2.48 $\frac{A-4}{20-4}=\frac{9-3}{15-3}$ $\quad A=12\,mA$ $\quad \frac{c}{100\%}=\frac{9-3}{15-3};\ c=50\%$

2.49 $\frac{A-4}{20-4}=\frac{10-3}{15-3}$ $\quad A=13.33\,mA$ $\quad \frac{c}{100\%}=\frac{10-3}{15-3};\ c=58.3\%$

2.50 $\frac{A-4}{20-4}=\frac{14-3}{15-3}$ $\quad A=18.67\,mA$ $\quad \frac{c}{100\%}=\frac{14-3}{15-3};\ c=91.7\%$

2.51 $\frac{A-4}{20-4}=\frac{4-3}{15-3}$ $\quad A=5.33\,mA$ $\quad \frac{c}{100\%}=\frac{4-3}{15-3};\ c=8.33\%$

2.52 DCSs have replaced analog controllers due to lower cost per control loop, but analog controller can implement faster controller cycle times than DCS's while they are probably comparable with regard to reliability. DCS's have replaced supervisory control computers due to increased reliability.

Fieldbus technology is likely to replace DCS's in the future because of lower installation costs since a single data highway wire can replace hundreds of input/output wires. In addition, since fieldbus technology supports smart sensors and valves, it is likely to result in greater overall system reliability and performance.

The key issues for developments in the future are capital and installation costs, system performance as affected by the control computer, and system reliability.

2.53 The deadband of a control valve is the largest positive and negative change in the signal to the control valve that does not produce a noticeable positive and negative change in the measured flow rate through the valve. A 9% change would not always produce a measurable change in the measured flow rate. On the other hand, if the stem position were very close to a position where it stem can change, then a 2% change in the output could produce a measurable change in the flow rate.

2.54 $Q_f=21.7\sqrt{14/1}=81.2\,GPM$ for a specific gravity of one.

2.55 From Table 2.1 and using linear interpolation, C_v = 38.85

$$Q_f=38.75\sqrt{35/1}=229.3\,GPM$$

2.56 The specific gravity is 44/62.4=0.705; therefore, $Q_f=86.4\sqrt{82/.705}=931.8\,GPM$

2.57 From Table 2.1 and using linear interpolation, C_v = 38.85. The specific gravity is 0.705

$$Q_f=5.46\sqrt{14/0.705}=24.3\,GPM$$

2.72 From Table 2.2, ΔP=18.0 by linear interpolation. Rearranging Equation 2.2,

$$C_v = \frac{74}{\sqrt{18/0.65}} = 14.1$$

From Table 2.1 using linear interpolation, the valve position is equal to 53%.

2.73 From the table for this problem, ΔP=0.6 by linear interpolation. Rearranging Equation 2.2,

$$C_v = \frac{105}{\sqrt{0.6/1}} = 135.6$$

From Table 2.1 using linear interpolation, the valve position is equal to 79%.

2.74 For the average flow rate (60 GPM), ΔP=20.1 psi. Then,

$$C_v = \frac{60}{\sqrt{20.2/1}} = 13.35$$

For a 1.5-inch valve, it would have a valve position of 75% and a 2-inch valve would have a valve position of 52%; therefore, a 2-inch valve is selected. Now checking the valve position at the maximum flow rate (67%) and the minimum flow rate(36%); therefore, a 2-inch valve is selected because the turndown ratio is only 3.

2.75 For the average flow rate (50 GPM), ΔP=22.6 psi. Then,

$$C_v = \frac{50}{\sqrt{22.6/0.65}} = 8.48$$

For a 1-inch valve, it would have a valve position of 73% and a 1.5-inch valve would have a valve position of 66% and a 2-inch valve would have a valve position of 44%; therefore, a 1.5-inch valve is selected because it is the closest to 67% open. Now checking the valve position at the maximum flow rate (81%) and the minimum flow rate(41%); therefore, a 1.5-inch valve is selected.

2.76 For the average flow rate (250 GPM), ΔP=20.8 psi. Then,

$$C_v = \frac{250}{\sqrt{20.8/1}} = 54.8$$

For a 3-inch valve, it would have a valve position of 67% and a 4-inch valve would have a valve position of 66% and a 4-inch valve would have a valve position of 61%; therefore, a 3-inch valve is selected because it is the closest to 67% open. Now checking the valve position at the maximum flow rate, a 3-inch valve is not large enough. For a 4-inch valve, the valve position at the maximum flow rate is 82% and is 37%, both of which are satisfactory; therefore, a 4-inch valve is selected.

2.77 For the average flow rate (250 GPM), ΔP=20.8 psi. Then,

$$C_v = \frac{250}{\sqrt{20.8/0.65}} = 44.2$$

For a 3-inch valve, it would have a valve position of 63% and a 4-inch valve would have a valve position of 56%; therefore, a 3-inch valve is selected because it is the closest to 67% open. Now checking the 3-inch valve is not able to handle the maximum flow rate. For a 4-inch valve at the maximum flow rate the valve position is 75% and at the minimum flow rate 32%; therefore, a 4-inch valve is selected.

2.78 For the average flow rate (150 GPM), ΔP=27.0 psi. Then,

$$C_v = \frac{150}{\sqrt{27.0/1}} = 28.9$$

For a 2-inch valve, it would have a valve position of 67% and a 3-inch valve would have a valve position of 55%; therefore, a 2-inch valve is selected because it is the closest to 67% open. Now checking the 2-inch valve is not able to handle the maximum flow rate. For a 3-inch valve at the maximum flow rate the valve position is 68% and at the minimum flow rate 30%; therefore, a 3-inch valve is selected.

2.79 $T = 50 + 150\frac{7-4}{20-4} = 78.1°C$

2.80 $P = 25 + 150\frac{5.5-4}{20-4} = 39.1\ psi$

2.81 $F = 1000 + 10{,}000\frac{12.2-4}{20-4} = 6125\ \ lb/hr$

2.82 Since the mA reading is below 4 mA, the sensor is not functioning properly.

2.83 $L = 10 + 75\frac{6.8-4}{20-4} = 23.1\%$

2.84 $I = 4 + 16\frac{300-100}{400} = 12\ mA$

2.85 $I = 4 + 16\frac{202-14.7}{250} = 16.0\ mA$

2.86 $I = 4 + 16\frac{300 - 14.7}{250} = 22.3\ mA$ Something is wrong with this sensor because the reading is out of range.

2.87

$$I = 4 + 16\frac{66{,}732 - 15{,}000}{100{,}000} = 12.3\ mA$$

2.88 $I = 4 + 16\frac{47 - 12}{65} = 12.6\ mA$

2.89

$$Span = 16\frac{100 - 80}{10 - 8} = 160\ psig$$

$$Zero = 80 - 160\frac{8 - 4}{16} = 40\ psig$$

2.90

$$Span = 16\frac{150 - 100}{10 - 8} = 400°\ F$$

$$Zero = 150 - 400\frac{10 - 4}{16} = 0°\ F$$

2.91

$$Span = 16\frac{15{,}000 - 10{,}000}{12 - 7} = 16{,}000\ lb / h$$

$$Zero = 15{,}000 - 16{,}000\frac{12 - 4}{16} = 7{,}000\ lb / h$$

2.92

$$Span = 16\frac{250 - 180}{10 - 6} = 280\ psig$$

$$Zero = 250 - 280\frac{10 - 4}{16} = 145\ psig$$

2.93

$$Q = \frac{(0.6)(3.183\,in^2)(ft^2 / 144\,in^2)}{\sqrt{1-(0.5)^2}} \sqrt{\frac{(2)(2\,lb_f / in^2)(32.2\ lb_m \cdot ft / lb_f \cdot s^2)}{(62.4\,lb_m / ft^3)(ft^2 / 144\,in^2)}}$$

$$= 0.264\,ft^3 / s = 118.5\ GPM$$

2.94

$$Q = \frac{(0.6)(2.66 in^2)(ft^2 / 144\,in^2)}{\sqrt{1-(0.6)^2}} \sqrt{\frac{(2)(10\,lb_f / in^2)(32.2\ lb_m \cdot ft / lb_f \cdot s^2)}{(62.4\,lb_m / ft^3)(ft^2 / 144\,in^2)}}$$

$$= 0.5341\,ft^3 / s = 239.7\ GPM$$

2.95

$$Q = \frac{(0.6)(1.506\,in^2)(ft^2 / 144\,in^2)}{\sqrt{1-(0.67)^2}} \sqrt{\frac{(2)(1.5\,lb_f / in^2)(32.2\ lb_m \cdot ft / lb_f \cdot s^2)}{0.65(62.4\,lb_m / ft^3)(ft^2 / 144\,in^2)}}$$

$$= 0.1565\,ft^3 / s = 70.3\ GPM$$

2.96

$$Q = \frac{(0.6)(0.6795 in^2)(ft^2 / 144\,in^2)}{\sqrt{1-(0.45)^2}} \sqrt{\frac{(2)(2.3\,lb_f / in^2)(32.2\ lb_m \cdot ft / lb_f \cdot s^2)}{0.65(62.4\,lb_m / ft^3)(ft^2 / 144\,in^2)}}$$

$$= 0.0727\,ft^3 / s = 32.6\ GPM$$

2.97 β greater than 0.7 is out of the range for an orifice meter**;** therefore, β=0.87 is not a valid orifice meter.

2.98

$$\Delta P = \frac{(150\,gal / \min)^2 (\min / 60\,s)^2 (ft^3 / 7.481\,gal)^2 (62.4\,lb_m / ft^3)[1-(0.6)^2]}{(2)(32.2\,lb_m \cdot ft / lb_f \cdot s^2)(0.6)^2 (4.583\,in^2)^2 (ft^2 / 144\,in^2)}$$

$$= 1.32\ psi$$

2.99

$$\Delta P = \frac{(150\,gal / \min)^2 (\min / 60\,s)^2 (ft^3 / 7.481\,gal)^2 (62.4\,lb_m / ft^3)[1-(.4)^2]}{(2)(32.2\,lb_m \cdot ft / lb_f \cdot s^2)(0.6)^2 (2.037\,in^2)^2 (ft^2 / 144\,in^2)}$$

$$= 8.77\ psi$$

2.100

$$\Delta P = \frac{(60\,gal/\min)^2(\min/60\,s)^2(ft^3/7.481\,gal)^2\,0.65(62.4\,lb_m/ft^3)[1-(0.43)^2]}{(2)(32.2\,lb_m\cdot ft/lb_f\cdot s^2)(0.6)^2(1.367\,in^2)^2(ft^2/144\,in^2)}$$
$$=1.965\ psi$$

2.101 β should be greater than 0.3 for the proper design of an orifice meter; therefore, β=0.23 is outside the valid region for an orifice meter design.

2.102

$$\Delta P = \frac{(40\,gal/\min)^2(\min/60\,s)^2(ft^3/7.481\,gal)0.65(62.4\,lb_m/ft^3)^2[1-(0.59)^2]}{(2)(32.2\,lb_m\cdot ft/lb_f\cdot s^2)(0.6)^2(1.168\,in^2)^2(ft^2/144\,in^2)}$$
$$=0.699\,psi$$

2.103 Since the line pressure is 200 psig and the 4% of it is 8 psi, a 5 psi differential pressure sensor is chosen. Assuming that a 5 psi pressure drop occurs at the maximum flow rate (150 GPM), β is calculated by

$$\beta = \sqrt{\frac{1}{1+\psi}}$$

$$\psi = \frac{2C_d^2 A_1^2 g_c \Delta P}{\rho Q_f^2}$$

$$\psi = \frac{(2)(0.6)^2(7.393\,in^2)^2(32.2\,lb_m\cdot ft/lb_f\cdot s^2)(5\,lb_f/in^2)}{(62.4\,lb_m/ft^3)(150\,gal/\min)^2(ft^3/7.481\,gal)^2(12\,in/ft)^2}$$
$$=6.314$$
$$\beta = 0.370$$

Let use examine a smaller ΔP (2 psi). For this case β=0.533, which provides less pressure drop and less restriction in the line, and is selected in this case. The Reynolds number is 1.5×10^5. Therefore, each of the three restrictions on the orifice design are met, i.e., β between 0.2 and 0.7, pressure drop is less than 4% of the line pressure, and the Reynolds number is between 10^4 and 10^7. Also, the turndown ratio is 2.5 which is less than the maximum for a conventional differential pressure cell.

2.104 Since the line pressure is 100 psig and the 4% of it is 4 psi, a 2 psi differential pressure sensor is chosen. Assuming that a 2 psi pressure drop occurs at the maximum flow rate (350 GPM), β is calculated by