5.9.3

$h_p \leq [(P_{atm} - P_{vapor})/\gamma] - [H'_s + V^2/2g + h_L]$ where

H'_s= 15 ft, V = Q/A = 11.0 ft/s, & from the book jacket

P_{atm}=14.7psi= 2117 lbs/ft^2; P_{vapor}=0.344psi= 49.5 lbs/ft^2

$(P_{atm} - P_{vapor})/\gamma = (2117 - 49.5)/(62.3) = 33.2$ ft.

Also, the h_L on the suction side of the pump is:

$h_L = h_f + [\sum K](V)^2/2g = [f(L/D) + \Sigma K]\cdot[(V)^2/2g]$ and

$e/D = 0.00085/(10/12) = 0.00102$; $\nu = 1.08 \times 10^{-5}$ ft^2/s

$VD/\nu = (11.0)(10/12)/(1.08 \times 10^{-5}) = 8.49 \times 10^5$

And from the Moody diagram, f = 0.020; thus

$h_L = [0.020\{35/(10/12)\}+2.6]\cdot[(11.0)^2/2g] = 6.46$ ft, and

$h_p \leq [(P_{atm} - P_{vapor})/\gamma] - [H'_s + V^2/2g + h_L]$

$\mathbf{h_p} \leq [33.2\text{ft}] - [15.0\text{ft} + (11.0)^2/2g + 6.46\text{ft}] = \mathbf{9.86\ ft}$

5.9.4

$h_p \leq [(P_{atm} - P_{vapor})/\gamma] - V_i^2/2g$ - h_L- σH_P where

$H_S + H_P = H_R + h_L$; (Eq'n 4.2), $H_R - H_S = 82$ ft; and

$h_L = h_f + [\sum K]\{(V)^2/2g\} + h_{L(suction)}$

$K_d = 1.0$ (exit coef.), no other minor losses.

$h_f = KQ^m = [(4.73 \cdot L)/(D^{4.87} \cdot C^{1.85})]Q^{1.85}$

$h_f = [(4.73 \cdot 1250)/(0.5^{4.87} \cdot 130^{1.85})]1.40^{1.85} = 39.6$ ft

$h_L = h_f + V^2/2g + h_{suction}$; where V = 7.13 ft/s. Now,

$H_P = 82$ ft + [39.6 ft + 1.65 ft + $(7.13)^2/2g$] = 124 ft

Table 1.1: P_{vapor}= 0.07275atm[33.8 ft/1 atm] = 2.46 ft

$(P_{atm} - P_{vapor})/\gamma$ = 33.8 ft – 2.46 ft = 31.3 ft

Therefore, $h_p \leq [(P_{atm} - P_{vapor})/\gamma] - V_i^2/2g$ - h_L- σH_P.

h_p $\leq$ 31.3 ft – $(7.13)^2/2g$ – 1.6 ft – (0.08)(124 ft) **= 19.0 ft**

5.9.6

$h_p \leq [(P_{atm} - P_{vapor})/\gamma] - [H'_s + V^2/2g + h_L]$ where

$h_p = 10.2$ ft; Q = 3000gpm (1 cfs/449 gpm) = 6.68 cfs;

Thus, $V = Q/A = (6.68\ ft^3/s)/[\pi(0.5ft)^2] = 8.51$ ft/s

P_{atm}= 14.7 psi = 2117 lbs/ft^2; (from book jacket)

P_{vapor}= 0.3387 psi = 48.8 lbs/ft^2; (from Table 1.1)

$(P_{atm} - P_{vapor})/\gamma = (2117 - 48.8)/(62.3) = 33.2$ ft,

h_L (suction side) is: $h_L = [f(L/D) + \Sigma K]\cdot[(V)^2/2g]$

$h_L = [0.014(10/1) + 3.5]\cdot[(8.51)^2/2g] = 4.09$ ft, and

$h_p \leq [(P_{atm} - P_{vapor})/\gamma] - [H'_s + V^2/2g + h_L]$;

$10.2\ ft \leq [33.2\ ft] - [H'_s + (8.51)^2/2g + 4.09\ ft]$;

$H'_s = 17.8$ ft

5.10.4

Using the appropriate US units identified after Equation (5.6), convert to the US unit system for specific speed: 1 cfs = 449 gpm and 12.5 cfs = 5610 gpm

And since geometrically similar pumps have the same specific speed, the pump head can be found using:

$N_{s(model)} = [\omega(Q)^{1/2}]/(H_p)^{3/4}$

$N_{s(model)} = [(1150)(449)^{1/2}]/(18)^{3/4} = 2790$

$N_{s(field)} = [\omega(Q)^{1/2}]/(H_p)^{3/4}$

$2790 = [\omega(5610)^{1/2}]/(95)^{3/4}$; $\boldsymbol{\omega} = \mathbf{1130}$ **rpm**

Also, $N_{s(model)} = [\omega(\mathbf{P_i})^{1/2}]/(H_p)^{5/4}$

$N_{s(model)} = [1150(3.1)^{1/2}]/(18)^{5/4} = 54.6$

Now, $N_{s(field)} = [\omega(\mathbf{P_i})^{1/2}]/(H_p)^{5/4}$

$54.6 = [1130(\mathbf{P_i})^{1/2}]/(95)^{5/4} = 54.6$; $\mathbf{P_i = 205}$ **hp**

Now based on the equation given in Example 5.10:

$(Q/\omega D^3)_{model} = (Q/\omega D^3)_{field}$

$[449/\{(1150)(0.5)^3]_{model} = [5610/\{(1130)(D)^3]_{field}$

D = 1.17 ft

5.11.2

Determine the system head curve:

$H_{SH} = H_s + h_L$; where $h_L = [f(L/D) + \sum K](V^2/2g)$;

$e/D = 0.18/350 = 0.00051$; thus $f = 0.017$ and

$H_{SH} = 40 + [0.017(150/0.35)+4.7](V^2/2g)$

$H_{SH} = 40+12.0(V^2/2g)$; $V = 4Q/[\pi(0.35m)^2] = 10.4Q$

Using this equation, plug in a range of Q values, determine H_{SH}, and superimpose this system curve on the best pump characteristic curve. This yields:

Q (m^3/sec)	V (m/sec)	H_s (m)	h_L (m)	H_{SH} (m)
0.10	1.04	40.0	0.7	40.7
0.12	1.25	40.0	1.0	41.0
0.14	1.46	40.0	1.3	41.3

From Figure 5.23, with Q = 120 L/sec & Hp = 41.0 m, Pumps III and IV will work. From Figure 5.24:

Pump III; ω = 4350 rpm, e ≈ 58%, Q ≈ 130 L/s, and Hp ≈ 41 m'; alternatively select **Pump IV; ω = 4050 rpm, e ≈ 63% (best choice) Q ≈ 140 L/s, Hp ≈ 41 m**

5.11.4

Determine Q vs. H_{SH} (system). Apply Equation 5.19

$H_{SH} = H_s + h_L$; where $h_L = h_f + [\sum K](V)^2/2g$; and

$K_e = 0.5$, $K_d = 1.0$, and $h_f = KQ^{1.85}$ (Table 3.4) where

$K = (4.73 \cdot L)/(D^{4.87} \cdot C^{1.85})$ and therefore:

Pipeline Data			Reservoir Data		
L =	7800	ft	E_A =		ft
D =	1.00	ft	E_D =		ft
C =	90		H_s =	100.0	ft
$h_f = KQ^m$			Minor Losses		
m =	1.85		ΣK =	1.50	
K =	8.95		g =	32.2	ft/sec^2

Q (gpm)	Q (cfs)	h_f (ft)	h_{minor} (ft)	H_s (ft)	H_{SH} (ft)
0	0.00	0.0	0.0	100.0	100.0
200	0.45	2.0	0.0	100.0	102.0
400	0.89	7.2	0.0	100.0	107.3
600	1.34	15.3	0.1	100.0	115.4
700	1.56	20.3	0.1	100.0	120.4
800	1.78	26.0	0.1	100.0	126.2
1000	2.23	39.4	0.2	100.0	139.5

Plotting Q vs H_{SH} on Figure 5.11.5: the match point is:

Q ≈ 700 gpm (1.56cfs), **H_p ≈ 121 ft, e_p ≈ 85%, P_i ≈ 26 hp**

$P_o = \gamma Q H_P = (62.3\ lb/ft^3)(1.56\ ft^3/sec)(121\ ft)$

P_o = 11,800 ft-lb/sec(1 hp/550 ft·lb/sec) = **21.5 hp**

$e_p = P_o/P_i$ = 21.5/26 = 83% ≈ **85%**

Loop	Pipe	Q (m^3/sec)	K (sec^2/m^5)	h_f (m)	h_f/Q (sec/m^2)	New Q (m^3/sec)
3	*GH*	0.033	1894	2.10	63.1	0.033
(clockwise)	*HF*	0.063	3068	12.17	193.2	0.063
	EG	0.008	3068	0.20	25.0	0.008
			$\sum h_{fc}$ =	14.48	281.4	$\equiv\sum(h_{fc}/Q_c)$
(counter)	*EF*	0.087	1894	14.34	164.8	0.087
			$\sum h_{fcc}$ =	14.34	164.8	$\equiv\sum(h_{fcc}/Q_{cc})$
				ΔQ =	0.0002	

Pipe	Q (m^3/sec)	Q (L/sec)	Length (m)	Diameter (m)	h_f (m)	ΔP (kPa)
AB	0.2043	204.3	300	0.30	8.1	79.0
AD	0.0957	95.7	250	0.25	3.8	37.6
BC	0.0796	79.6	350	0.20	12.0	117.6
BG	0.1246	124.6	125	0.20	10.5	102.8
GH	0.0332	33.2	350	0.20	2.1	20.4
CH	0.0296	29.6	125	0.20	0.6	5.8
DE	0.0957	95.7	300	0.20	14.9	145.6
EG	0.0083	8.3	125	0.15	0.2	2.1
EF	0.0872	87.2	350	0.20	14.4	140.9
HF	0.0628	62.8	125	0.15	12.1	118.5