

Texas On-Site Wastewater Treatment
Research Council 19th Annual Conference

The Hydraulics of Small Wastewater Systems

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The Hydraulics of Small Wastewater Systems

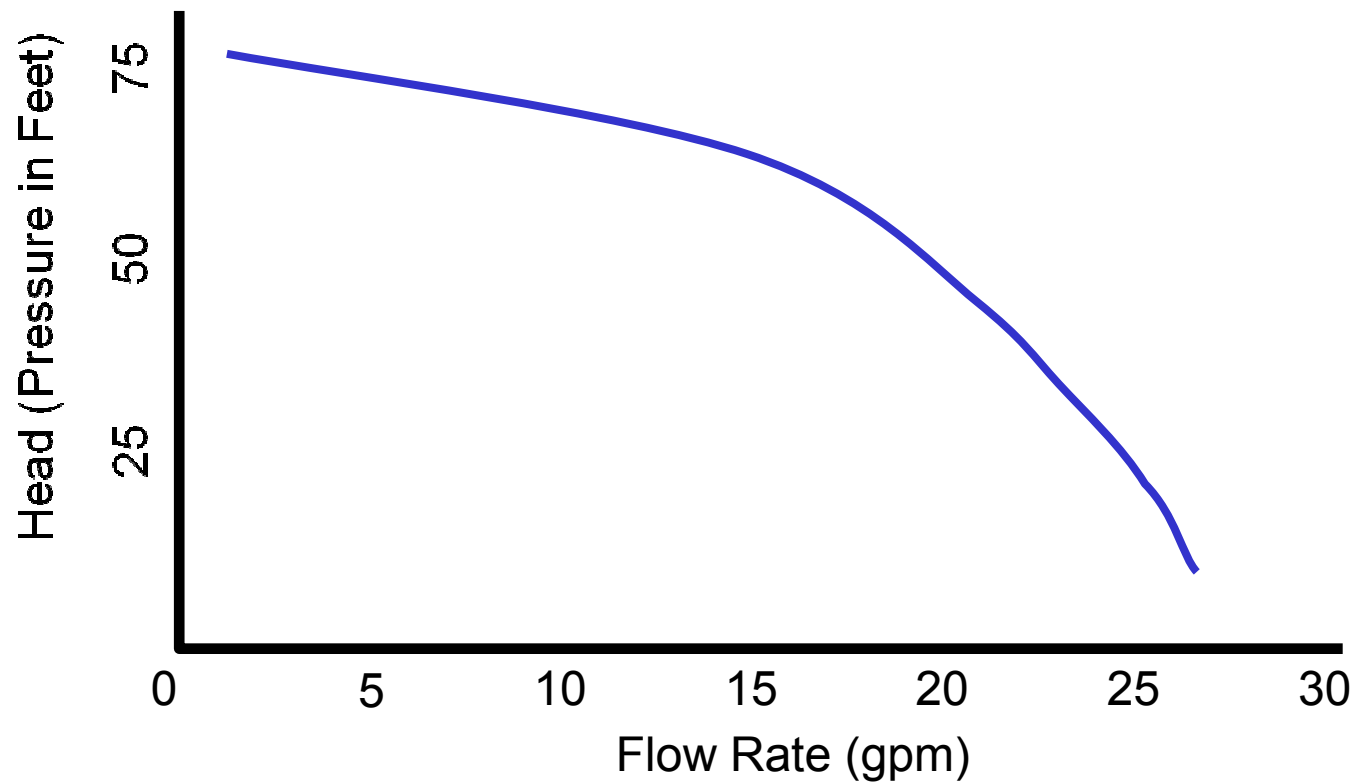
- More systems are being installed with pumps
 - Pump to trench and/or distribution box
 - Pressurized distribution
 - Drip systems
 - Low pressure distribution
 - Pump to treatment

Selecting a Pump

- Selecting a pump is the next to last task
 - The last task is the pump controls
- Four design issues for pump selection
 - Location
 - Pressure
 - Flow
 - Solids

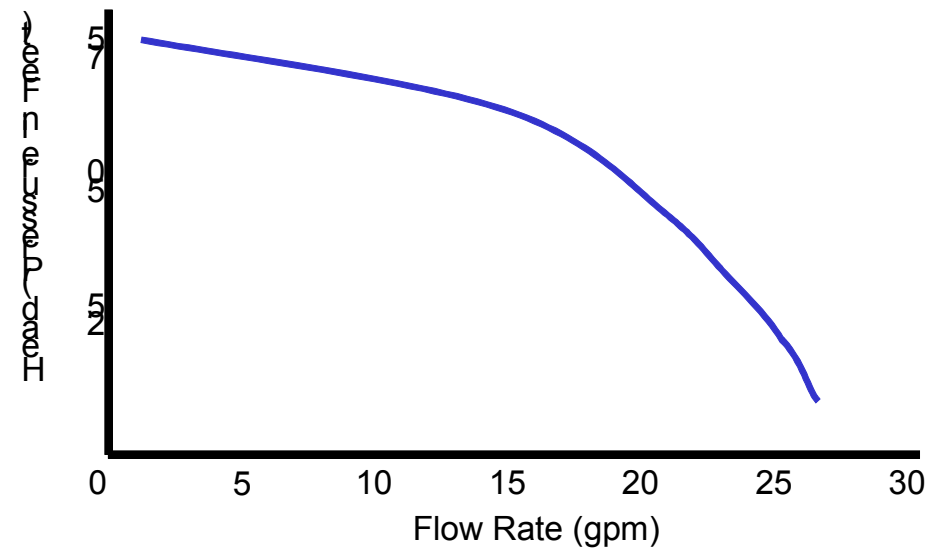
Pump Curve

This presentation assumes centrifugal pumps

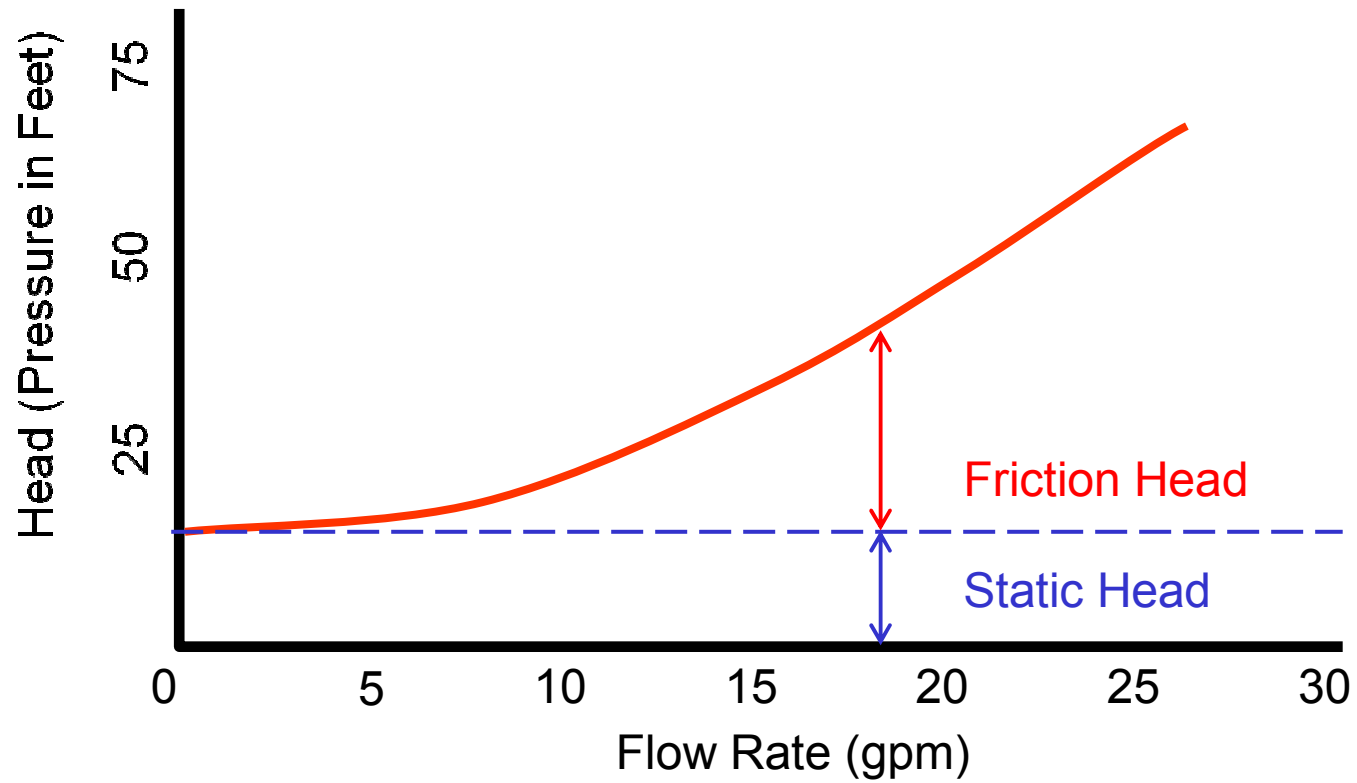


Pump Curve

- All pumps have a curve
 - Water pumps
 - Air pumps
 - Blowers
- Relates the flow rate that can be generated against a known pressure

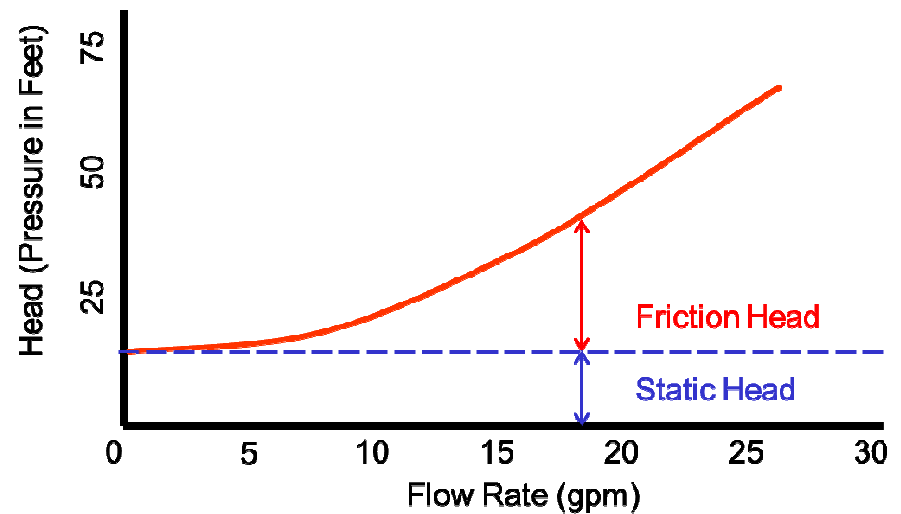


System Curve



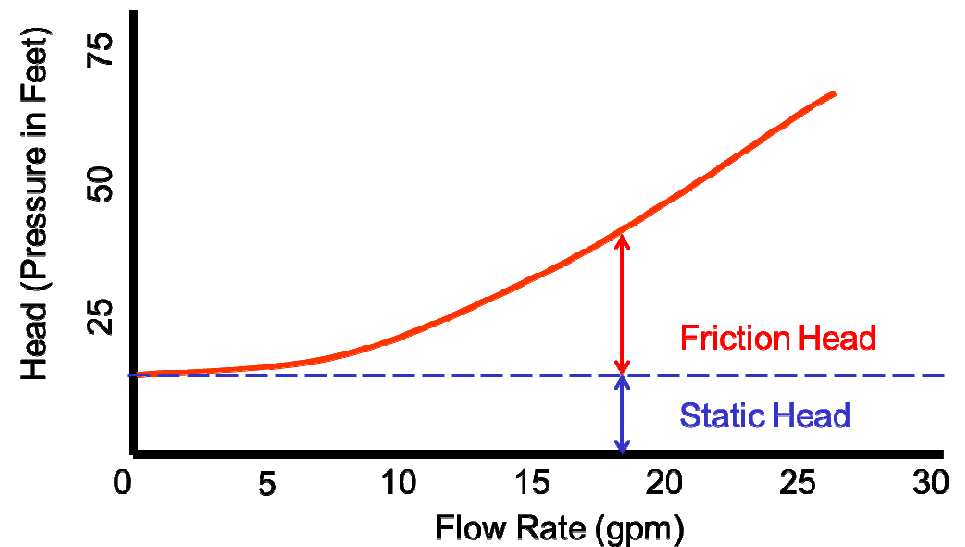
Static Head – Part 1

- Elevation Change
 - From low water level to highest elevation
 - Not really static because water level elevation changes
 - Must be able to pump water to the greatest difference in elevation



Static Head – Part 2

- Pressure requirement for operation
 - May need 10 psi minimum to operate emitters
 - May need 5 feet of head for orifice

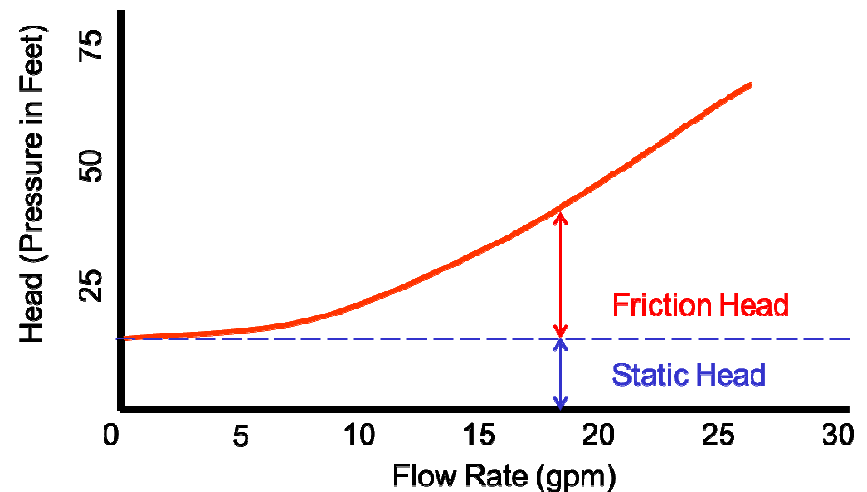


Friction Head

- Friction Components
 - Pipe friction
 - Related to fluid velocity
 - Related to material roughness
 - Fittings
 - How much turbulence is created in transition
 - Directional changes
 - Filters
 - Clean filter eventually becomes a dirty filter
- The higher the flow the greater the friction

Friction Head

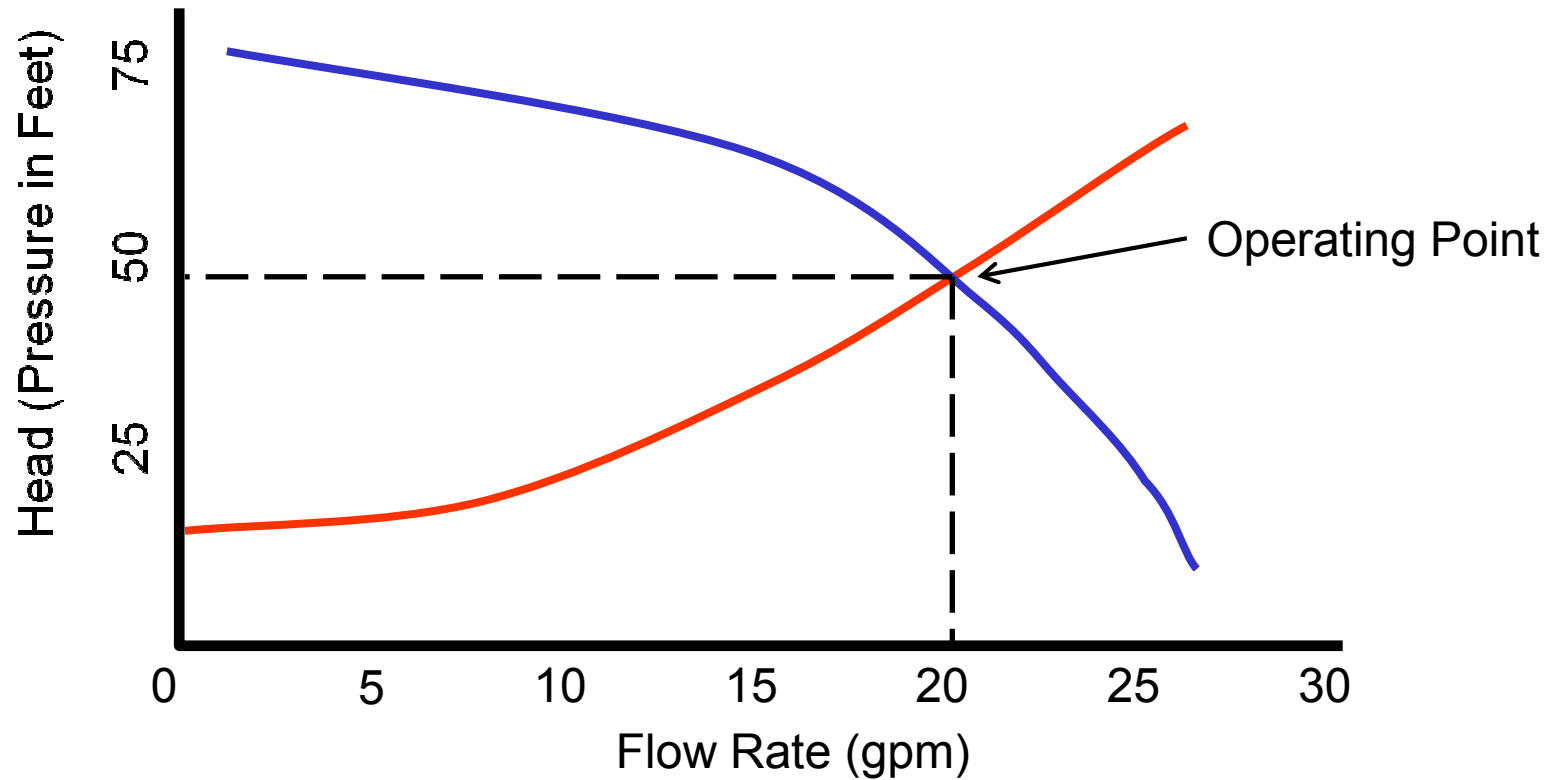
- Flowing water
 - The greater the velocity
 - The greater the friction
 - Usually try to limit velocity to 5 feet per second or less
 - Also reduced water hammer



Total Dynamic Head

- Is the combination of...
 - static head
 - friction head
 - this is the pressure that can be measured at the discharge of the pump

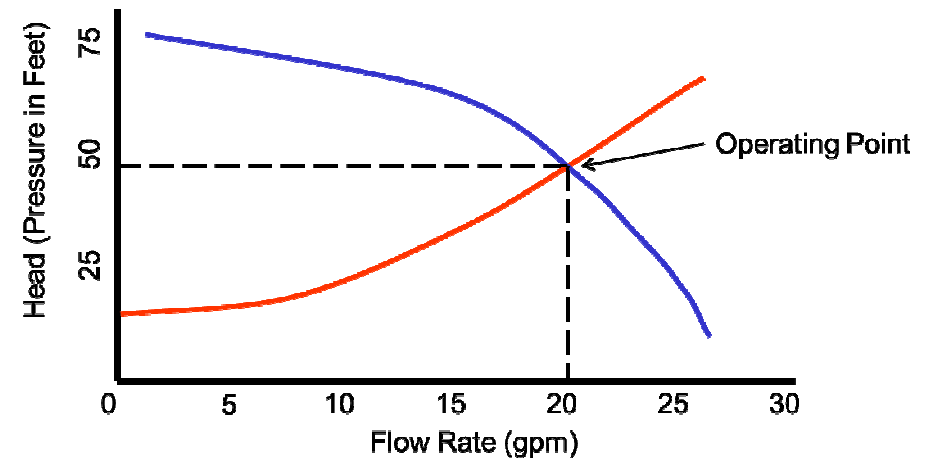
System Curve & Pump Curve



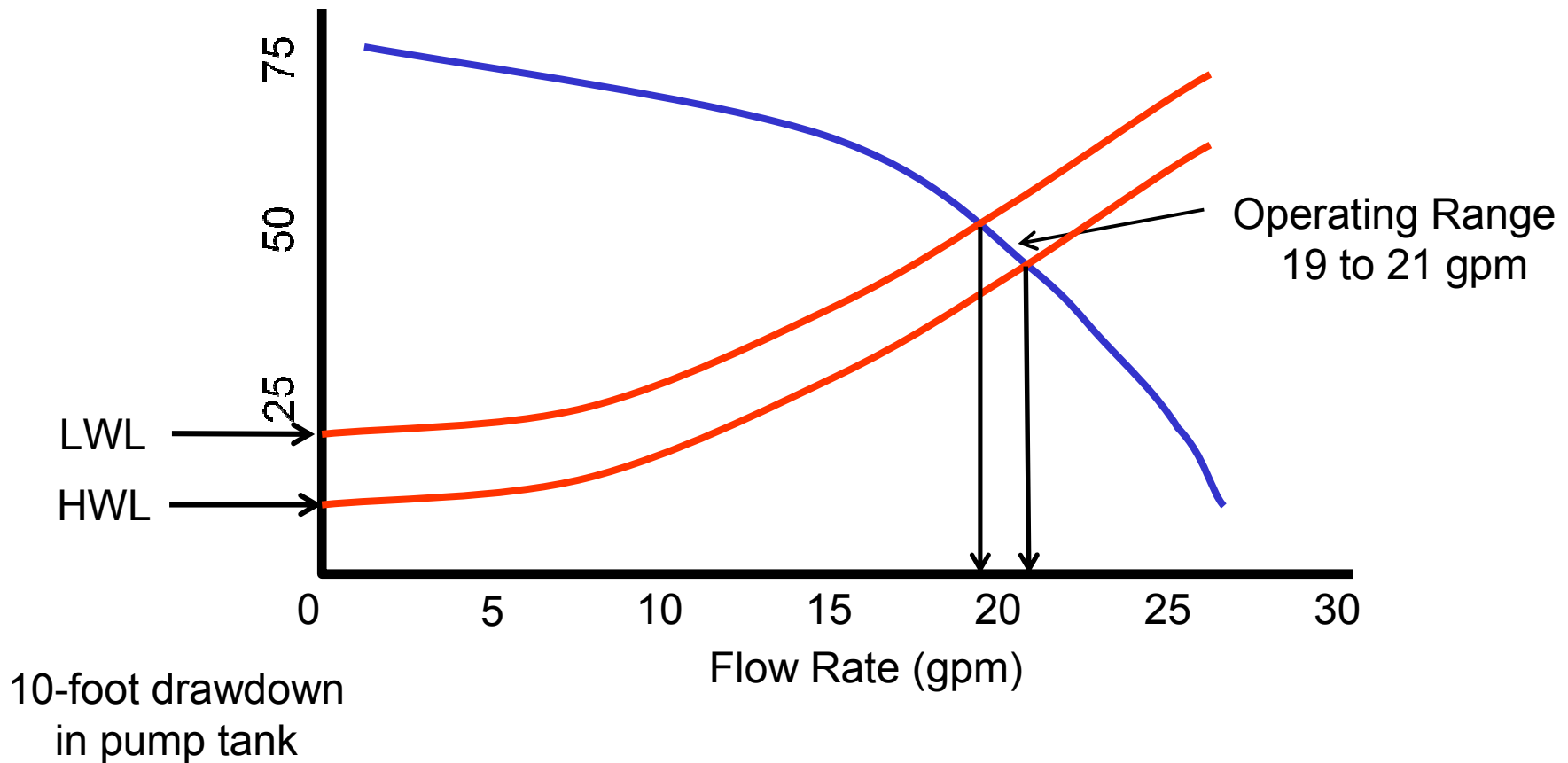
21 gpm at 49 feet of head

Operating Point

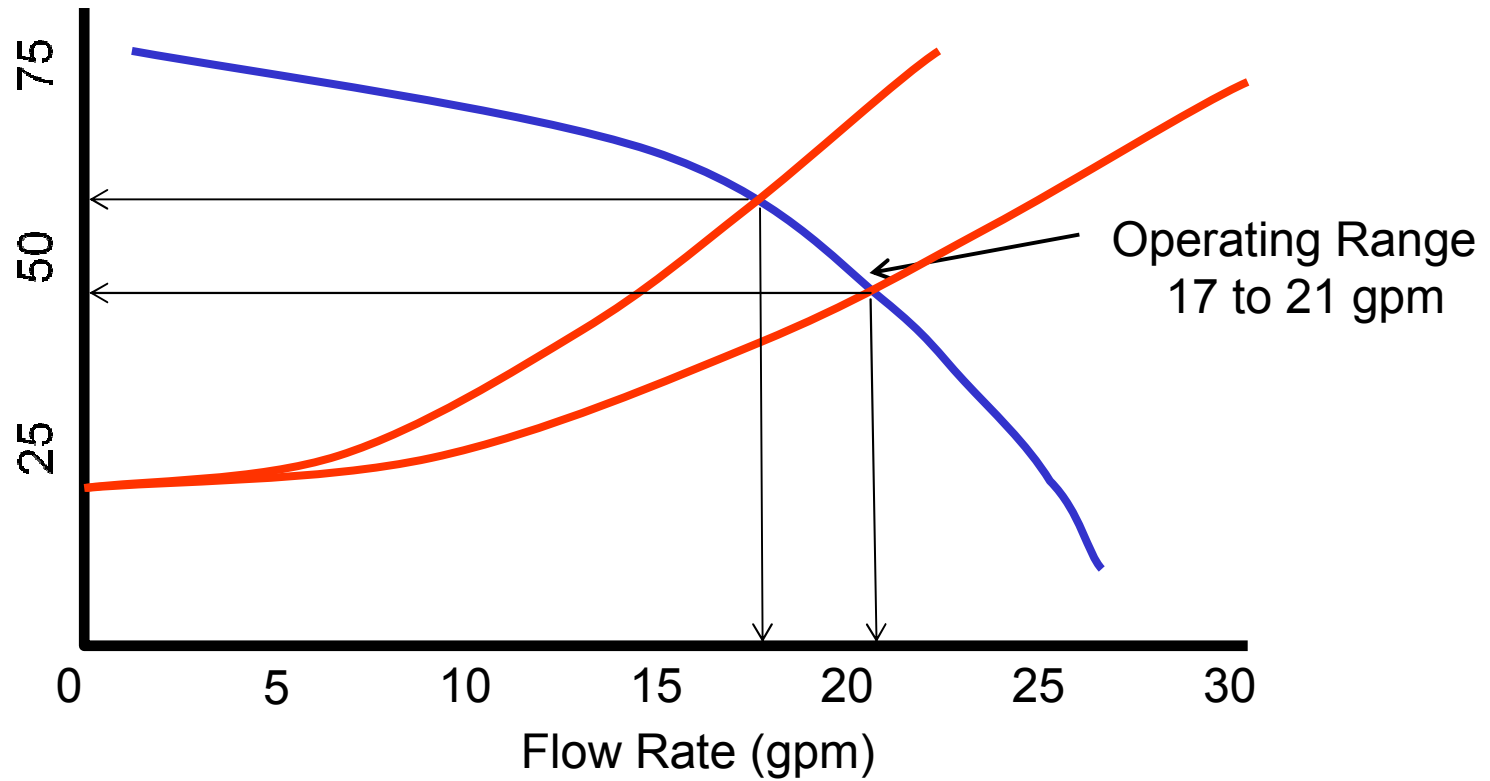
- Point where the
 - Flow and pressure of pump matches the flow and pressure of the system.



We Really have an Operating Range



What about a Dirty Filter



Our Goal is to Develop the System Curve for a Site

- Not complicated
 - But must be complete
- We will use pipe tables to minimize calculations
 - Tabulate pipe friction at various flows
- Account for fittings, valves, and filters
 - Need manufacturer's information
 - These are also in the form of curves

Pipe Tables

- Material
 - PVC Sch 40
- Diameter
 - Nominal and actual
- Flow rate
 - Gallons per minute
- Friction loss
 - psi per 100 feet

Schedule 40 IPS PVC Plastic Pipe										
Nominal Size	1/2"		3/4"		1"		1-1/4"		1-1/2"	
Pipe ID	0.622		0.824		1.049		1.380		1.610	
Pipe OD	0.840		1.050		1.315		1.660		1.900	
Wall	0.109		0.113		0.133		0.140		0.145	
Flow GPM	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss
1	1.06	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.16	0.00
2	2.11	1.55	1.20	0.39	0.74	0.12	0.43	0.03	0.32	0.02
3	3.17	3.28	1.80	0.83	1.11	0.26	0.64	0.07	0.47	0.03
4	4.22	5.59	2.41	1.42	1.48	0.44	0.86	0.12	0.63	0.05
5	5.28	8.45	3.01	2.15	1.86	0.66	1.07	0.17	0.79	0.08
6	6.33	11.84	3.61	3.01	2.23	0.93	1.29	0.25	0.95	0.12
7	7.39	15.75	4.21	4.01	2.60	1.24	1.50	0.33	1.10	0.15
8	8.45	20.17	4.81	5.13	2.97	1.59	1.72	0.42	1.26	0.20
9	9.50	25.09	5.41	6.39	3.34	1.97	1.93	0.52	1.42	0.25
10	10.56	30.50	6.02	7.76	3.71	2.40	2.14	0.63	1.58	0.30
11			6.62	9.26	4.08	2.86	2.36	0.75	1.73	0.36
12			7.22	10.88	4.45	3.36	2.57	0.89	1.89	0.42
13			7.82	12.62	4.83	3.90	2.79	1.03	2.05	0.48
14			8.42	14.48	5.20	4.47	3.00	1.18	2.21	0.56
15			9.02	16.45	5.57	5.08	3.22	1.34	2.36	0.63
16			9.63	18.54	5.94	5.73	3.43	1.51	2.52	0.71
17			10.23	20.74	6.31	6.41	3.65	1.69	2.68	0.80
18			10.83	23.06	6.68	7.12	3.86	1.88	2.84	0.89
19			11.43	25.48	7.05	7.87	4.08	2.07	2.99	0.98
20			12.03	28.02	7.42	8.66	4.29	2.28	3.15	1.08
22					8.17	10.33	4.72	2.72	3.47	1.28

Using Pipe Tables

- Got to know your flow rate
 - Example 10 gpm
 - Look at 10 gpm and find a pipe diameter that provides a velocity 5 feet per second or less
 - Need a 1-inch diameter pipe
 - 2.40 psi per 100 feet
 - Velocity 3.71 fps

Schedule 40 IPS PVC Plastic Pipe											
Nominal Size	1/2"		3/4"		1"		1-1/4"		1-1/2"		
Pipe ID	0.622		0.824		1.049		1.380		1.610		
Pipe OD	0.840		1.050		1.315		1.660		1.900		
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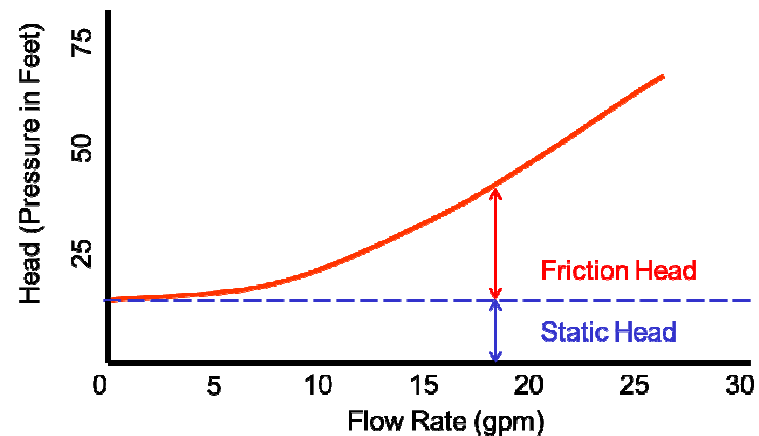
Three Pieces of Information

- Determined a pipe diameter
- Determined the friction
- Determined that velocity was greater than the scour velocity

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22					8.17	10.33	4.72	2.72	3.47	1.28	

Problem—Units of Pressure

- Pump curve
 - Feet of head
- Pipe table
 - Pounds per square inch
- Conversion
 - 2.31 feet of water head per psi



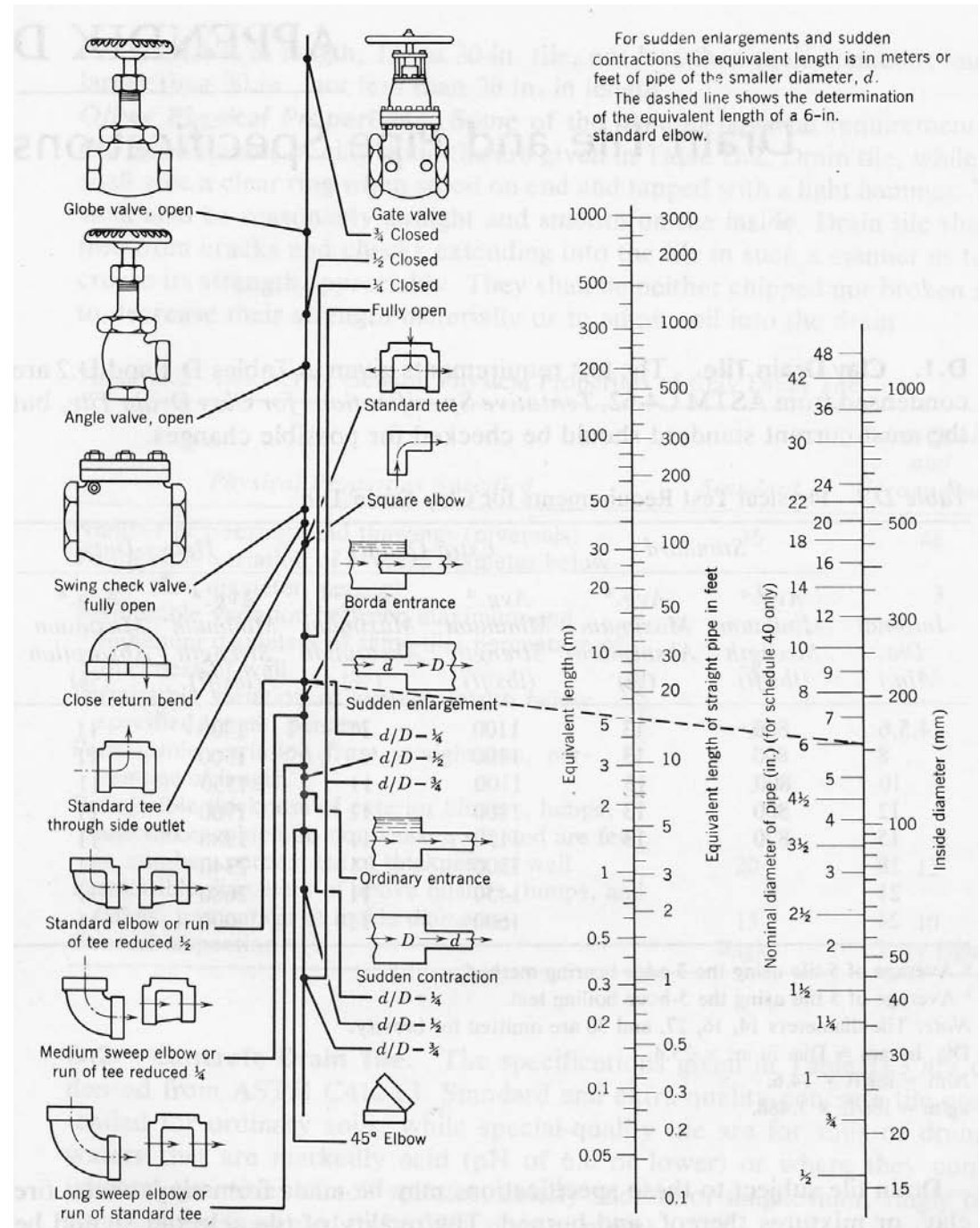
Example: 10 psi is equal to 23.1 feet of head

Friction from Fittings

- Elbows
 - Short radius
 - Long radius sweep
- Diameter changes
 - Reducing coupling
 - bushings
- Couplings
- Backflow preventers
 - Ball check valves
 - Swing Flap
 - Spring loaded

Equivalent Pipe Length Method

- Converts friction from fitting into equivalent length of pipe
 - of same diameter
 - handy for common fittings



Friction from In-Line Devices

- Devices that
 - Regulate flow
 - Measure flow
 - Filter water
 - Direct flow
- All have very significant headloss components
 - Need manufacturer specific information

Diaphragm Valves

Pressure losses

flow		Pressure loss			
		80-3/4"		80-1"	
gpm	m ³ /h	psi	bar	psi	bar
2.2	0.5	1.42	0.10	1.42	0.10
4.4	1	1.60	0.11	1.42	0.10
8.8	2	1.65	0.11	1.42	0.10
13.2	3	2.90	0.20	1.65	0.11
17.6	4	4.35	0.30	2.61	0.18
22.0	5	6.82	0.47	3.63	0.25
26.4	6			4.83	0.33
30.8	7			6.09	0.42



Disc Filters

FILTER APPLICATION RECOMMENDATIONS

FLOW RATE (GPM)	HEAD LOSS (psi)								
	3/4"	1"	1" Super	1 1/2"	1 1/2" Super	2" Dual	2" Super	3" Twin	3" Angle
5	0.60	0.25							
10	2.50	0.60							
13	3.40	1.34							
17	5.87	2.10							
22		3.24	1.10	1.10					
26			1.50	1.30	1.50				
31			2.10	1.70	2.10				
35			2.50	2.30	2.50				
44					4.20	0.30	0.30		
66						0.63	0.63		
88						1.03	1.03	0.64	0.44
110						1.47	1.47	0.98	0.58
132								1.37	0.73
154								1.80	0.88
176								2.28	1.03
198									1.32
220									1.61



3/4" Filter

Flow range:	1-12 GPM
Maximum pressure:	140 psi
Filtering surface area:	24.8 sq. in.
Filtering volume:	5.8 cu. in.
Length:	8 1/16"
Width:	9 5/8"
Weight:	.8 lbs.
Distance between end connections:	6"
Inlet/outlet diameter:	3/4" male
Part Number:	25A45-XXX

Indexing Valves

■ Pressure Loss:

4 Outlet Valve:	Flow (GPM)	20	40	60	80	100
	PSI Loss	2.5	3.5	5.0	7.5	10.0
6 Outlet Valve:	Flow (GPM)	20	40	60	80	100
	PSI Loss	3.0	4.0	6.0	9.0	11.0

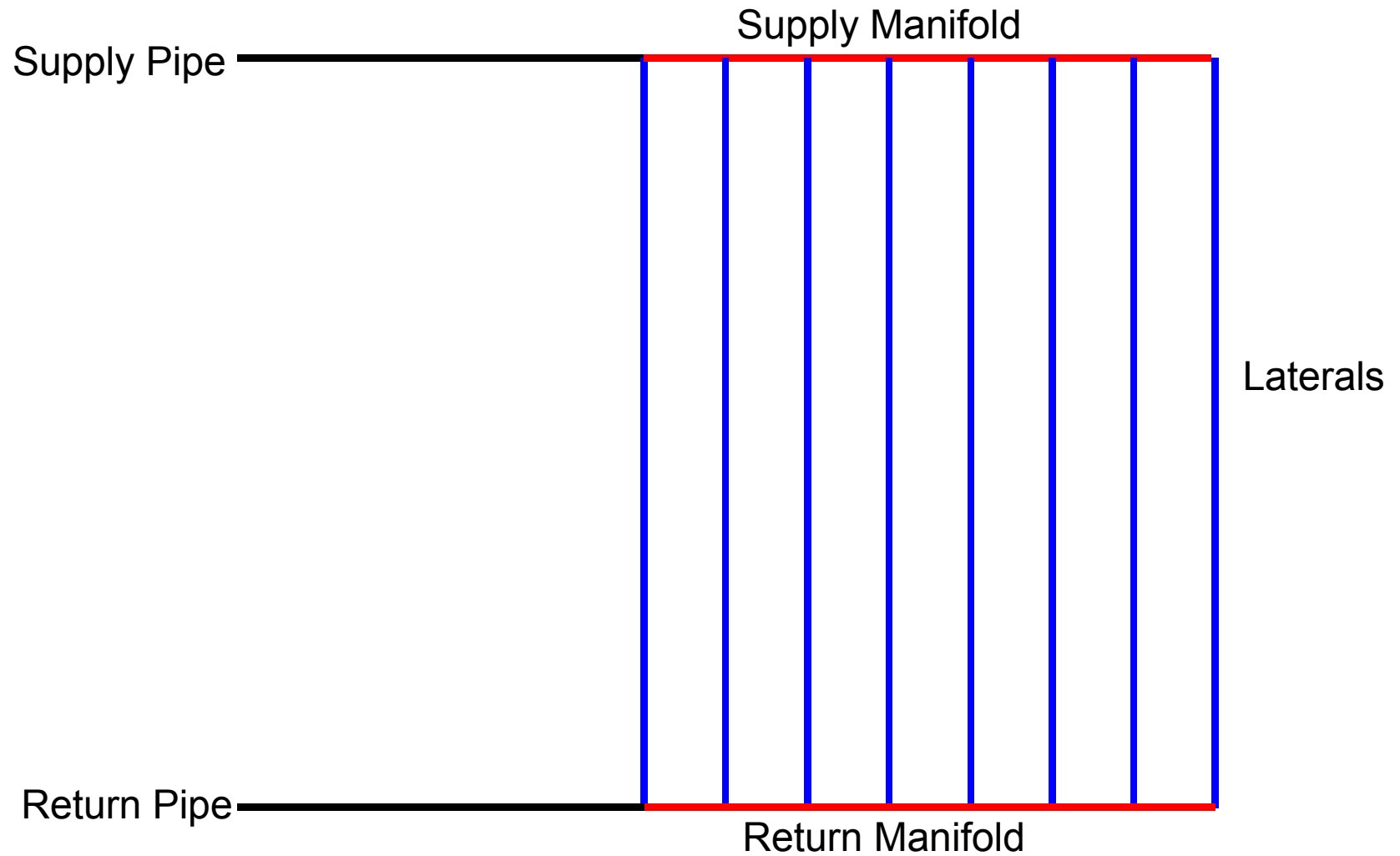


Water (flow) Meters

GPM	Pressure Loss Through Water Meters (psi)					
	5/8"	3/4"	1"	1-1/2"	2"	3"
6	1.3	0.7				
8	2.3	1				
10	3.7	1.6	0.7			
12	5.1	2.2	0.9			
14	7.2	3.1	1.1			
16	9.4	4.1	1.4			
18	12	5.2	2.2			
20	15	6.5	2.8	0.8		
22		7.9	3.4	1		
24		9.5	4	1.2		
26		11.2	4.6	1.4		
28		13	5.3	1.6		
30		15	7.4	1.8	0.7	
35			9.6	2.6	1	
40			12.3	3.3	1.6	
45			15	4.1	1.9	
50				4.9	2.7	0.7
60				7.2	3.7	1
70				9.8	4.9	1.3
80				12.8	6.2	1.6
90				16.1	7.8	2
100				20	11.3	2.5
120					14.5	3.4
140					20	4.5



Distribution System



Manifolds and Laterals

- Have multiple locations for water to leave pipe
 - Flow in pipe decreases with length
 - Friction loss decreases with length
- Take flow rate at beginning of manifold and pipe length.
 - Determine headloss as if straight pipe
 - Divide headloss by 3.

Question.....

- What is controlling the flow from the laterals?
 - Orifice or sprayer
 - Size lateral diameter to have less than 10% flow rate change along length
 - Use flow rate at beginning of lateral and lateral length, determine headloss assuming 'straight pipe,' and divide headloss by 3
 - Example: 100 feet, twenty 5/32" orifices, 0.5 gpm each, 10 gpm in lateral

What if we used 1" dia. Laterals?

- 10 gpm
 - 2.40 psi/100'; 0.80 psi as lateral – 1.84 feet of head
 - Orifice equation, $Q = CA(gH)^{0.5}$
 - Using headloss as pressure difference across lateral
 - Flow difference is 0.40 gpm across length
 - 80% difference in orifice flow rate across lateral length

Now try 2" dia. Lateral

- 10 gpm
 - 0.09 psi/100'; 0.03 psi as 100' lateral, 0.07 feet of head
 - 0.076 gpm difference in orifice flow across lateral length
 - 1.5% difference
 - good enough

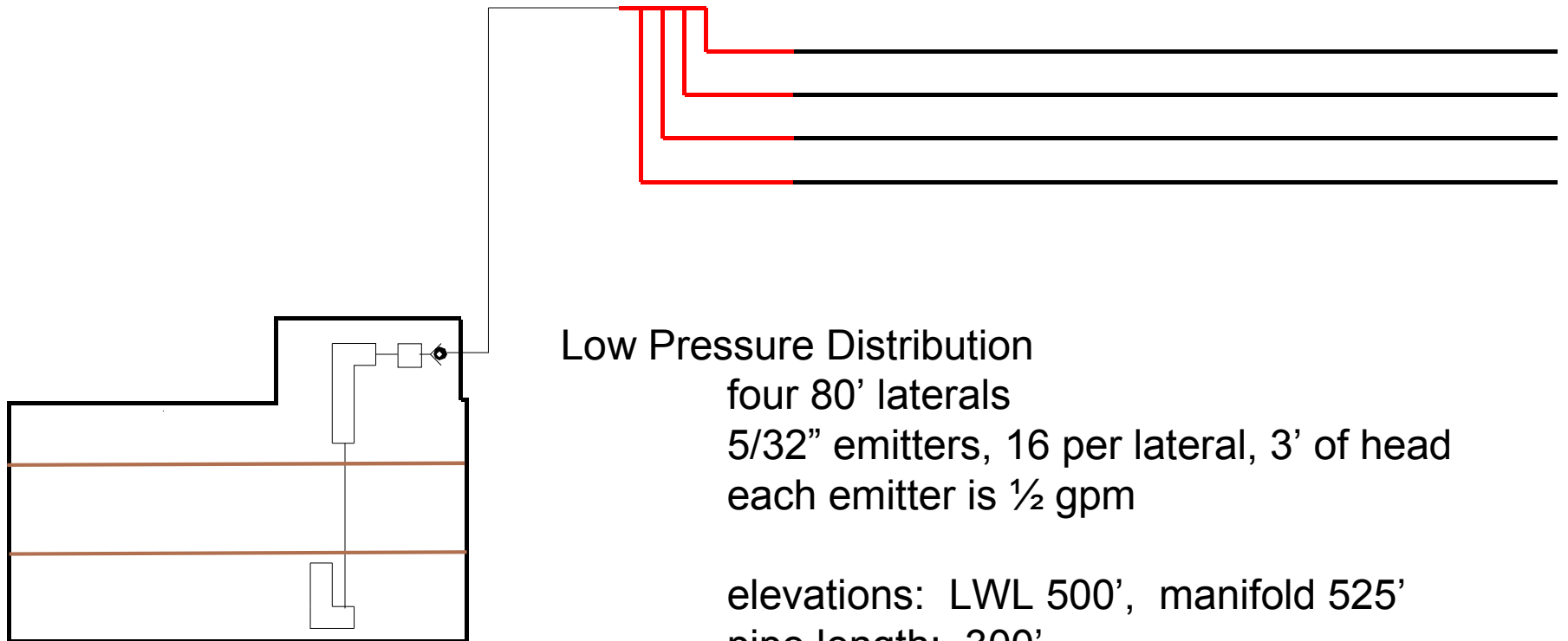
Now, Remember,

- The laterals are in parallel
 - We only need to account for them one time
 - not four times (assuming four laterals)

What about Pressure Compensating Emitters?

- The lateral is the drip tubing
 - Use manufacturer's headloss tables
 - Need at least 10 psi of available pressure to drive emitters
 - Remember to account for pressure needed for forward flush

Quick Example



Low Pressure Distribution

four 80' laterals

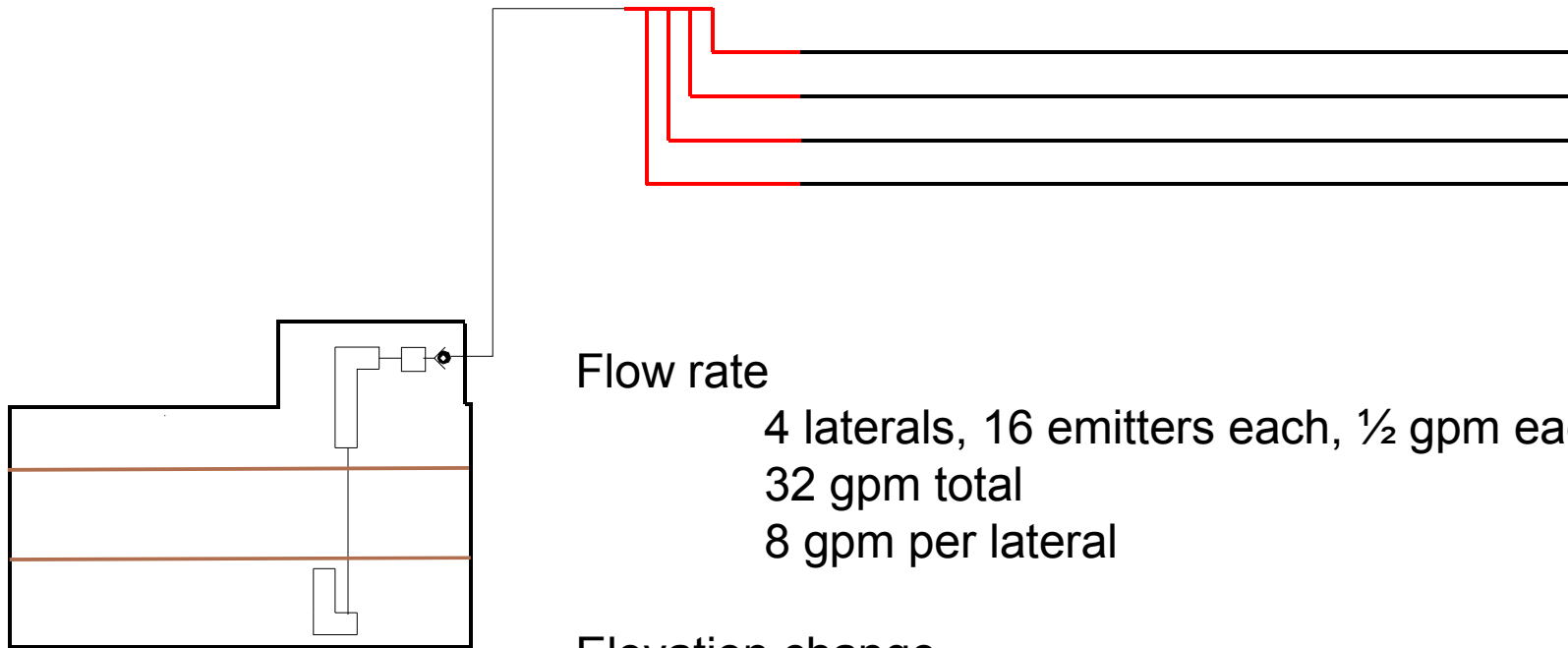
5/32" emitters, 16 per lateral, 3' of head
each emitter is 1/2 gpm

elevations: LWL 500', manifold 525'

pipe length: 300'

includes pressure filter & flow meter

Basic Information



Flow rate

4 laterals, 16 emitters each, $\frac{1}{2}$ gpm each
32 gpm total
8 gpm per lateral

Elevation change

25'

Operating pressure at end of laterals

3'

Laterals

- 80-foot
 - 8 gpm each
 - 1.5 diameter sch 40: 0.123' of headloss
 - Orifice flow ranges from 0.51 to 0.50 gpm (2%)

Water Meter and Filter

- Water Meter
 - 1" meter
 - Headloss
 - 7.4 psi at 30 gpm
 - (17 feet of head)
 - 9.6 psi at 35 gpm
 - (22 feet of head)
- Pressure Filter
 - Manufacturer literature indicates to add 1 foot of head for friction
 - Assume dirty filter provides 13 feet of headloss

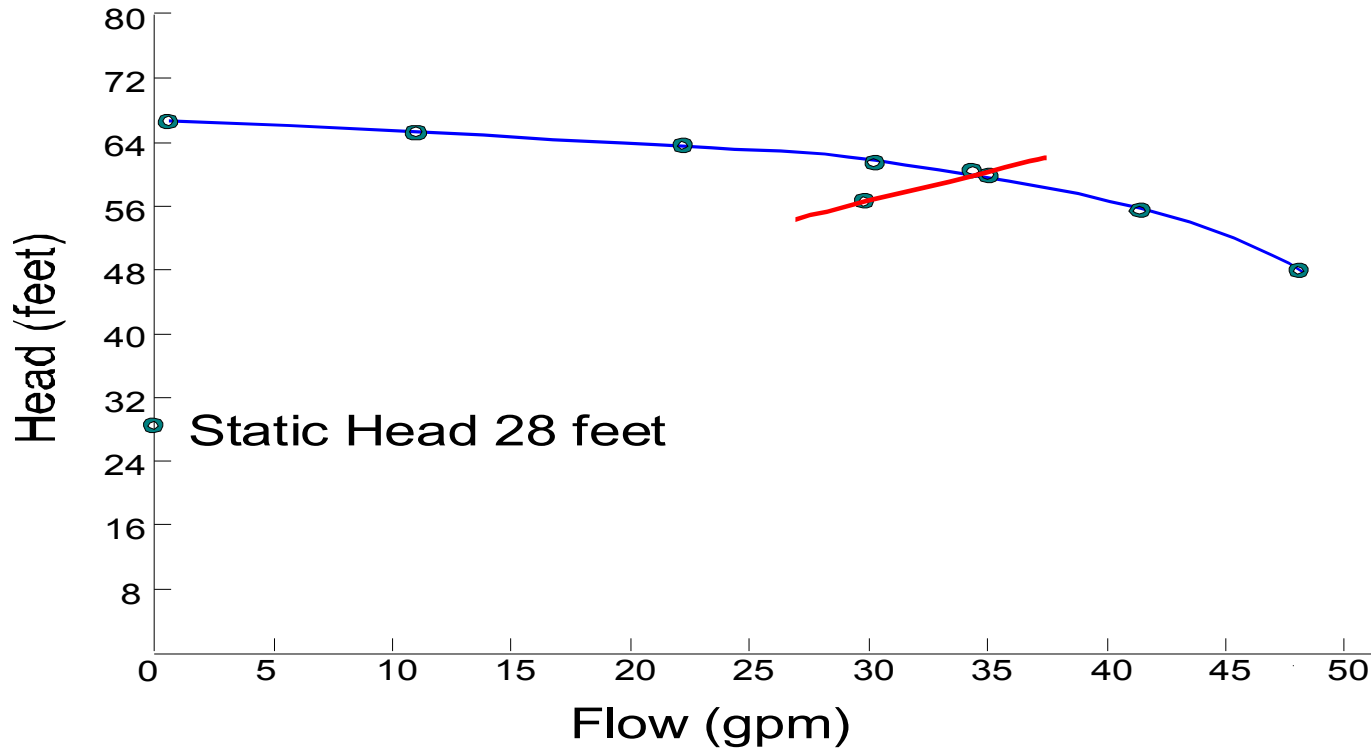
Pipe & Fittings Friction

- 300 feet of distance
 - 32 gpm design flow
 - Pipe tables
 - 2" diameter
 - 0.76 psi/100'
 - Velocity 3.06 fps
 - 5.3 feet headloss
- Fittings
 - 4 els
 - 5 feet of pipe each
 - 2 sudden contractions
 - 3 feet of pipe
 - 4 feet of pipe
 - Check valve
 - 10 feet of pipe
 - Equivalent
 - approx. 40 additional feet of pipe
 - About 1 foot of headloss

Pressure

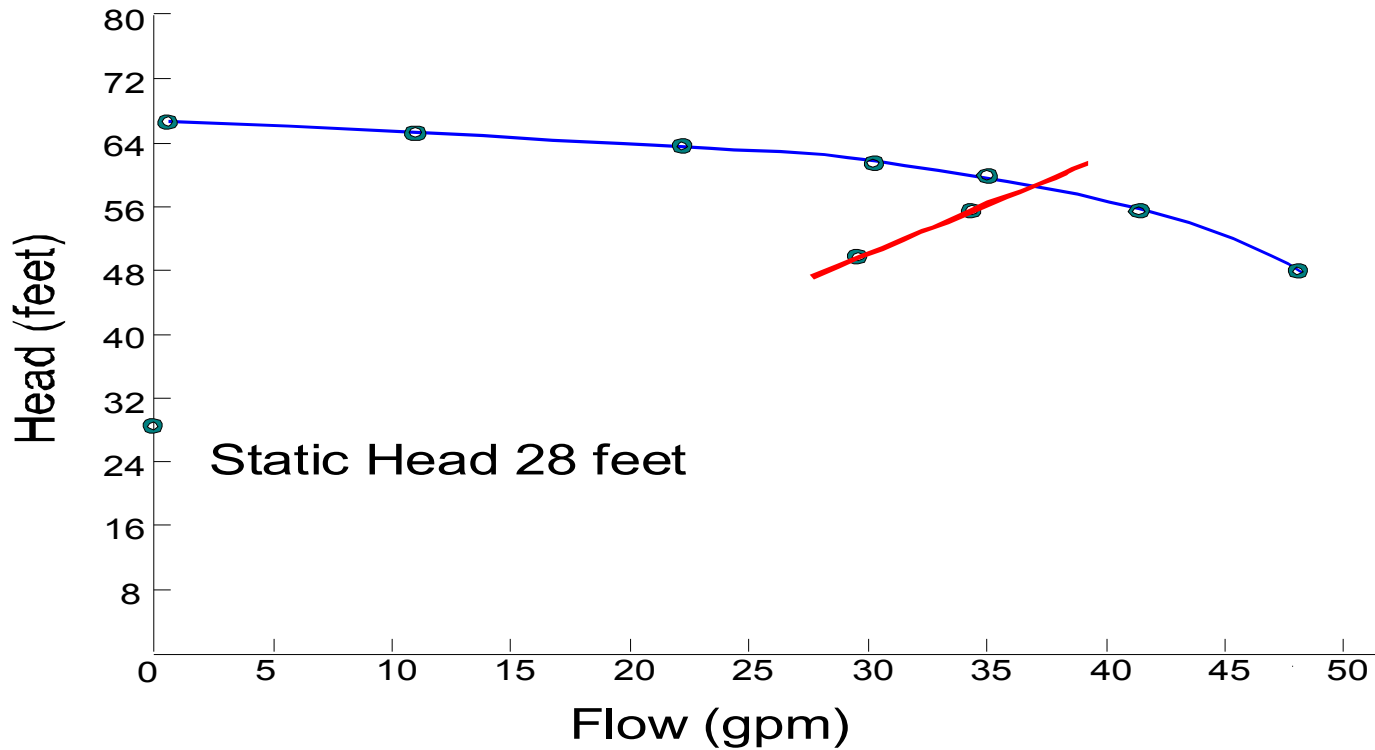
- Operating head
 - 3 feet
- Elevation head
 - 25 feet
- Friction head
 - @ 30 gpm 29 feet
 - @ 35 gpm 35 feet
 - Includes 6' for slightly dirty filter
- System Curve
 - @ 30 gpm 57 feet
 - @ 35 gpm 63 feet

System & Pump Curve



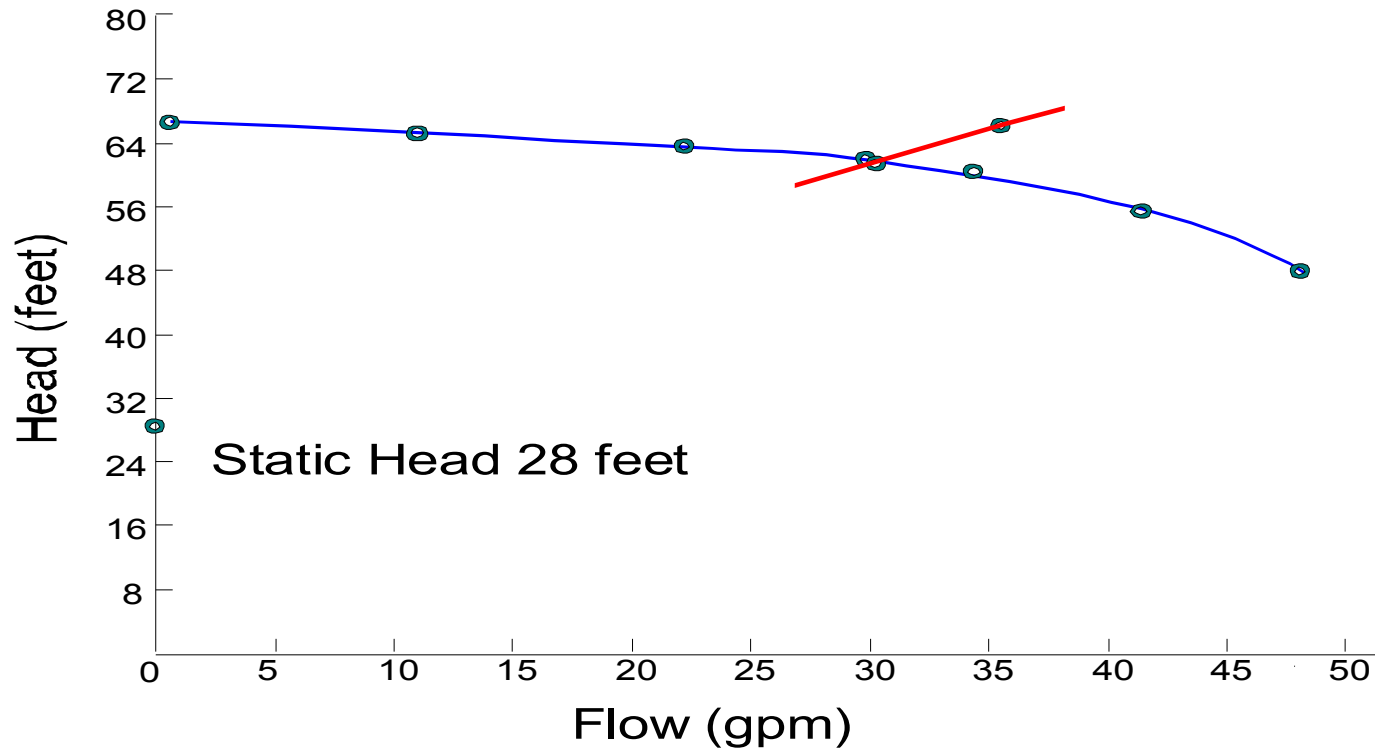
Assuming slightly dirty filter and LWL
Operating point would be about 35 gpm with 63 feet of head

System & Pump Curve



Assuming clean filter and HWL
Operating point would be about 37 gpm with 60 feet of head

System & Pump Curve



Assuming very dirty filter and LWL
Operating point would be about 30 gpm with 64 feet of head

Is this Range of Flow Okay?

- HWL to LWL
 - two feet of head
 - about 1 gpm difference with this pump
- Clean filter to dirty filter
 - Assuming 5 psi (12 feet of head) of headloss across filter is the “threshold for cleaning”
 - About 5 gpm difference with this pump
- Yeah, it's okay

Discussion Time

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