ME444 ENGINEERING PIPING SYSTEM DESIGN

CHAPTER 5 : PIPE SIZING

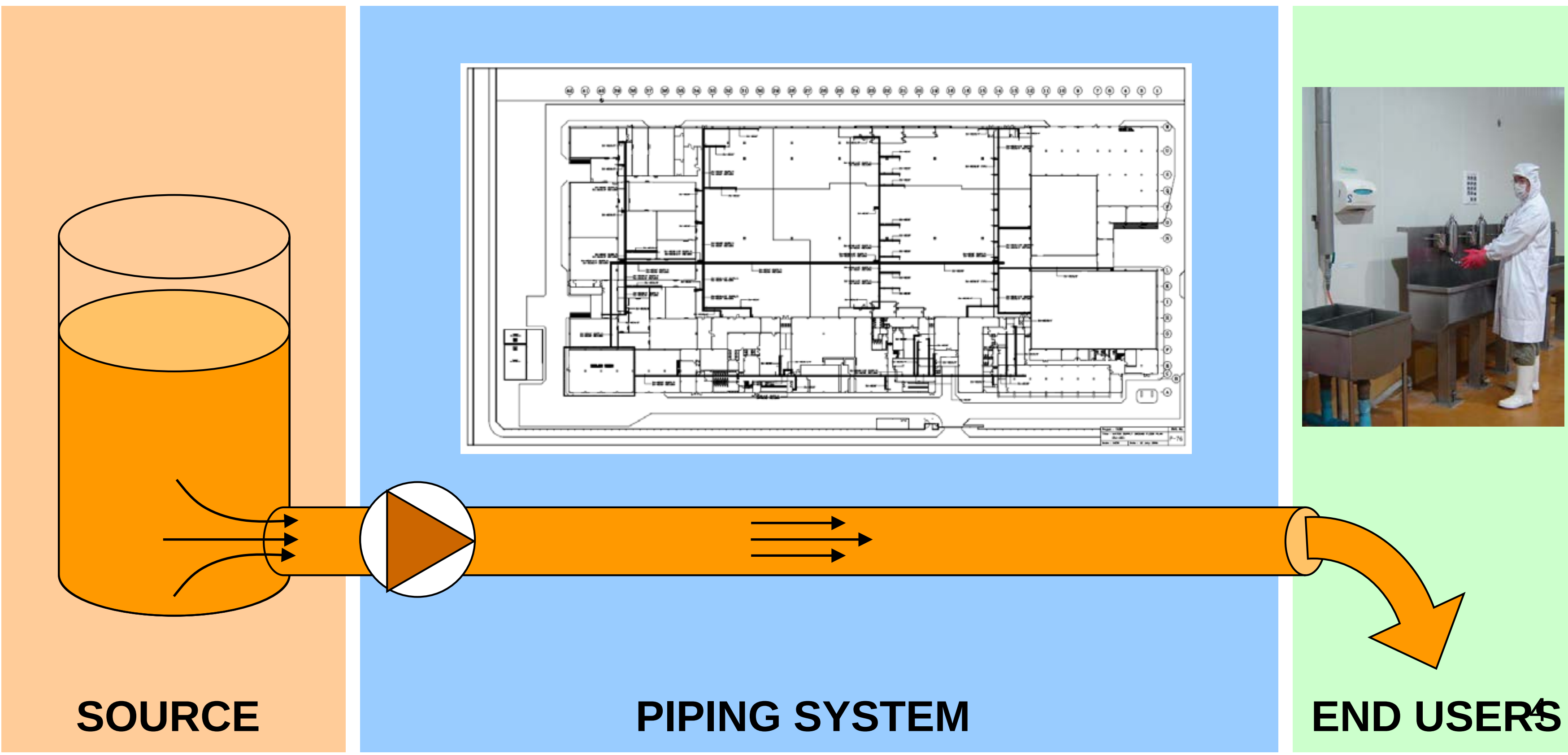
LAST SESSION

1. CHARACTERISTICS OF FLOW
2. BASIC EQUATIONS
3. PRESSURE DROP IN PIPE
4. ENERGY BLANCE IN FLUID FLOW

CONTENTS

1. PIPING SYSTEM DESIGN PROCEDURE

Always works from the output then determine the input and the piping system



DESIGN PROCEDURE

1. Study system specification, type and properties of **fluid**.

2. Determine **material** specification, pressure rating, temperature rating of equipment.

3. Gather **end user** requirements: location, pressure, temperature, flow rate.

4. Consider the availability of the **source**. Is there enough pressure and flow rate?

DESIGN PROCEDURE (2)

5. Study architectural drawings. Design the **path** of the pipeline. Determine the use of valves and other accessories.

6. Perform detail design: **pipe sizing**.

7. **Pump** selection (if required)

8. For power piping system, evaluate **strength** of pipes.

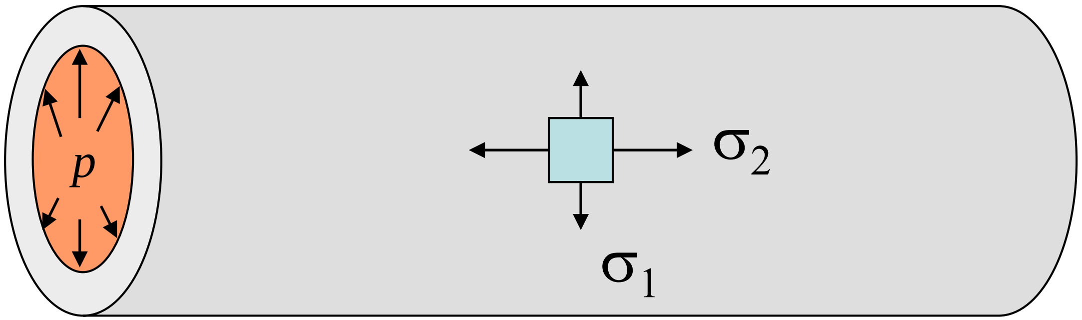
DESIGN PROCEDURE (3)

9. Create drawings of the plan, schematic and detail installation.

10. Adjust the drawing to combine with other systems.

11. Evaluate construction cost.

2. PIPE THICKNESS



Hoop stress σ_1 or σ_θ

Barlow equation

$$\sigma_\theta = \frac{pD}{2t}$$

Internal pressure

Internal diameter

Pipe wall thickness

ASME B31

Adjust the Barlow equation to account for other factors.

$$t_{\min} = \frac{pD}{2(SE + py)} + A$$

Material Strength

Tolerance

Joint efficiency factor

Temperature factor

Material Strength

ASTM Specification	Grade	Type	Manufacturing Process	Available Sizes, mm	Minimum Tensile Strength, MPa	Basic Allowable Stress S, MPa	Joint Efficiency Factor E	Allowable Stress[b] S_E, MPa	Allowable Stress Range[c] S_A, MPa
A53 Steel	—	F	Cont. Weld	15 to 100	310	77.5	0.6	46.5	117
A53 Steel	B	S	Seamless	15 to 660	413	103	1.0	103	155
A53 Steel	B	E	ERW	50 to 500	413	103	0.85	87.6	155
A106 Steel	B	S	Seamless	15 to 660	413	103	1.0	103	155
B88 Copper	—	—	Hard Drawn	8 to 300	248	62	1.0	62	93.1

[a] Listed stresses are for temperatures to 340°C for steel pipe (to 205°C for Type F) and to 120°C for copper tubing.

[b] To be used for internal pressure stress calculations in Equations (1) and (2).

[c] To be used only for piping flexibility calculations; see Equations (3) and (4).

$$t_{\min} = \frac{pD}{2(\boxed{S}E + py)} + A$$

Joint Efficiency Factor

Spec. no.	Class material	Description	E_j (2)*	Notes
Carbon steel				
API 5L		Seamless	1.00	
		Electric resistance welded	0.85	
		Electric fusion welded, double butt, straight or spiral	0.85	
		Furnace butt welded	0.60	
A 53	Type S	Seamless	1.00	
	Type E	Electric resistance welded	0.85	
	Type F	Furnace butt welded	0.60	
A 105		Forgings and fittings	1.00	
A 106		Seamless	1.00	
A 120		Seamless	1.00	
		Electric resistance welded	0.85	
		Furnace butt welded	0.60	
A 134		Electric fusion welded, sin-	0.80	

$$t_{\min} = \frac{pD}{2(S\boxed{E} + py)} + A$$

Temperature Factor

(Interpolate for intermediate values) (ASME B31.1)

	Temp, °F (°C)					
	900 (482) and below	950 (510)	1,000 (538)	1,050 (566)	1,100 (593)	1,150 (621) and above
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7

$$t_{\min} = \frac{pD}{2(SE + p\boxed{y})} + A$$

Tolerance

Type of pipe	A, in
Cast-iron pipe, centrifugally cast	0.14
Cast-iron, pit-cast	0.18
Threaded-steel, wrought-iron, or nonferrous pipe:	
⅜ in and smaller	0.05
½ in and larger	Depth of thread
Grooved-steel, wrought-iron or nonferrous pipe	Depth of groove
Plain-end steel, wrought-iron or tube:	
1 in and smaller	0.05
1¼ in and larger	0.065
Plain-end nonferrous pipe or tube	0.000

$$t_{min} = \frac{pD}{2(SE + py)} + \boxed{A}$$

3. PIPE SIZING

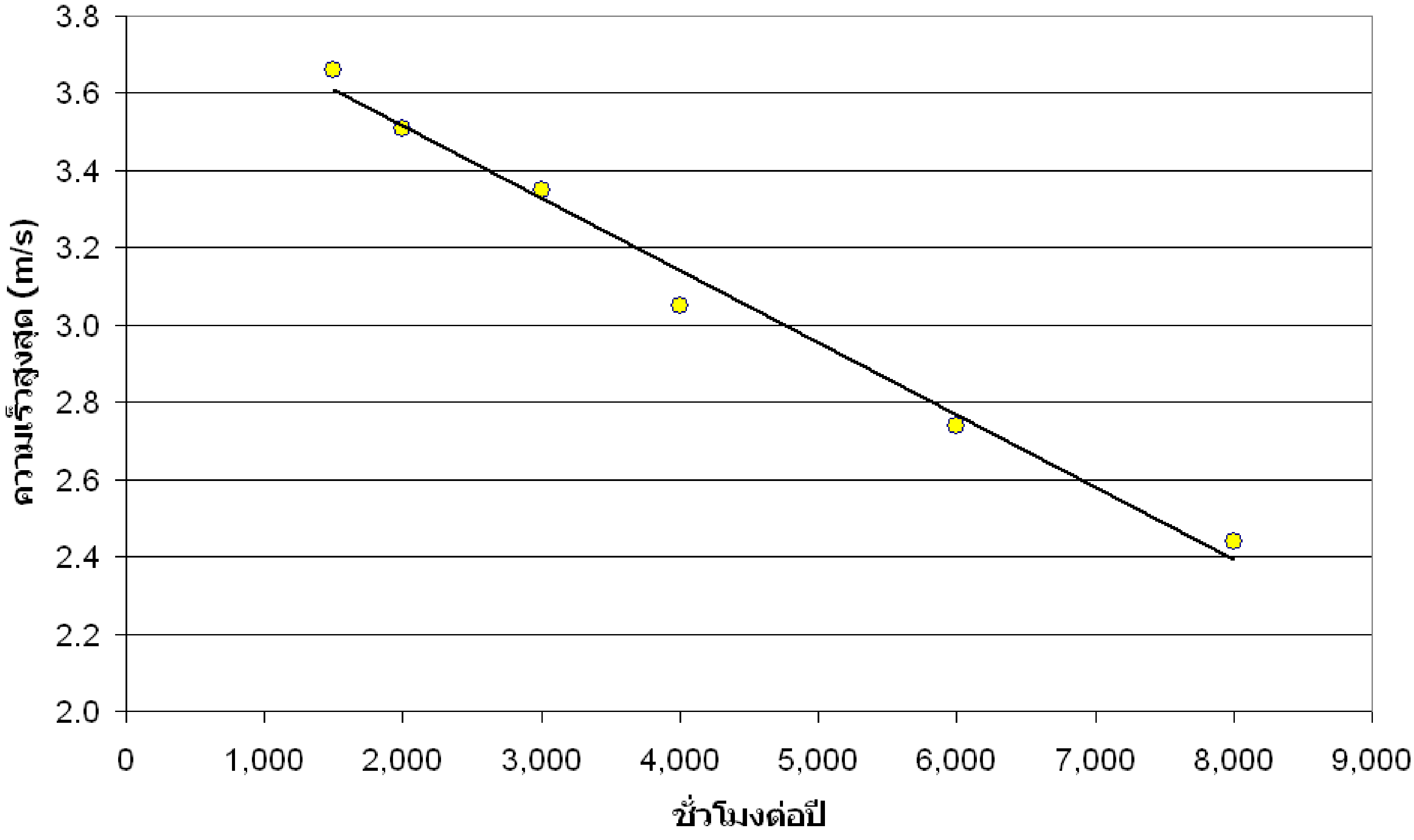
Recommended Velocity

Type of pipe	Velocity (m/s)
Pump discharge	2.4 – 3.6
Pump suction	1.2 – 2.1
Drain pipe	1.2 – 2.1
Header	1.2 – 4.6
Riser	0.9 – 3.0
General water supply	1.2 – 3.0
Main potable water supply	0.9 – 2.1
Boiler feed water	2.5 – 4.6

Maximum Velocity to Prevent Erosion

Service hours per year	Max. Velocity (m/s)
1500	3.66
2000	3.51
3000	3.35
4000	3.05
6000	2.74
8000	2.44

Maximum Velocity to Prevent Erosion



Recommend velocity for different pipe sizes

Small pipe → higher drop at same velocity

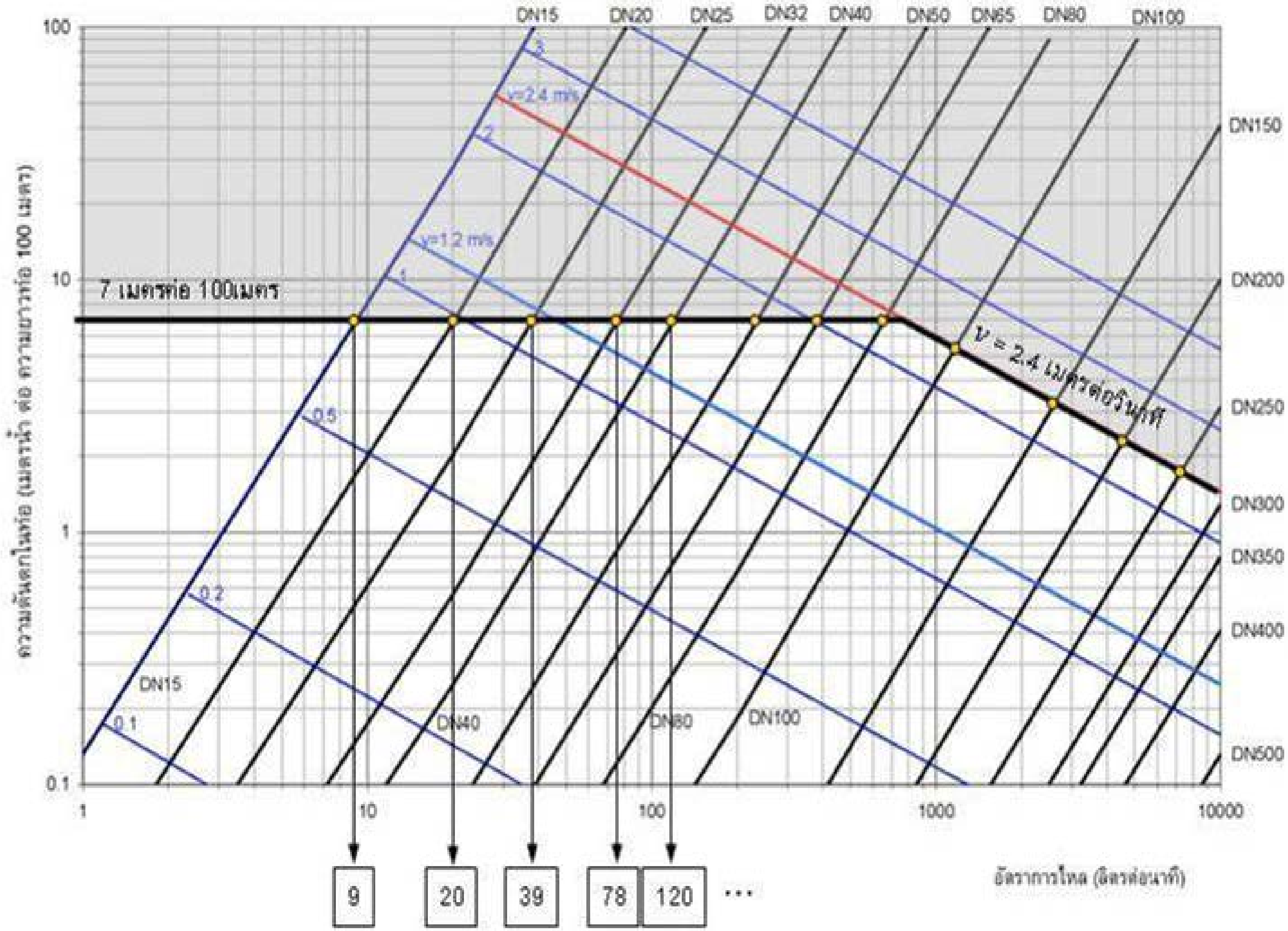
Pipe Dimension		Velocity
Inches	mm	m/s
1	25	1
2	50	1.1
3	75	1.15
4	100	1.25
6	150	1.5
8	200	1.75
10	250	2
12	300	2.65

Case 1: Size by velocity

1. Determine flow rate in each section
2. Sizing pipe according to velocity
3. Compute pressure drop

Flowrate (lpm)	DN (mm)	Velocity (m/s)	Pressure Drop (m/100m)
9 (14)*	15	0.8 (1.2)	6.24 (14.2)
20 (24)*	20	1.0 (1.2)	6.72 (9.45)
39	25	1.2	6.98
78	32	1.4	6.98
120	40	1.5	6.73
230	50	1.8	6.57
390	65	2.1	6.88
670	80	2.3	6.88
1,200	100	2.4	5.31
1,850	125	2.4	3.88

Size by velocity



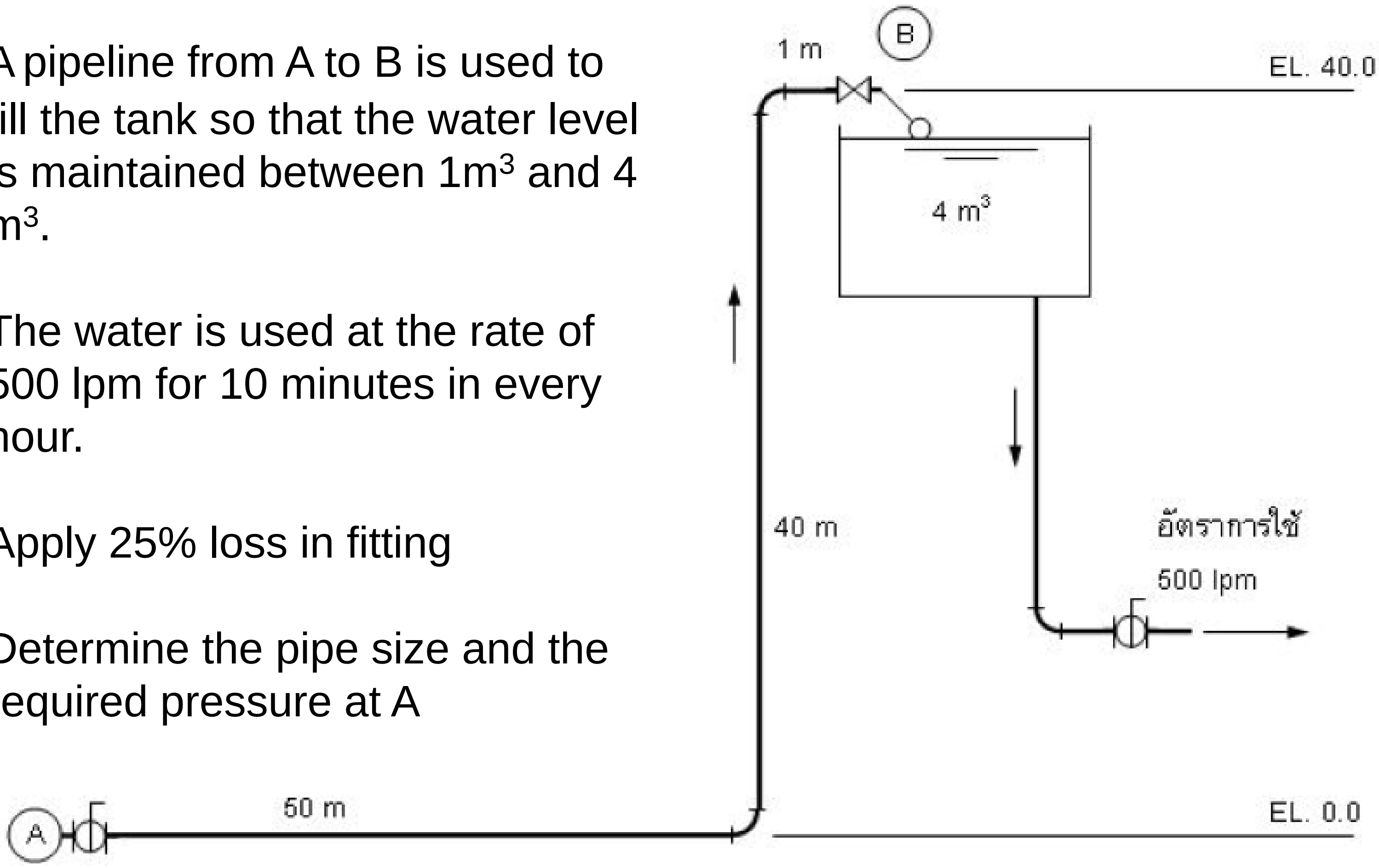
Example 5.1

A pipeline from A to B is used to fill the tank so that the water level is maintained between 1m^3 and 4 m^3.

The water is used at the rate of 500 lpm for 10 minutes in every hour.

Apply 25% loss in fitting

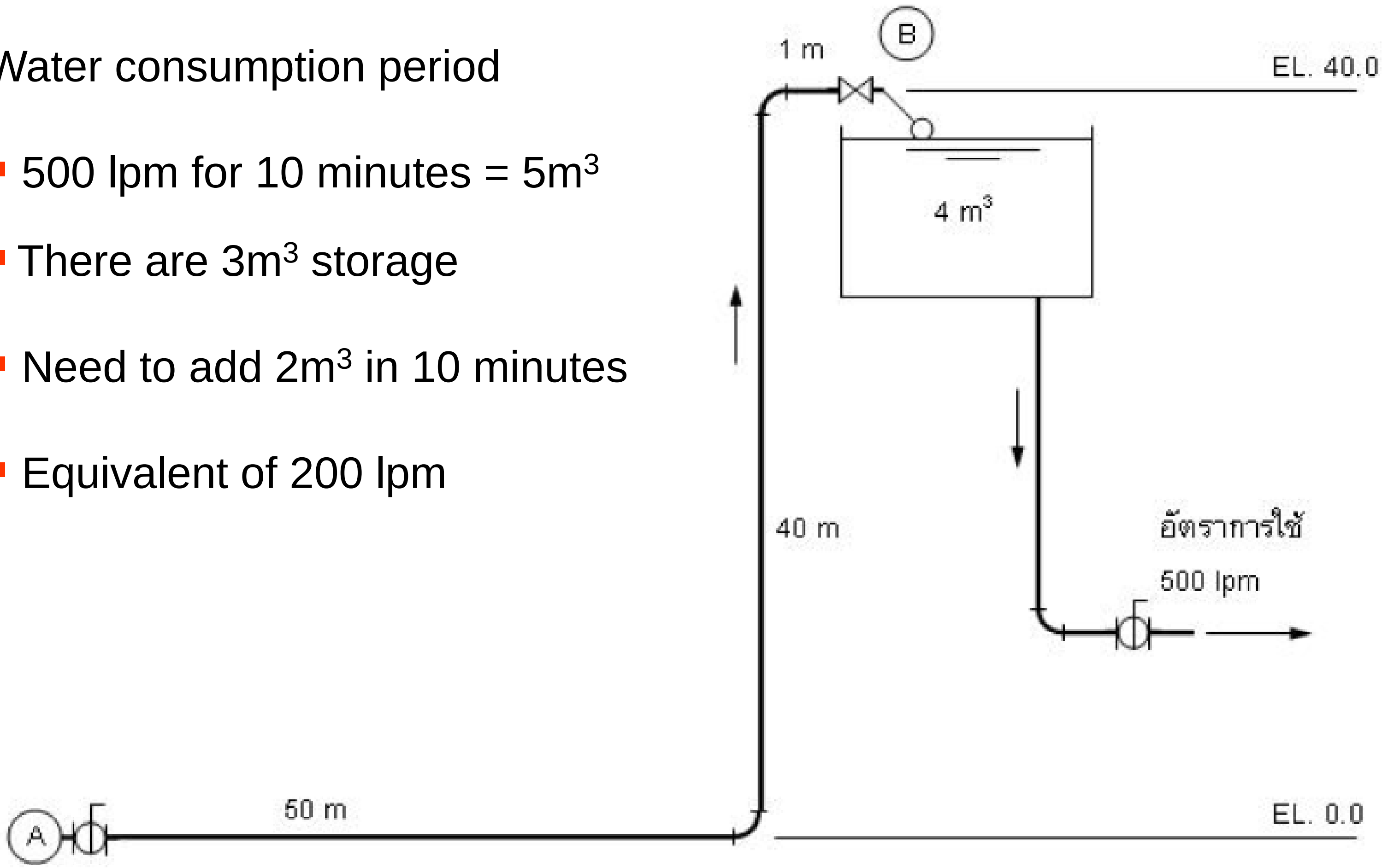
Determine the pipe size and the required pressure at A



Example 5.1 (2)

Water consumption period

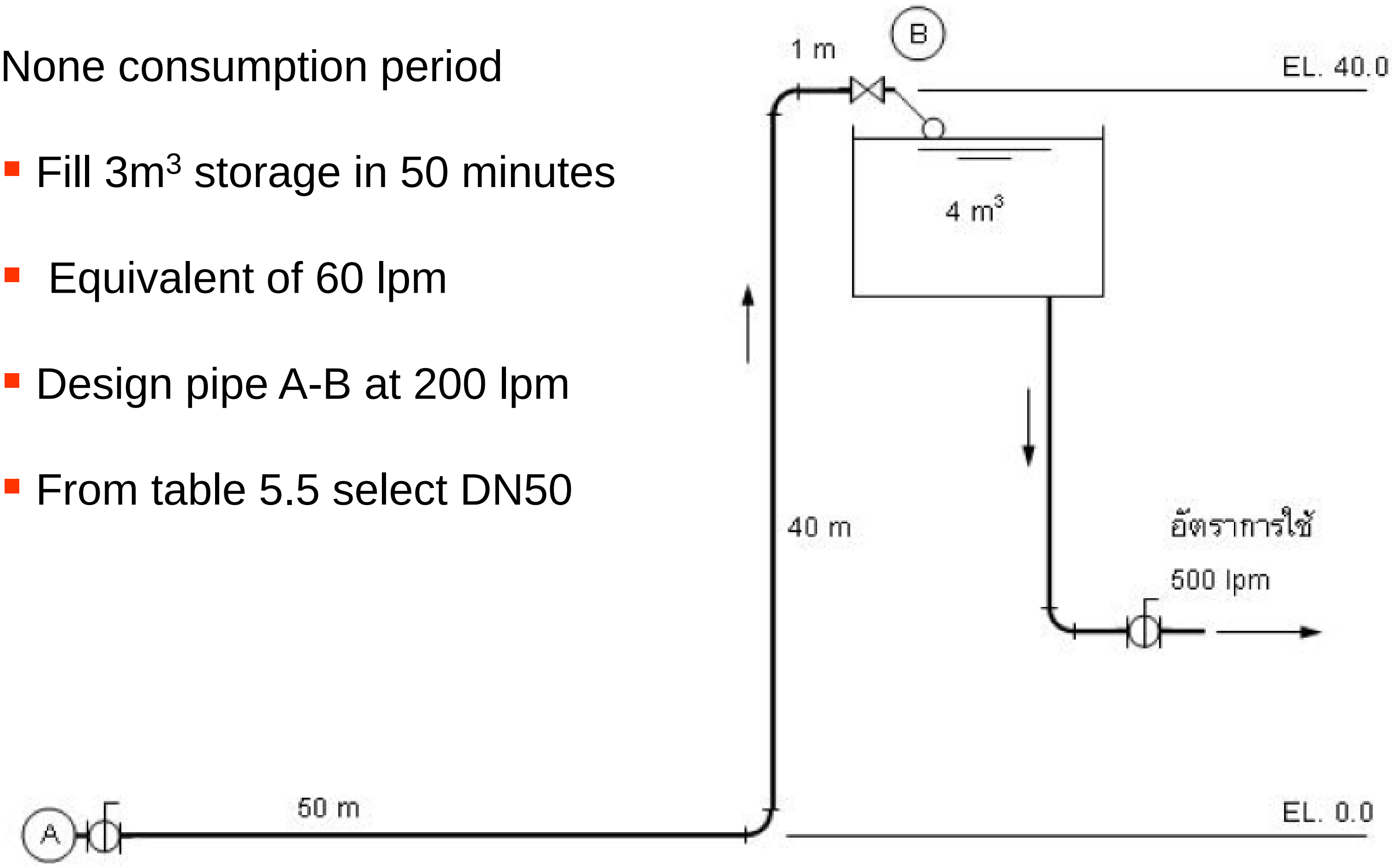
- 500 lpm for 10 minutes = $5m^3$
- There are $3m^3$ storage
- Need to add $2m^3$ in 10 minutes
- Equivalent of 200 lpm



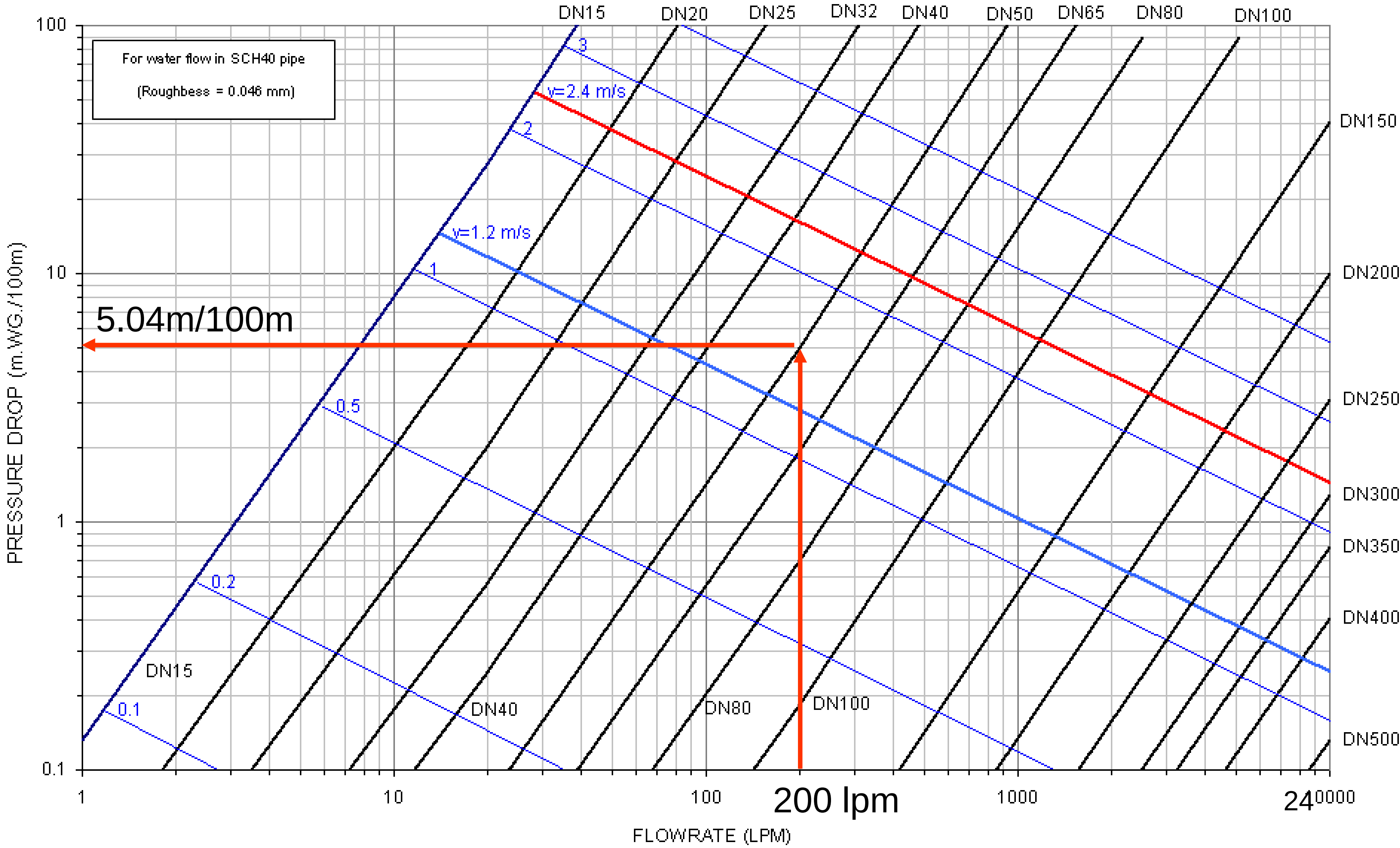
Example 5.1 (3)

None consumption period

- Fill $3m^3$ storage in 50 minutes
- Equivalent of 60 lpm
- Design pipe A-B at 200 lpm
- From table 5.5 select DN50



Example 5.1 (4)

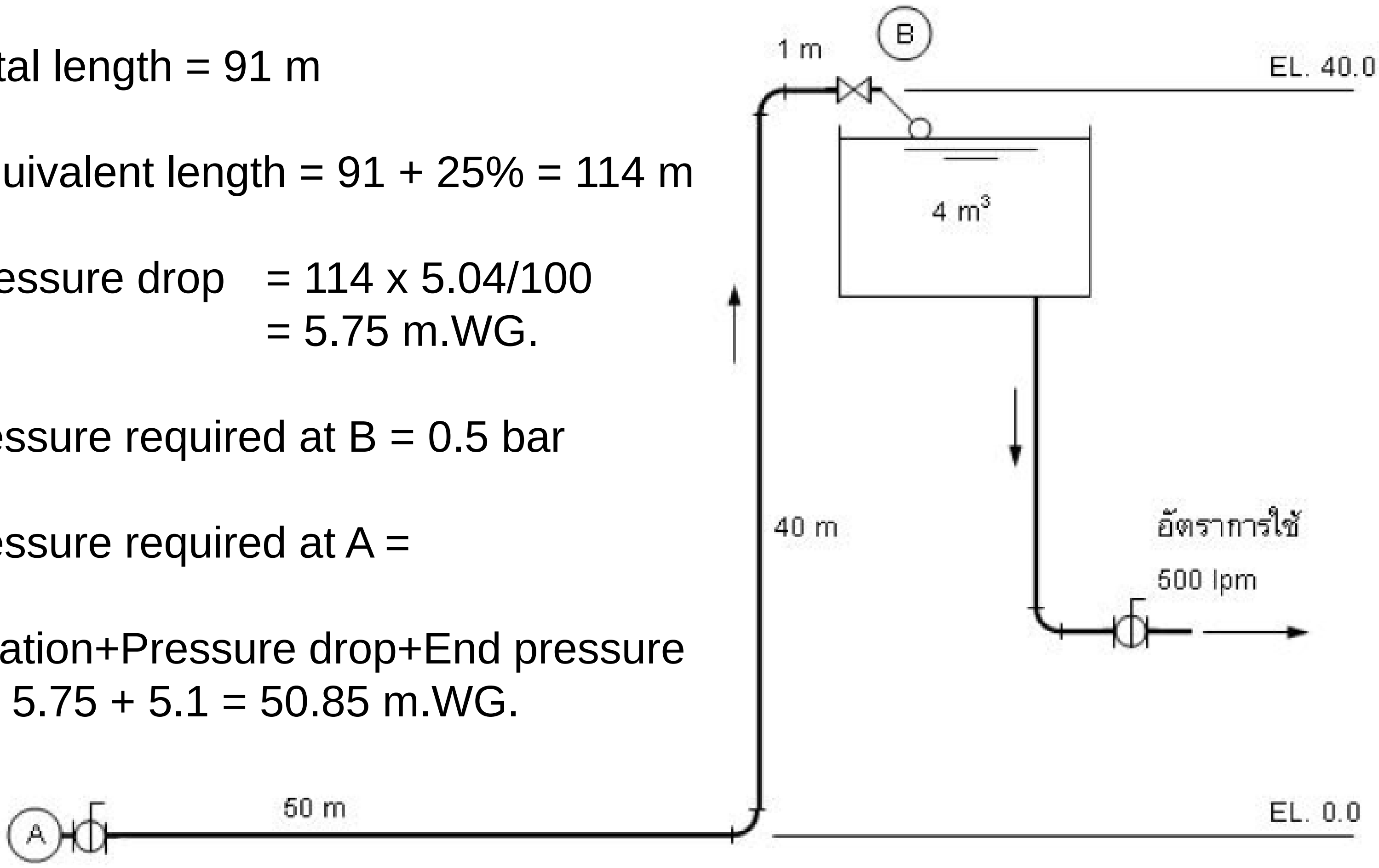


For water flow in SCH40 pipe
(Roughbess = 0.046 mm)
DN15
DN20
DN25
DN32
DN40
DN50
DN65
DN80
DN100
DN150
DN200
DN250
DN300
DN350
DN400
DN500
v=2.4 m/s
v=1.2 m/s
3
2
1
0.5
0.2
0.1
5.04m/100m
200 lpm
24
100
10
1
0.1
1
10
100
1000
10000
PRESSURE DROP (m.WG./100m)
FLOWRATE (LPM)

Example 5.1 (4)

- Total length = 91 m
- Equivalent length = 91 + 25% = 114 m
- Pressure drop = 114 x 5.04/100
  = 5.75 m.WG.
- Pressure required at B = 0.5 bar
- Pressure required at A =

Elevation+Pressure drop+End pressure
40 + 5.75 + 5.1 = 50.85 m.WG.



Case 2: Size by pressure drop

1. Measure the critical path
2. Add 25%-50% for minor loss
3. Compute allowable pressure drop per 100m
4. Extract data from the graph to form a reference table
5. Determine flow rate in each section
6. Size each section according to the table
7. Compute actual pressure drop

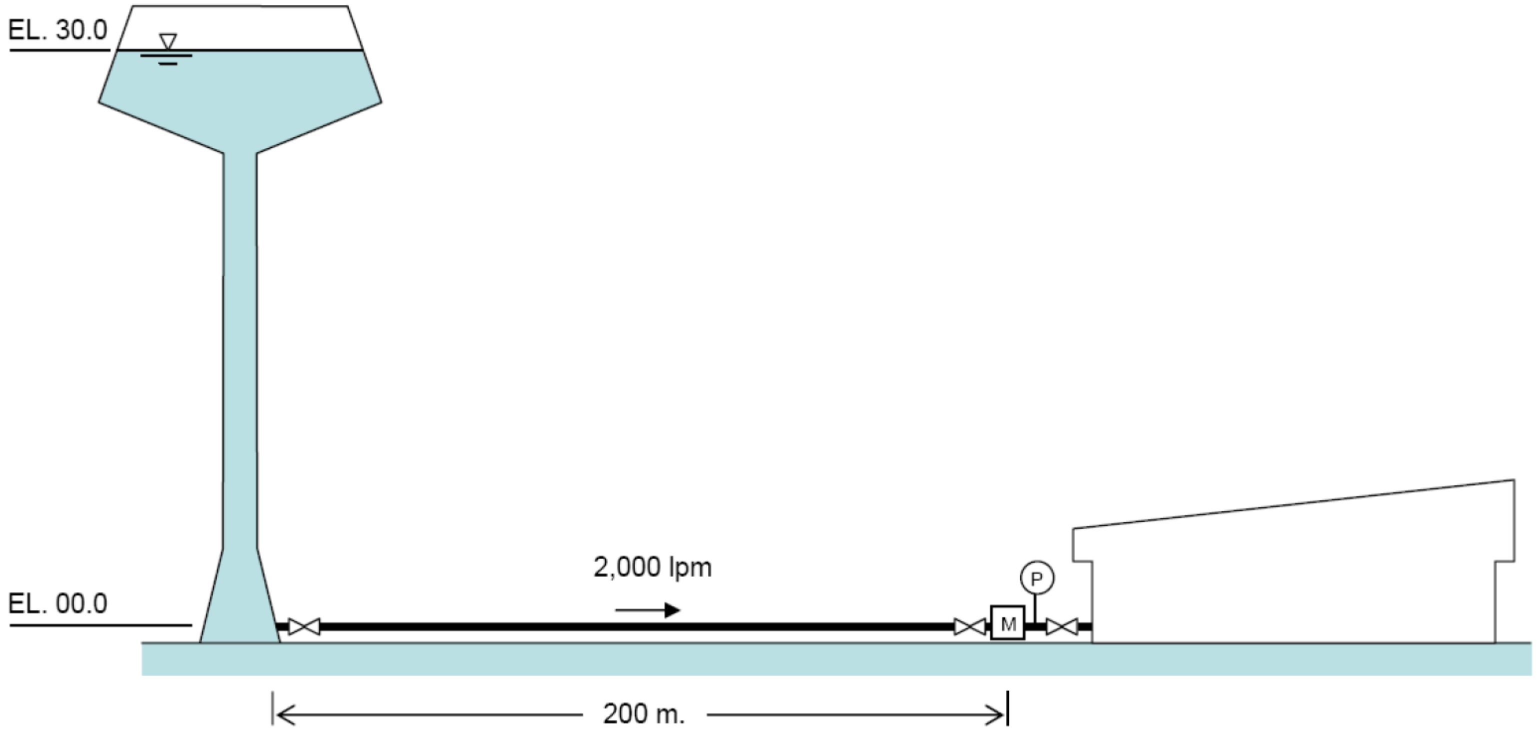
Table 5.4

ขนาดระบุ DN (mm)	อัตราไหลสูงสุด (lpm) ที่อัตราความดันตกต่างๆ				
	3 m/100m	4 m/100m	5 m/100 m	6 m/100m	7 m/100m
15	6	7	8	8	9
20	13	15	17	18	20
25	25	29	32	36	39
32	50	58	65	72	78
40	78	91	102	113	122
50	152	177	200	220	237
65	252	293	330	364	393
80	434	500	567	625	676
100	890	1,000	1160	1183 (1,280)	1183 (1,385)
125	1620	1,850	1,850 (2,100)	1,850 (2,320)	1,850 (2,320)
150	2620	2,700 (3,045)	2,700 (3,350)		
200	4,600 (5,800)				
250	7,300 (9,100)				
300	10,400 (13,000)				
350	12,500 (15,700)				
400	16,400 (20,500)				
500	25,800 (32,300)				

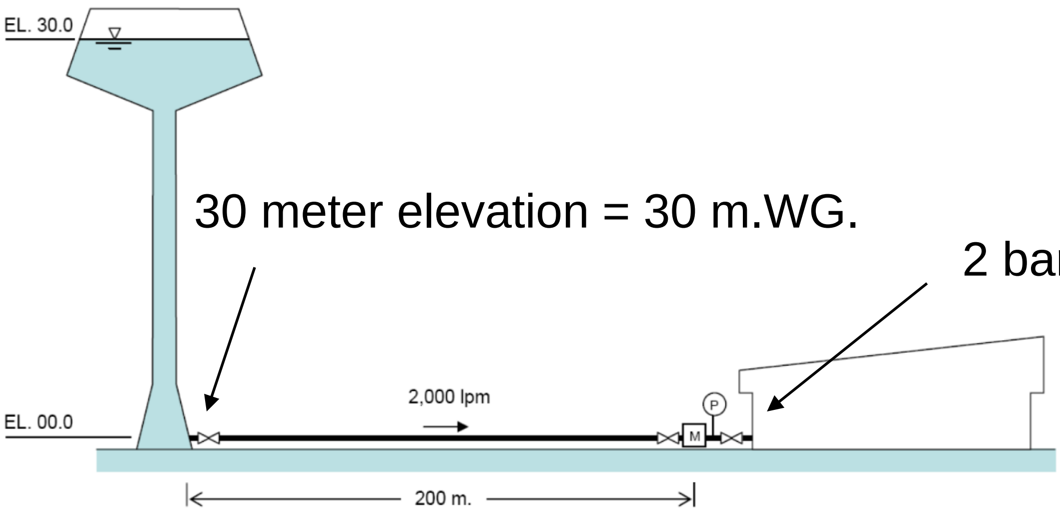
* คิดที่ความเร็วไม่เกิน 2.4 m/s ยกเว้นตัวเลขในวงเล็บคิดที่ความเร็วไม่เกิน 3 m/s

Example 5.2

Design a main pipe to supply water from 30 m. storage tank to a factory loacated 200 m away. The water pressure at the meter in front of the factory shall be more than 2 bar(g) when the factory consumes 2000 lpm. Assume 25% minor loss.



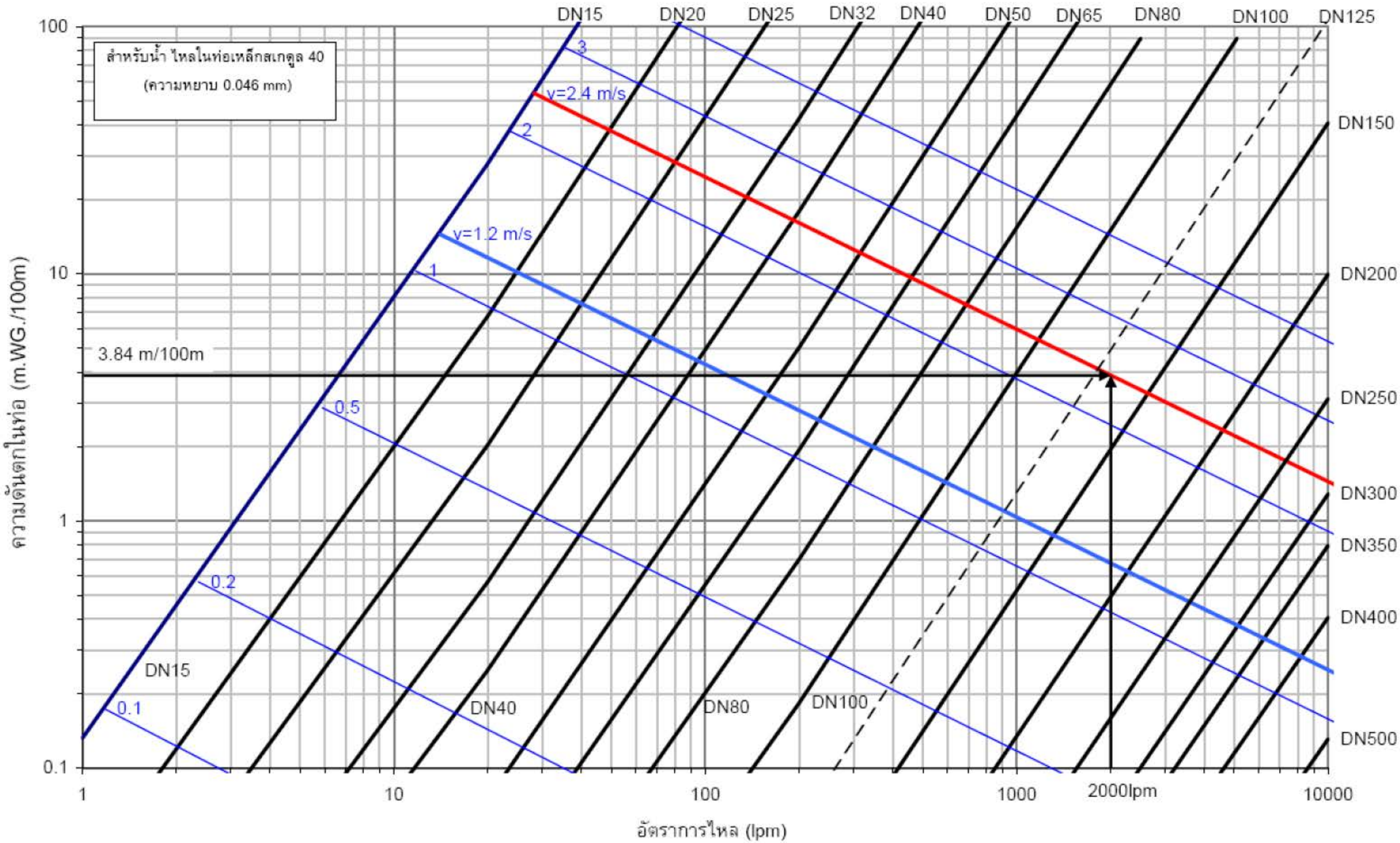
Example 5.2 (2)



Pressure drop Δp = 30-20.4 = 9.6 m.WG.

Equivalent pipe length 200m + 25% minor loss = 250 m

Pressure drop rate = 9.6 m.WG./ 250 m * 100 m = 3.84 m/100m



2000 lpm @ <3.84 m/100m → DN150

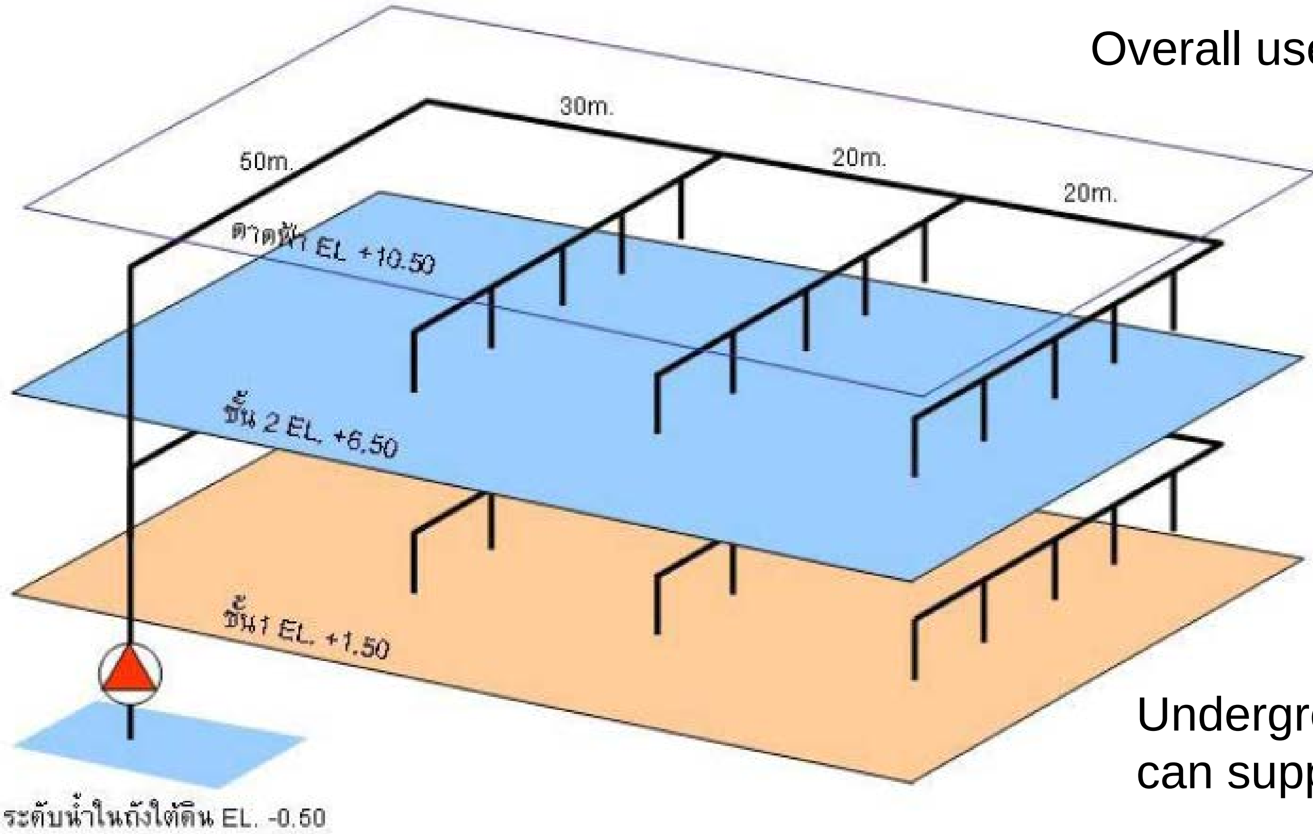
Example 5.3

A 2 storey factory require water supply of 20lpm at 1.5 barg to each of its 30 outlets. The horizontal pipe shall run at 1 m. below the ceiling of each floor, then drop down to the outlet 1 m. above the floor.

Use factor of each branch = 100%

Use factor of each floor = 80%

Overall use factor = 80%



Size the pipe

Underground pump
can supply 480lpm@32m.WG.

Example 5.3 (2)

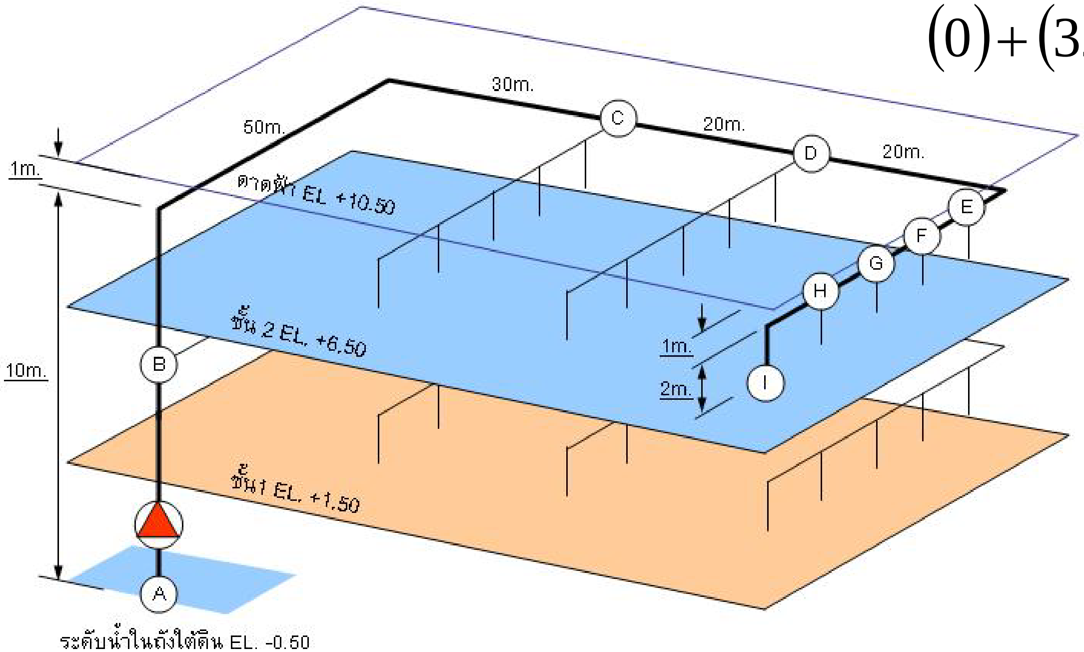
Critical path = A → I

Pressure added by pump

$$z_A + \boxed{\frac{p_A}{\rho g}} + \frac{v_A^2}{2g} = z_I + \frac{p_I}{\rho g} + \frac{v_I^2}{2g} + h_L$$

$$(0) + (32) + (0) = (8) + (15.30) + (0) + h_L$$

$$h_L = 8.7\,\text{m.WG.}$$

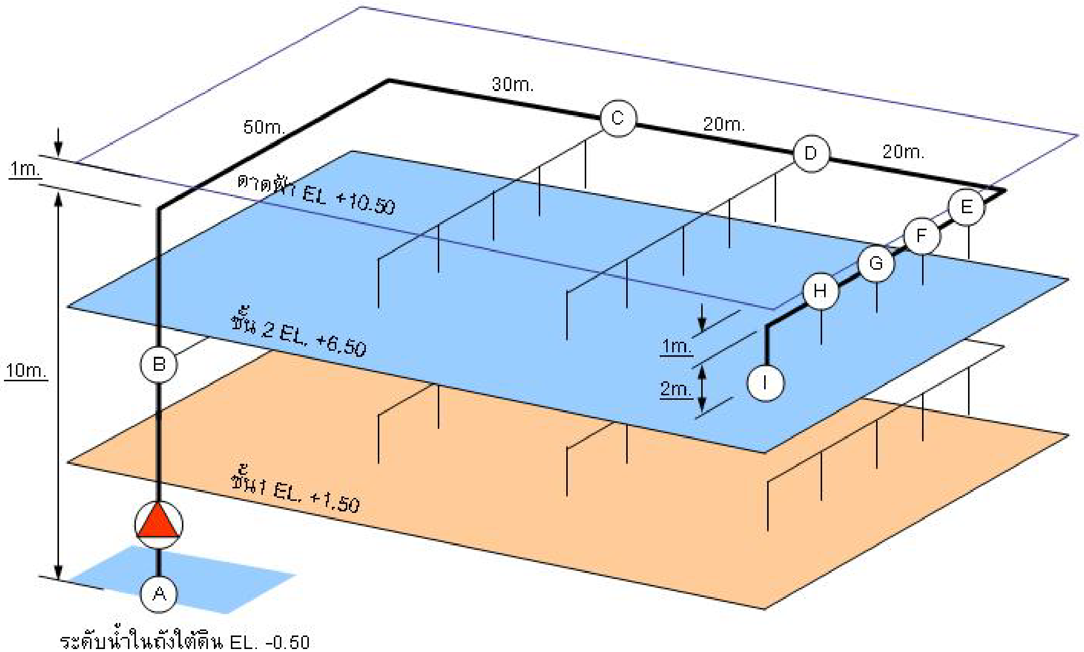


480lpm@32 m.WG.

Example 5.3 (3)

1. Measure length of the critical path = A → I

$$L = 10 + 50 + 30 + 20 + 20 + 50 + 2 = 182\text{m}$$



2. Compute equivalent length

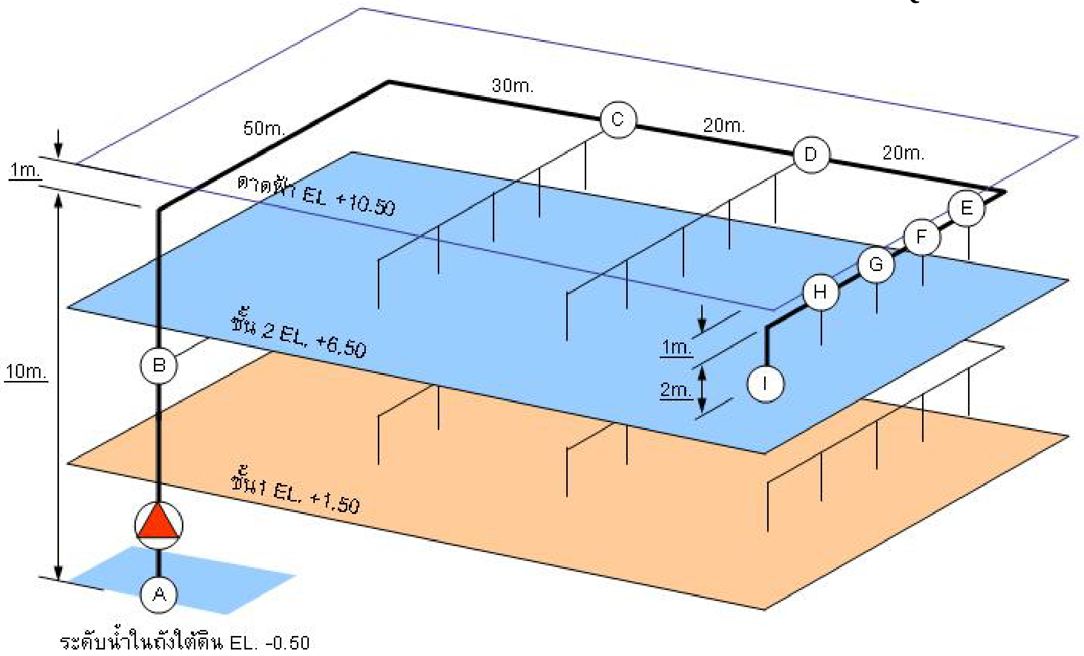
$$L_{EQ} = 182 + 25\% = 227.5\text{m}$$

480lpm@32 m.WG.

Example 5.3 (4)

3. Compute pressure drop per 100m

$$dp = \frac{h_L}{L_{EQ}} \times 100 = \frac{8.7}{227.5} \times 100 = 4 \ \text{m/100m}$$

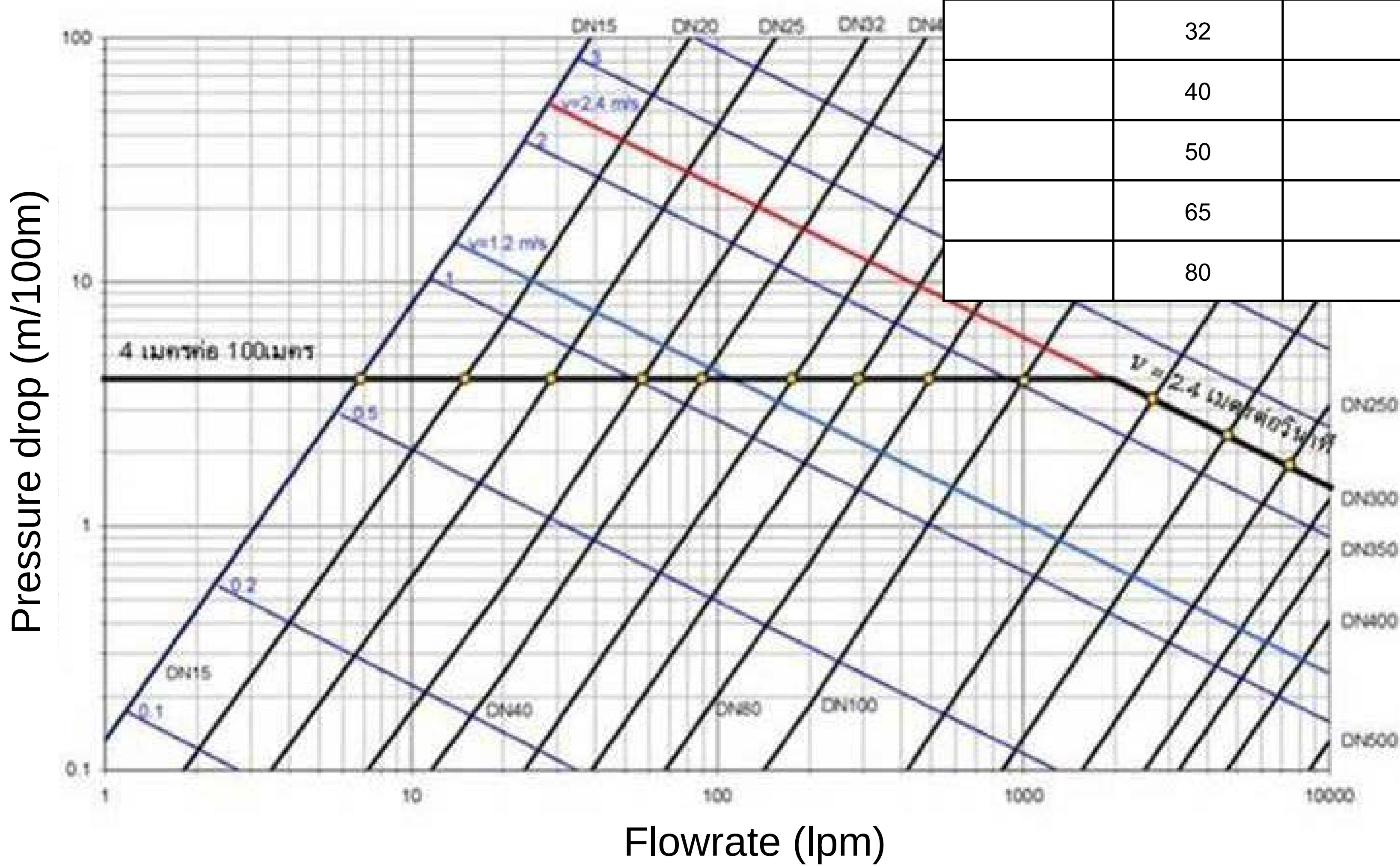


480lpm@32 m.WG.

Example 5.3

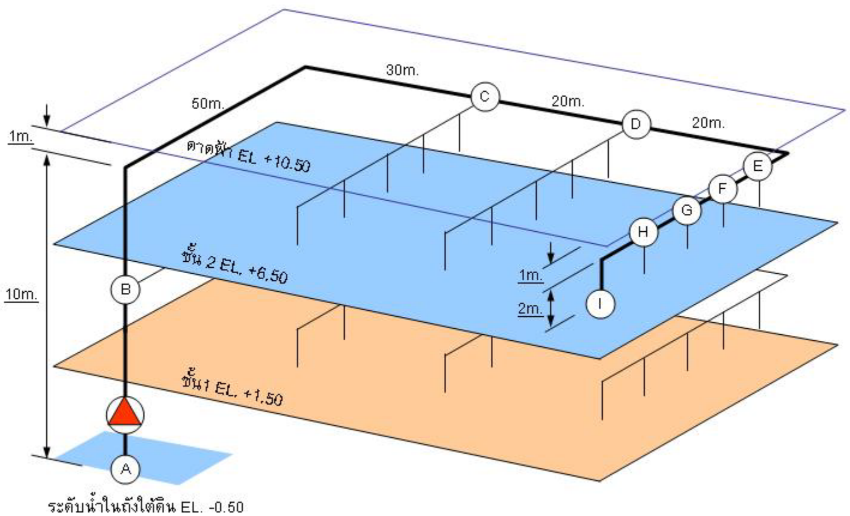
4. Construct pipe sizing table

Max Flowrate (lpm)	Pipe Size DN (mm)	Velocity (m/s)	Pressure drop (m/100m)
	15		
	20		
	25		
	32		
	40		
	50		
	65		
	80		



Example 5.3 (6)

5. Sum up the flow in each section



Section	Sum Flow rate (lpm)	Use factor	Design Flow rate (lpm)	Length (m)
A-B				
B-C				
C-D				
D-E				
E-F				
F-G				
G-H				
H-I				

Example 5.3 (7)

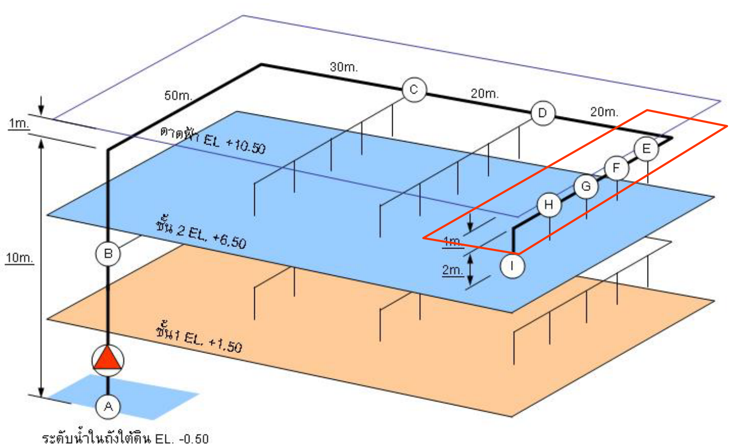
6 Size the pipe and 7 compute pressure drop

Max Flowrate (lpm)	Pipe Size DN (mm)	Velocity (m/s)	Pressure drop (m/100m)
7	15	0.6	3.94
15	20	0.7	3.95
29	25	0.9	4.00
58	32	1.0	3.99
91	40	1.2	3.99
177	50	1.4	3.99
293	65	1.5	3.98
500	80	1.7	3.92

Section	Design Flow rate (lpm)	Length (m)	Pipe Size DN (mm)	Velocity (m/s)	Pressure Drop	
					m/ 100m	m
A-B	480	6				
B-C	240	84				
C-D	200	20				
D-E	100	30				
E-F	80	10				
F-G	60	10				
G-H	40	10				
H-I	20	12				

Example 5.3 (8)

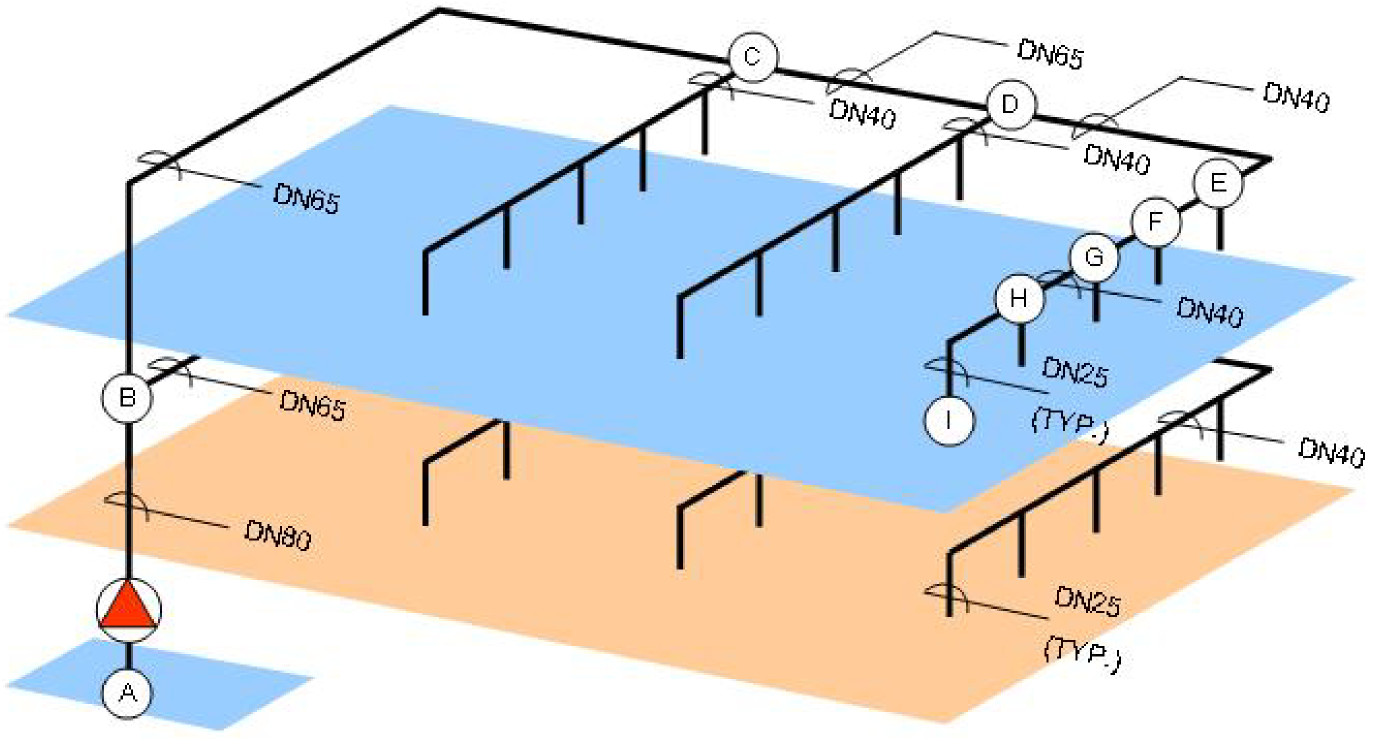
7. Fine tuning the design.



Section	Design Flow rate (lpm)	Length (m)	Pipe Size DN (mm)	Velocity (m/s)	Pressure drop	
					m/ 100m	m
A-B	480	6	80	1.677	3.63	0.22
B-C	240	84	65	1.263	2.73	2.29
C-D	200	20	65	1.052	1.94	0.39
D-E	100	30	***40***	***1.268***	4.77	1.43
E-F	80	10	***40***	***1.015***	3.13	0.31
F-G	60	10	***40***	***0.761***	1.83	0.18
G-H	40	10	***40***	***0.507***	0.87	0.09
H-I	20	12	25	0.598	2.02	0.24
					รวม	5.15

Example 5.3 (9)

8. Draw the pipe sizes



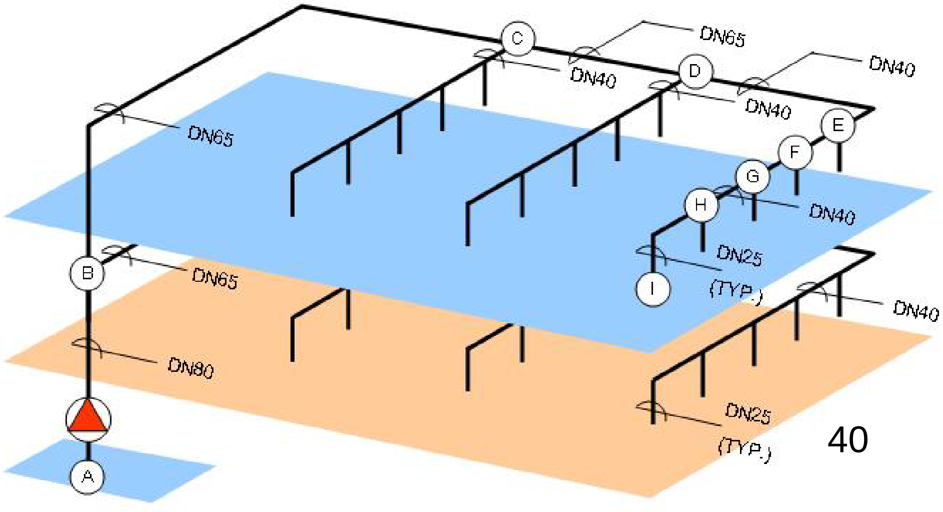
Comments

- Actual pressure drop usually smaller than the design limit.

- If there the outlets are just exits, the flow will be very high at the outlets located near the pump and very low at the last one.

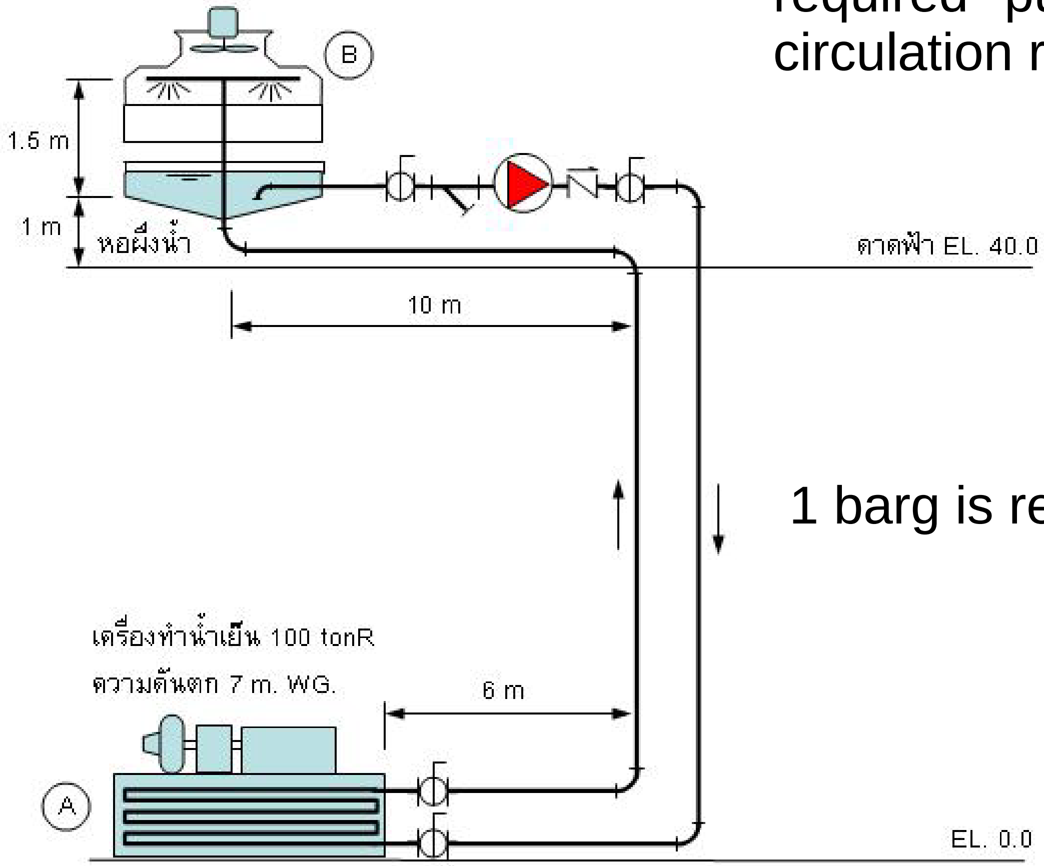
- The actual operating point of the pump may vary (discussed in the next chapter)

- In actual condition there will be valves at the outlets to control the flow.



Example 5.4

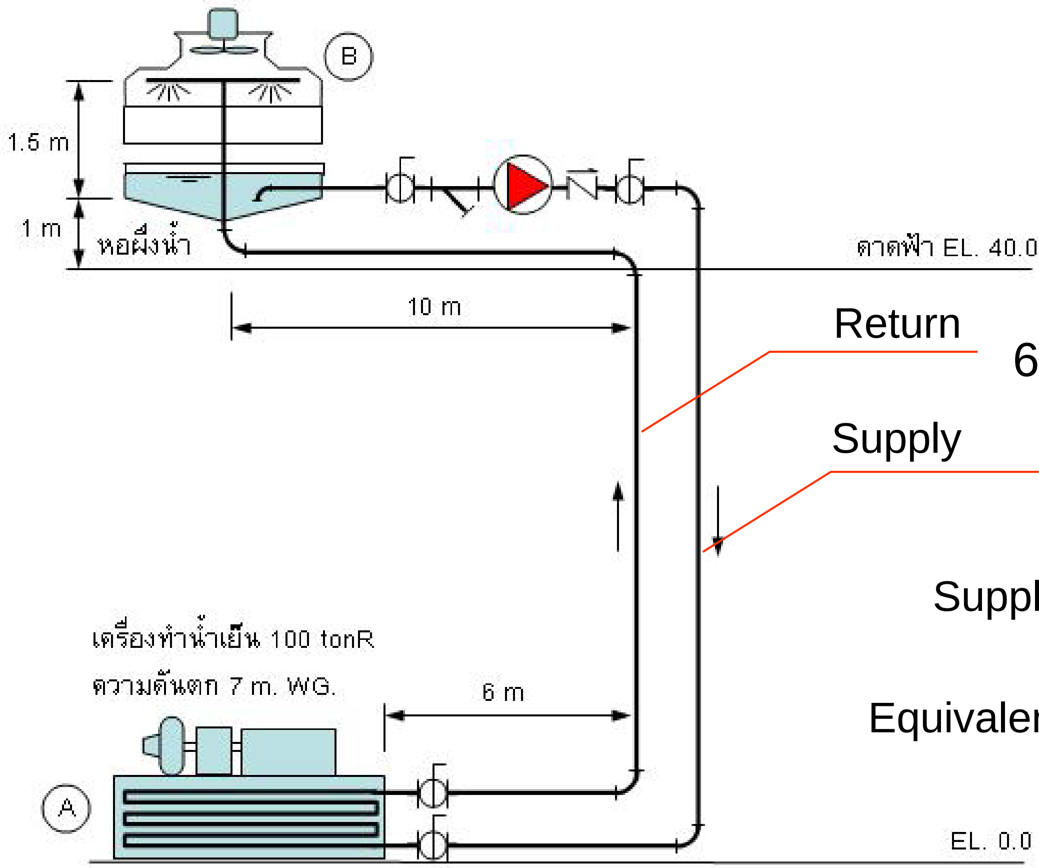
Size the condenser water pipes for 100 TonR system and compute the required pump head. The required circulation rate is 9 lpm/TonR.



1 barg is required at B

Example 5.4 (2)

Required flowrate = 9 lpm/tonR x 100 tonR = 900 lpm



Return: 6 + 40 + 10 + 2.5 = 58.5 m

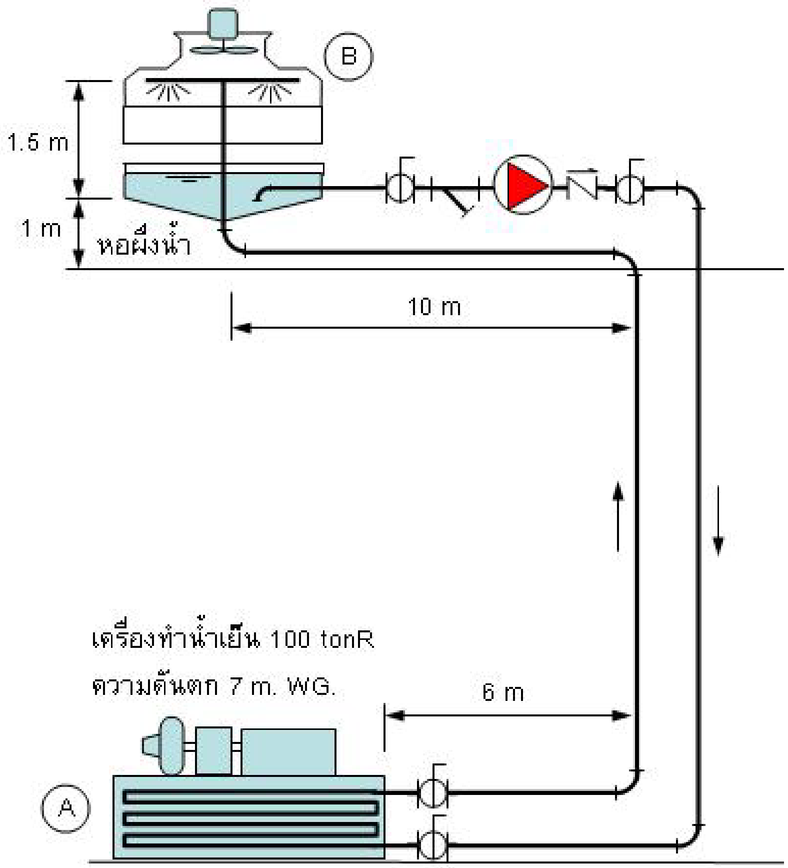
Supply: 6 + 40 + 10 + 1 = 57 m

Supply+Return = **115.5 m**

Equivalent Length = 115.5 x 1.25 = 144 m

Example 5.4 (3)

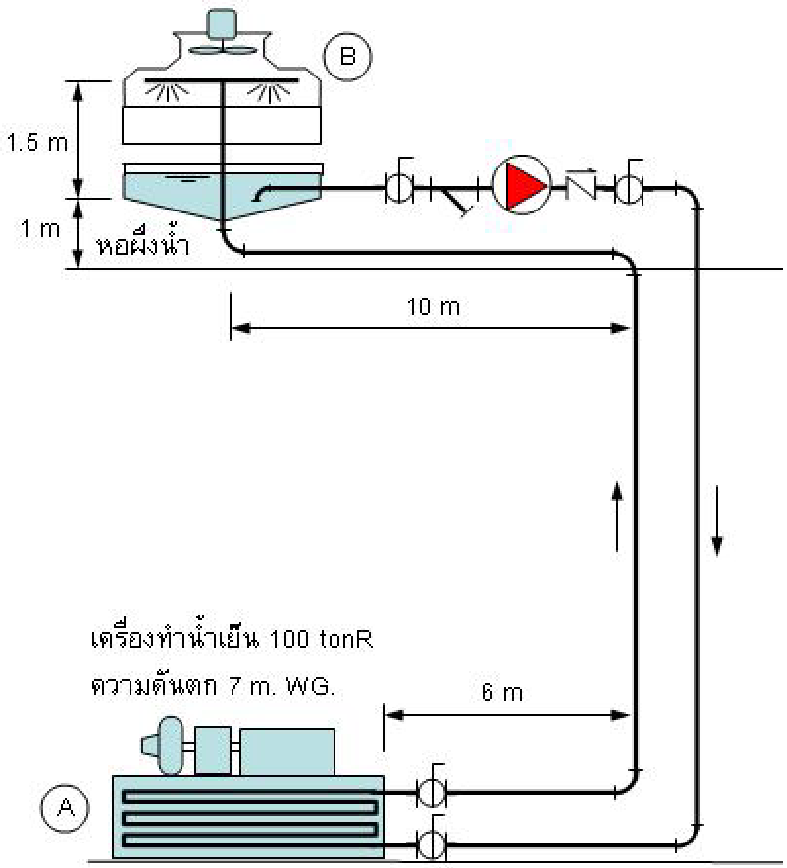
Size the pipe for 4m/100m pressure drop
At 900 lpm



อัตราไหลสูงสุด (lpm)	ขนาดระบุ DN (mm)	ความเร็ว (m/s)	ความดันตก (m/100m)
7 (14)*	15	0.6 (1.2)	3.94 (14.2)
15 (24)*	20	0.7 (1.2)	3.95 (9.45)
29 (40)*	25	0.9 (1.2)	4.00 (7.32)
58 (66)*	32	1.0 (1.2)	3.99 (5.09)
91	40	1.2	3.99
177	50	1.4	3.99
293	65	1.5	3.98
500	80	1.7	3.92
1,000	100	2.0	3.74
1,850	125	2.4	3.88
2,700	150	2.4	3.17

Example 5.4 (4)

At 900 lpm actual pressure drop = 3.06 m/100m
So drop in pipe = 3.06/100x143 = 4.41 m.WG.

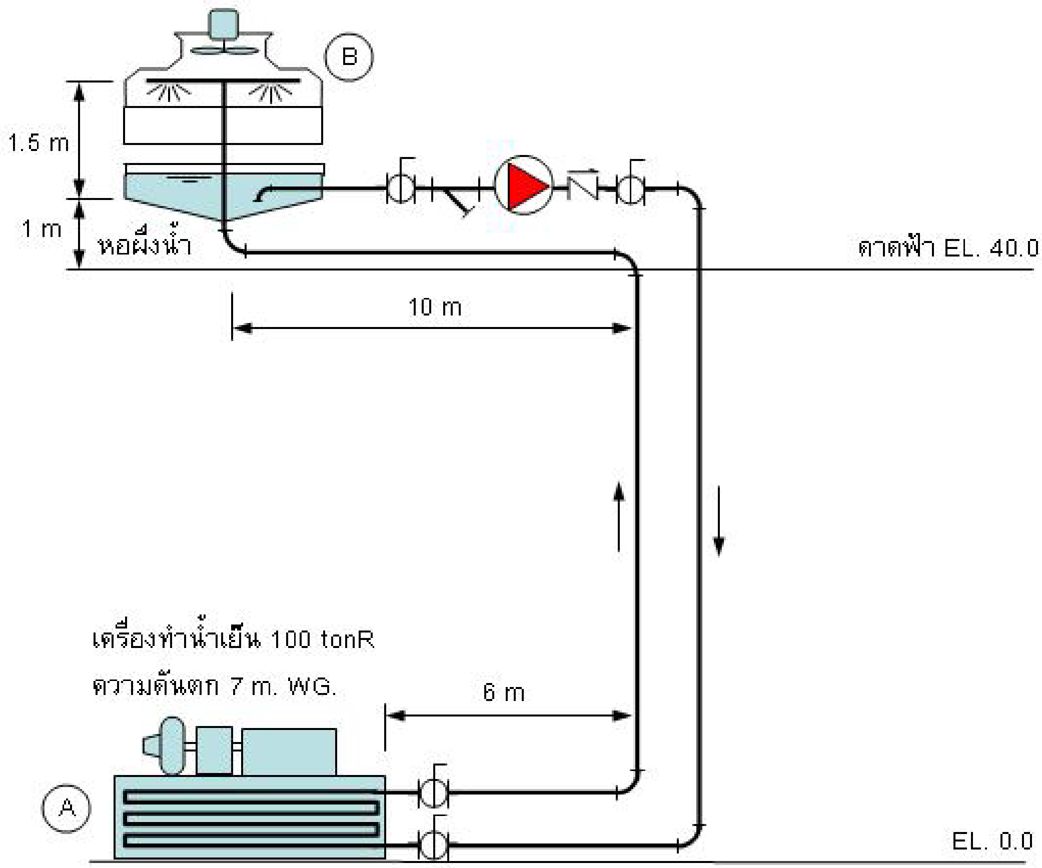


Pressure require at pump =

Pressure drop in pipe +
Pressure drop in chiller+
Pressure required at B +
Elevation

= 4.41 + 7 + 1.5 + 10.2 = 23.1 m.WG.

Comments



- Elevation is the different between suction and discharge of the pump
- During installation both pipe must be filled before pump can operate
- What is the difference btw installing pump on roof and in the basement?
- In practical the condenser pipe shall be the next larger size to account for scale forming in a long run

Homework

5.2) จงกำหนดขนาดท่อทั้งหมด และ คำนวณเฮดที่ต้องการจากปั๊มสำหรับการใช้งาน 100% โดยต้องการให้ความดันน้ำก่อนทางออกในทุกจุดมีค่าไม่ต่ำกว่า 0.5 barG ใช้อัตราความดันตก **5m/100m** ในการออกแบบ และให้เผื่อความดันสูญเสียในข้อต่อและวาล์วเป็น 25% ของการสูญเสียในท่อตรง