073	.034	.010	115		3.57	1.23	.326	.044	.012
4	6.54	1.60	.482	.124	.058	.017	120		3.86	1.33	.353	.048	.013
5	9.88	2.42	0.728	.187	.088	.026	125		4.16	1.44	.381	.051	.013
6	13.85	3.39	1.02	.263	.123	.036	130		4.48	1.55	.409	.055	.015
7	18.42	4.51	1.36	.349	.163	.048	135		4.80	1.66	.439	.059	.016
8	23.58	5.77	1.74	.447	.209	.061	140		5.14	1.77	.469	.064	.017
9	29.32	7.17	2.16	.556	.260	.076	145		5.48	1.89	.501	.068	.018
10		8.72	2.62	0.676	0.316	0.092	150			2.02	0.533	0.072	0.019
11		10.40	3.13	.806	.377	.110	160			2.27	.601	.081	.021
12		12.22	3.68	0.947	.443	.129	170			2.64	.672	.091	.024
13		14.17	4.26	1.10	.513	.150	180	10 in		2.82	.747	.101	.026
14		16.25	4.89	1.26	.589	.172	190			3.12	.826	.112	.029
15		18.46	5.56	1.43	.668	.196	200	0.011		3.43	.908	.123	.032
16		20.80	6.26	1.61	.754	.220	210	.012		3.76	0.994	.134	.035
17			7.01	1.80	.843	.247	220	.013		4.09	1.08	.147	.038
18			7.79	2.00	0.937	0.274	230	.014		4.45	1.18	.159	.042

Water Hammer

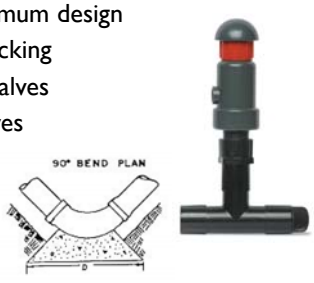
- Water hammer occurs when the flow of water in a pipe is abruptly changed or stopped
- When water hammer occurs, a high intensity pressure wave travels back through the piping system until it reaches a "point of relief"
  - valve, sprinkler, elbow, poor glued joint, stressed pipe

Causes of water hammer

1. Valve closure
2. Uncontrolled flow velocity in empty pipes
3. Trapped air in long runs of pipe
4. Reverse flow when pumps stop

Avoiding water hammer

- 5 ft/s maximum design
- Thrust blocking
- Air relief valves
- Check valves

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