Supplemental Problem A-6 Ch. 12 Materials Handling

Goal: Determine total installed cost of pump & piping system

Given:

Water pipe	275	gpm		75	F	1000	feet
	delivery rate			water temperature		length	304.8 meter length
black carbon steel			Insulation, 85% magnesia			1.5	inch thickness
Fittings	40		Valves	4			
Pump	10	hp	centrifugal				
Motor	AC		enclosed	3-phase	1800	rpm	

Approach: Determine optimum pipe diameter, use eqn. 12-15 or Fig. 12-3

$$D_{i,opt} = 0.363\, m_v^{0.45}\, \rho^{0.13}\, \mu^{0.025}$$

a } Determine pump maximum output pressure from hp & unit analysis
Estimate actual efficiencies of pump and motor, Fig.'s 12-17 & 12-18

b } Determine pipe purchase cost from Fig. 12-4
Determine fittings price from Fig. 14-4 (old 4th ed)
Determine valve purchase cost from Fig. 12-8 (flanged)
Determine pump purchase cost from Fig. 12-20
Determine magnesia insulation purchase cost from Fig. 12-12
Update with M&S equipment cost index

c } Determine installation and insulation from Ch. 6 page 246 top paragraph info

d } Forecast future M&S equipment cost index from handout figures

Parameters:

Water density	62.4	lb./ft^3	297	K water t	996	kg/m^3
	0.855	cP			0.000855	Pa s
Jan. 2002	1,102.5	M&S	Jan. 2002		1,431.7	2nd qtr 2008
Jan. 1990	904.0	M&S	Jan. 1990 for P&T 4th ed. Fittings cost			
Installation	45	%	of total installed cost for installation labor			
Insulation	20	%	of total installed cost for insulation material & labor			

from page 246 1st paragraph, assume mid-range values

Calculations:

convert to SI units for use of text figures

water delivery rate	m_v =	0.0174	m^3/s	23.9	C water temperature	
				0.6	ft^3/s	velocity
eqn. 12-15 optimum diameter		0.120	m	4.7	inch diameter	1.52 meters/sec
select standard nominal pipe size, round up to	6	6.065	inches	0.154	meters, actual ID	0.93 meters/sec

alt. round down to | 4 | 4.026 | 0.102 | 2.11 meters/sec

Answer a} check Reynolds Number for Turbulent flow, $N_{Re} = D V \rho / \mu$ m m3/s/m2 kg/m3 / kg/m s

N_{Re} = 167,081 much > 2,100 thus Turbulent

Equivalent ΔP_{PSI} = 10 hp * 550 ft-lb/hp-sec / m_v ft^3/sec / 144 in^2/ft^2 429.7096 kPa from 10 hp * 0.745W/hp / m3/s

m2 kg / s3 m3/s 62.3 psi lbf / in^2 429.8306 kPa from psi * 6.894

Pump capacity factor = m^3/s * kPa 7.46 m^3/s x kPa

Alt. 4" pipe

Read pipe Fig. 12-4 pp 503	0.15	meter	$30	per meter Sch.40 Carbon-steel welded pipe	0.1 m	$18
Read fittings Fig. 14-4 copy	0.15	meter (in 1990)	$90	per Tee Sch.40 Carbon-steel welded fitting	0.1 m	$40
Read valves Fig. 12-8 pp 505	0.15	meter	$1,100	per Gate valve flanged 1035 kPa carbon steel	0.1 m	$750
Read pump Fig. 12-20 pp 518	7.46	m^3/s x kPa	$3,700	AVS horizontal, 150 psi		
Read insulation Fig. 12-12 pp 5	0.15	meter	$18	per meter 85% magnesia 0.038m thick	0.1 m	$15

Jan. 2002		length * cost/length	$9,144				$5,486
M&S update purchased cost	pipe	$11,874	2nd qtr 2008	$11.87	current $/foot price	$7.12	$7,125
	fittings	$5,701		$142.54	current $/tee price	$63.35	$2,534
	valves	$5,714		$1,428.45	current $/valve price	$973.95	$3,896
	insulation	$7,125		$7.12	current $/foot price	$5.94	$5,937
	pump	$4,805		$4,804.80	current $/pump price		$4,805

Answer b} **$35,200** purchased cost of pump + pipe equipment in 2nd qtr 2008 **$24,300**

Cost to install pipe

Total Installed Cost = Purchased cost + 0.45 total installed

$ 64,000 TIC(1-0.45) = PC $ 44,182

Answer c} **$ 64,000** installed cost of pump+pipe in 2nd qtr 2008 **$ 44,200**

assume optimistic low projection of 1983-2003 year linear f 18 units per year 1454.2 5 quarters into futu

$65,000 low forecast of installed cost of pump+pipe

assume pessimistic projection of last 2.5 year linear fit 160 units per year 1631.7

$72,900 high forecast of installed cost of pump+pipe 64 assumed units/yr increase

80 forecast M&S index 3rd qtr 2008 1,511.7

Answer d} **$68,000** forecast installed cost of pump+pipe in 3rd qtr 2008 ± ~$1,500 reasonable range **$47,000**

prepared by: D. C. Drown

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Supplemental Problem A-6 part II Ch. 12 Materials Handling

Goal: Determine total installed cost of 3x5 pump & piping system

Given:

Water pipe	275	gpm		75	F	1000	feet
	delivery rate			water temperature		length	304.8 meter length
black carbon steel			Insulation, 85% magnesia			1.5	inch thickness
Fittings	40		Valves	4			
Pump	10	hp	centrifugal				
Motor	AC		enclosed	3-phase	1800 rpm		

Approach: Same as Part I except replace the single pump with 5 smaller 40% pumps
Design for 3 pumps each handling 40% of load and 2 on stand-by
Use 40% of pump capacity factor for each of the 5 pumps

Determine pump purchase cost from Fig. 12-20

Parameters:

Water density	62.4	lb./ft^3	297	K water temp	996	kg/m^3
	0.855	cP			0.000855	Pa s
Jan. 2002	1,102.5	M&S	Jan. 2002		1,431.7	2nd qtr 2008
Jan. 1990	904.0	M&S	Jan. 1990 for P&T 4th ed. Fittings cost			
Installation	45	%	of total installed cost for installation labor			
Insulation	20	%	of total installed cost for insulation material & labor			

from page 246 1st paragraph, assume mid-range values

Calculations:

convert to SI units for use of text figures

				23.9	C water temperature			
water delivery rate	m_v =	0.0174	m^3/s	0.6	ft^3/s		velocity	
eqn. 12-15 optimum diameter		0.120	m	4.7	inch diamete	actual ID	1.52	meters/sec
select standard nominal pipe size, round up to		**6.0**	inches	**0.152**	meters	**0.154**	0.93	meters/sec
select standard nominal pipe size, round down to		**4.0**	inches	**0.102**	meters	**0.102**	2.11	meters/sec

Answer a} check Reynolds Number for Turbulent flow, $N_{Re} = D V \rho / \mu$ m m3/s/m2 kg/m3 / kg/m s

N_{Re} = 167,081 much > 2,100 thus Turbulent 251,701

Equivalent ΔP_{PSI} = 10 hp * 550 ft-lb/hp-sec / m_v ft^3/sec / 144 in^2/ft^2 429.7096 kPa from 10 hp * 0.745W/hp / m3/s

m2 kg / s3 m3/s 62.3 psi lbf / in^2 429.8306 kPa from psi * 6.894 nominal 4"

Pump capacity factor = m^3/s * kPa 2.98 m^3/s x kPa 0.10

Read pipe Fig. 12-4 pp 503	0.15	meter	$30	per meter Sch.40 Carbon-steel welded pipe	$18
Read fittings Fig. 14-4 copy	0.15	meter (in 1990)	$90	per Tee Sch.40 Carbon-steel welded fitting	$40
Read valves Fig. 12-8 pp 505	0.15	meter	$1,100	per Gate valve flanged 1035 kPa carbon steel	$750
Read pump Fig. 12-20 pp 518	2.98	m^3/s x kPa	$2,800	AVS horizontal, 150 psi	
Read insulation Fig. 12-12 pp 5	0.15	meter	$18	per meter 85% magnesia 0.038m thick	$15

Jan. 2002 length * cost/length $9,144 $7,125

M&S update purchased cost		2nd qtr 2008		
pipe	$11,874	$11.87	current $/foot price	$7.12
fittings	$5,701	$142.54	current $/tee price	$63.35
valves	$5,714	$1,428.45	current $/valve price	$973.95
insulation	$7,125	$7.12	current $/foot price	$5.94
pumps	$18,180	$3,636.06	current $/pump price	

Answer b} **$48,600** purchased cost of pump+pipe equipment in 2nd qtr 2008 $33,500

Cost to install pipe

Total Installed Cost = Purchased cost + 0.45 total installed

$ 88,364 TIC(1-0.45) = PC $ 60,909

Answer c} **$88,400** installed cost of 3x5 pumps+pipe in 2nd qtr 2008 $60,900

$24,400 additional investment for redundant 3x5 pumps compared to single pump

38% increase in capital cost, but system could easily supply 20% more (50 gpm) water in an emergency

Note: neglected added costs for more valves and fittings to manifold the 5 pumps together in parallel

$23,369 need at least 8 more valves and 10 more fittings with 4" manifold $15,318

Answer c} **$112,000** installed cost of 3x5 pumps+pipe in 2nd qtr 2008 **$104,000** $ 76,000

prepared by: D. C. Drown

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