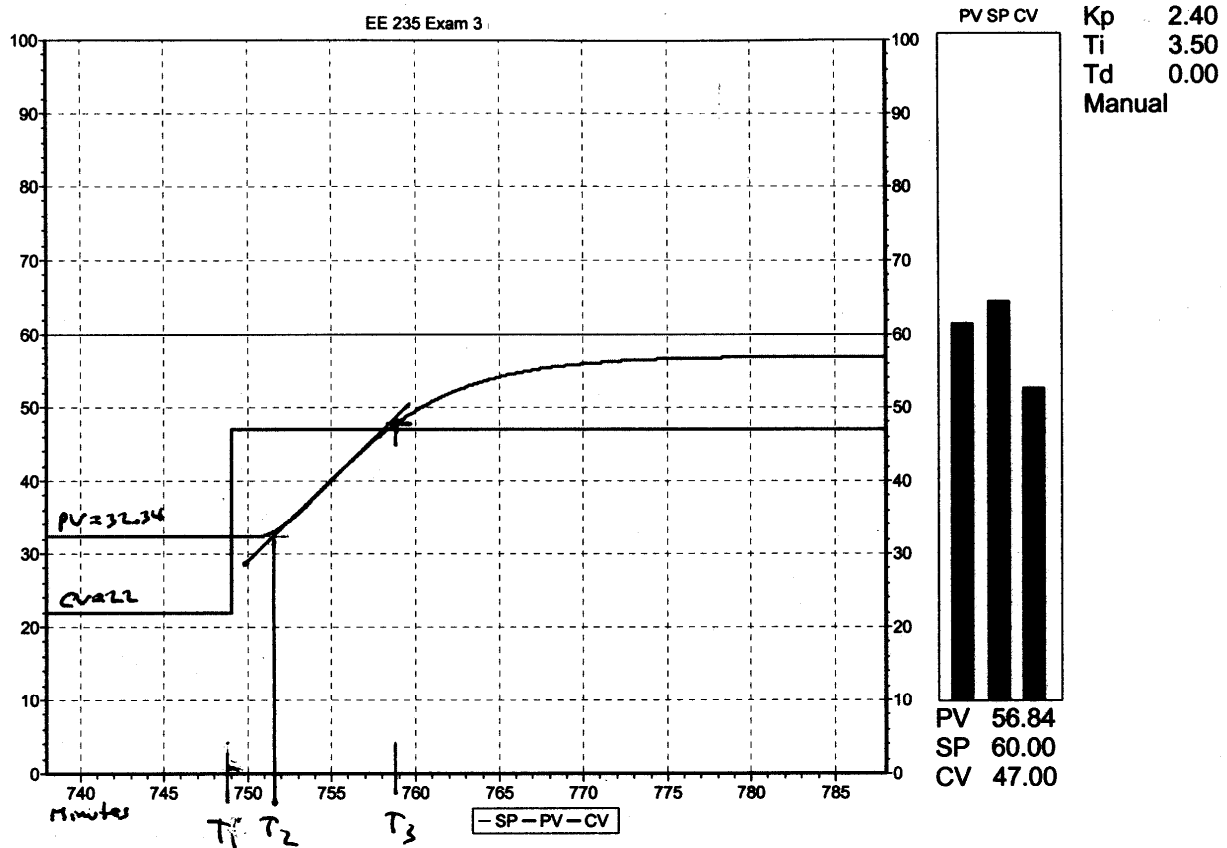


(a) First-order approximation

$$\Delta CV = 42 - 22 = 20$$

$$\Delta PV = 56.84 - 32.34 = 24.5$$

$$0.63\Delta PV + PV_1 = 0.63(24.5) + 32.34 = 15.44 + 32.34 = 47.78$$



$$T_1 = 749 \text{ min.}$$

$$T_2 \approx 751.7 \text{ min.}$$

$$T_3 \approx 758.8 \text{ min.} \quad \Leftarrow @47.78$$

$$\theta_D = T_2 - T_1 = 751.7 - 749 = 2.7 \text{ min.}$$

$$\tau_1 = T_3 - T_2 = 758.8 - 751.7 = 7.1 \text{ min.}$$

$$\text{Gain} = \frac{\Delta PV}{\Delta MV} = \frac{56.84 - 32.34}{47 - 22} = 0.98$$

$$(b) \text{ Model: } G(s) = \frac{0.98e^{-2.7s}}{7.1s + 1}$$

Cohen-Coon w/o constraints

$$\alpha = \theta_D / \tau = 2.7 / 7.1 = 0.38$$

PI control

$$K_P = (1/0.98)[(0.9)/(0.38) + 0.082] = 2.50$$

$$T_I = 2.7 \{ [3.33 + 0.333(0.38)] / [1 + 2.2(0.38)] \} = 5.08 \text{ min.}$$

Fertik

$$\alpha_F = \theta_D / (\tau + \theta_D) = 2.7 / (7.1 + 2.7) = 0.28$$

$$T_{ps} = \tau + \theta_D = 7.1 + 2.7 = 9.8$$

PI control (disturbance)

$$KK_P \approx 1.60 \Rightarrow K_P = 1.6 / 0.98 = 1.63$$

$$T_I / T_{ps} \approx 0.79 \Rightarrow T_I = 0.79(9.8) = 7.74 \text{ min.}$$

$$(c) \text{ Model: } G(s) = \frac{0.98e^{-2.7s}}{7.1s + 1}$$

Cohen-Coon w/constraints

$$\alpha = 0.38$$

PID control

$$K_P = (1.37/0.98) / [(0.38)^{-0.950}] = 3.50$$

$$T_I = 0.74(7.1) / [(0.38)^{0.738}] = 2.57 \text{ min.}$$

$$T_D = 0.365(7.1) / [(0.38)^{0.950}] = 1.03 \text{ min.}$$

Fertik

$$\alpha_F = 0.28$$

$$T_{ps} = 9.8$$

PID control (setpoint change)

$$KK_P \approx 1.35 \Rightarrow K_P = 1.35 / 0.98 = 1.38$$

$$T_I / T_{ps} \approx 0.53 \Rightarrow T_I = 0.53(9.8) = 5.19 \text{ min.}$$

$$T_D / T_{ps} \approx 0.28 \Rightarrow T_D = 0.28(9.8) = 2.74 \text{ min.}$$