Patm = 83.5

P1 = 300 + Patm

T1 = **T** ('R717' , P = P1 , x = 1)

h1l = **h** ('R717' , P = P1 , x = 0)

h1v = **h** ('R717' , P = P1 , x = 1)

P2 = 249.06 + Patm

T2 = **T** ('R717' , P = P2 , x = 1)

h2l = **h** ('R717' , P = P2 , x = 0)

h2v = **h** ('R717' , P = P2 , x = 1)

P3 = 1070.1 + Patm

T3 = 73.5

h3lv = **h** ('R717' , P = P3 , T = T3)

P4 = 220 + Patm

T4 = **T** ('R717' , P = P4 , x = 1)

h4l = **h** ('R717' , P = P4 , x = 0)

h4v = **h** ('R717' , P = P4 , x = 1)

P4h = 240 + Patm

T4h = **T** ('R717' , P = P4h , x = 1)

h4lh = **h** ('R717' , P = P4h , x = 0)

h4vh = **h** ('R717' , P = P4h , x = 1)

Pn1 = 1050 + Patm

Tn1 = **T** ('R717' , P = Pn1 , x = 1)

hn1l = **h** ('R717' , P = Pn1 , x = 0)

hn1v = **h** ('R717' , P = Pn1 , x = 1)

Pn2 = 274.2 + Patm

Tn2 = **T** ('R717' , P = Pn2 , x = 1)

hn2l = **h** ('R717' , P = Pn2 , x = 0)

hn2v = **h** ('R717' , P = Pn2 , x = 1)

Pn2h = 480 + Patm

Tn2h = **T** ('R717' , P = Pn2h , x = 1)

$hn2lh = \mathbf{h}('R717', P=Pn2h, x=0)$

$hn2vh = \mathbf{h}('R717', P=Pn2h, x=1)$

$Pn3 = 270.8 + Patm$

$Tn3 = \mathbf{T}('R717', P=Pn3, x=1)$

$hn3l = \mathbf{h}('R717', P=Pn3, x=0)$

$hn3v = \mathbf{h}('R717', P=Pn3, x=1)$

$Pn3h = 410 + Patm$

$Tn3h = \mathbf{T}('R717', P=Pn3h, x=1)$

$hn3lh = \mathbf{h}('R717', P=Pn3h, x=0)$

$hn3vh = \mathbf{h}('R717', P=Pn3h, x=1)$

$Pn4 = 240 + Patm$

$Tn4 = \mathbf{T}('R717', P=Pn4, x=1)$

$hn4l = \mathbf{h}('R717', P=Pn4, x=0)$

$hn4v = \mathbf{h}('R717', P=Pn4, x=1)$

$Pn4h = 453.3 + Patm$

$Tn4h = \mathbf{T}('R717', P=Pn4h, x=1)$

$hn4lh = \mathbf{h}('R717', P=Pn4h, x=0)$

$hn4vh = \mathbf{h}('R717', P=Pn4h, x=1)$

$Pn5 = 260 + Patm$

$Tn5 = \mathbf{T}('R717', P=Pn5, x=1)$

$hn5l = \mathbf{h}('R717', P=Pn5, x=0)$

$hn5v = \mathbf{h}('R717', P=Pn5, x=1)$

$Pn5h = 510 + Patm$

$Tn5h = \mathbf{T}('R717', P=Pn5h, x=1)$

$hn5lh = \mathbf{h}('R717', P=Pn5h, x=0)$

$hn5vh = \mathbf{h}('R717', P=Pn5h, x=1)$

$hn1l = hn2lh + a11 \cdot (hn2vh - hn2lh)$

$$-\frac{\Delta H_{r.s,PD}}{6} = aaaa \cdot 0.075599 \cdot L_{PD} \cdot \rho('R717', P=Pn2h, x=0) \cdot (hn2lh - hn2l)$$

$W = 3.5$

$$L = 1.27$$

$$g = 9.81$$

$$t = 13.5$$

$$t_{im} = 13.5$$

$$x_1 = 5$$

$$n = 35$$

$$y_{l.req} = 0.005$$

$$y_{l.m} = 0.001$$

$$y_s = 0.0015$$

$$Ins_{transm,losses,permod} = \frac{27 + 127}{8}$$

$$T_{wi} = 12$$

$$T_{l.o} = 0$$

$$T_{r.har} = \mathbf{T}(\text{'R717'}, P = Pn5h, x = 1)$$

$$T_{r.E.build} = \mathbf{T}(\text{'R717'}, P = Pn5, x = 0)$$

$$t_{pump} = 130$$

$$R_i = 0.68$$

$$del_T = \frac{0.5 + 0.7 + 0.566}{3}$$

$$V_{pd,Actual} = \pi \cdot \left[(2 \cdot R_i)^2 \cdot \frac{3.1}{4} + 1 / 6 \cdot (2 \cdot R_i)^3 \right]$$

$$V_{pd} = \frac{\pi}{4} \cdot 1.36^2 \cdot L_{PD}$$

$$L_{PD} = m_r \cdot \frac{7 / 6}{(2.6943 - 0.163493) \cdot R_i^2 \cdot \rho_{pd}}$$

$$\rho_{pd} = \rho(\text{'R717'}, T = Tn2 + del_T, x = 0)$$

$$\dot{V}_{pd} = m_r \cdot \frac{7 / 6}{\rho_{pd} \cdot t_{pump}}$$

$$m_{rl.circ,PD,to,E} = \dot{V}_{pd} \cdot 50 \cdot \rho_{pd}$$

$$c_{pd} = \mathbf{Cp}(\text{'R717'}, x = 0, T = Tn2 + del_T)$$

$$K_{pd} = \mathbf{k}\left[\text{'R717'}, x = 0, T = \frac{Tn2h + Tn2}{2}\right]$$

$$m_{rl.circ,PD,to,E} \cdot c_{pd} \cdot \frac{delT}{2 \cdot t_{pump}} = \frac{Tn2h - \left[Tn2 + \frac{del_T}{2} \right]}{\frac{1}{h_R} + 0.2 \cdot \frac{R_i}{K_{pd}}}$$

$$q_{dot1} = \frac{Tn2h - \left[Tn2 + \frac{del_T}{2} \right]}{\frac{1}{h_R} + 0.2 \cdot \frac{R_i}{K_{pd}}}$$

$$q_{dot2} = \frac{Tn2h - Tn2}{\frac{1}{h_R} + 0.2 \cdot \frac{R_i}{K_{pd}}}$$

$$c_{pd,hot} = \mathbf{Cp} \left(\text{'R717'}, x = 0, T = Tn2 + del_{T,hot} \right)$$

$$K_{pd,hot} = \mathbf{k} \left[\text{'R717'}, x = 0, T = \frac{Tn1 + Tn2}{2} \right]$$

$$\rho_{pd,hot} = \rho \left(\text{'R717'}, T = Tn2 + del_{T,hot}, x = 0 \right)$$

$$m_{rl.circ,PD,to,E,HG} = m_r \cdot \frac{7 / 6}{\rho_{pd} \cdot t_{pump}} \cdot 50 \cdot \rho_{pd,hot}$$

$$m_{rl.circ,PD,to,E,HG} \cdot c_{pd,hot} \cdot \frac{del_{T,hot}}{2 \cdot t_{pump}} = \frac{Tn1 - \left[Tn2 + \frac{del_{T,hot}}{2} \right]}{\frac{1}{h_R} + 0.2 \cdot \frac{R_i}{K_{pd,hot}}}$$

$$delT_{PD} = 1$$

$$delT_{ACC} = 0.9$$

$$delT_{PD,HG} = delT_{PD} \cdot \frac{Tn1}{Tn2h}$$

$$delT_{ACC,HG} = delT_{ACC} \cdot \frac{\Delta H_{rv.vent,PD.p,to,ACC.HG}}{\Delta H_{rv.vent,PD.p,to,ACC}}$$

$$delT_{ACC,p} = delT_{ACC} \cdot \left[\frac{\frac{\Delta H_{rv,PD.f,to,ACC}}{8} + \Delta H_{rl.cont,E,to,ACC} + \Delta H_{rlc}}{\frac{\Delta H_{rv,PD.f,to,ACC}}{8} + \Delta H_{rl.cont,E,to,ACC} + \Delta H_{rlc} + \frac{\Delta H_{rv.vent,PD.p,to,ACC}}{8}} \right]$$

$$c_w = \mathbf{Cp} \left(\text{'Water'}, T = T_{wi}, P = Patm \right)$$

$$c_I = \mathbf{Cp} \left(\text{'Ice'}, T = T_{r.E.build}, P = Patm \right)$$

$$\rho_{Ice} = \mathbf{rho} \left(\text{'Ice'}, T_{I.o} - 1 \right)$$

$$h_{sf} = 335$$

$P_{rE} = Pn5$

$P_{r.har} = Pn5h$

$P_{comp.inlet} = P2$

$P_{pumping.pumperdrum} = Pn2h$

$P_{filling.pumperdrum} = Pn2$

$P_{cond} = Pn1$

$\rho_I = \rho(\text{'Ice'}, T = -2, P = Patm)$

$a_E = W \cdot L$

$h_{rgevap.inlet} = \mathbf{h}(\text{'R717'}, P = P_{rE}, x = 1)$

$h_{rl,E} = \mathbf{h}(\text{'R717'}, P = P_{rE}, x = 0)$

$h_{rl.v,Eo} = \mathbf{h}(\text{'R717'}, P = P_{rE}, x = m)$

$m_{rdotcomplete} = m_{rdot} \cdot 7$

$$m_{rvtrap,E,t2} = a_E \cdot y_{inner} \cdot \frac{n}{specV_{rv.har}} \cdot (1 - ptrap)$$

$m_{rv.vent,PD.p,to,ACC} = (2.4981 + 0.48) \cdot R_i^2 \cdot L_{PD} \cdot \rho(\text{'R717'}, P = Pn2h, x = 1)$

$m_{rv.vent,PD.p,to,ACC.HG} = (2.4981 + 0.48) \cdot R_i^2 \cdot L_{PD} \cdot \rho(\text{'R717'}, P = Pn1, x = 1)$

$$m_{s,PD} = \rho_s \cdot \left[\frac{\pi}{4} \cdot (1.4^2 - 1.36^2) \cdot 2.8 + \frac{\pi}{6} \cdot (1.4^3 - 1.36^3)\right]$$

$$m_{s,ACC} = \rho_s \cdot \left[\frac{\pi}{4} \cdot (2^2 - 1.96^2) \cdot 5 + \frac{\pi}{6} \cdot (2^3 - 1.96^3)\right]$$

$m_{rltrap,E,t2} = \rho(\text{'R717'}, P = P_{r.har}, x = 0) \cdot a_E \cdot y_{inner} \cdot n \cdot ptrap$

$ptrap = 0.05$

$specV_{rv.har} = \mathbf{v}(\text{'R717'}, P = Pn5h, x = 1)$

$c_s = \mathbf{c}(\text{'Stainless}_{AISI304}\text{'}, T_{r.E.build})$

$c_{s,PD} = \mathbf{c}(\text{'Stainless}_{AISI304}\text{'}, Tn2)$

$c_{s,ACC} = \mathbf{c}(\text{'Stainless}_{AISI304}\text{'}, T4)$

$a51 = \rho(\text{'R717'}, P = P_{r.har}, x = 0)$

$\rho_s = \mathbf{rho}(\text{'Stainless}_{AISI304}\text{'}, T_{r.E.build})$

$h_{rgevap} = \mathbf{h}(\text{'R717'}, P = P_{rE}, x = 1)$

$h_{rfevap} = h_{rl,E}$

$h_{rl.har} = \mathbf{h}(\text{'R717'}, T = T_{r.har}, x = 0)$

$$h_{rl,E,to,ACC} = \mathbf{h}('R717', x=0, T=T_{r.E.build} + z)$$

$$z = \frac{4.5 + 5 + 4}{3 \cdot 2}$$

$$h_{rv.har} = \mathbf{h}('R717', x=1, P=Pn5h)$$

$$h_{rfcond} = \mathbf{h}('R717', x=0, P=Pn5h)$$

$$h_{rv.ACC} = \mathbf{h}('R717', x=1, P=P4)$$

$$h_{rl,ACC} = \mathbf{h}('R717', x=0, P=P4)$$

$$h_{rv,PD.f,to,ACC} = \mathbf{h}('R717', x=1, P=Pn2)$$

$$h_{rv,PD.p} = \mathbf{h}('R717', P=Pn2h, x=1)$$

$$a_E \cdot y_{inner} = ((0.035 - 0.0015 \cdot 2) \cdot (0.01 - 0.0015 \cdot 2)) \cdot W \cdot 30$$

$$V_E = a_E \cdot y_{inner} \cdot n$$

$$m = \frac{1}{x_1}$$

$$\rho_{rl} = \rho('R717', P=P_{rE}, x=0)$$

$$\rho_{rv} = \rho('R717', P=P_{rE}, x=1)$$

$$m_{l.b} = \rho_l \cdot n \cdot a_E \cdot (2 \cdot y_{l.req} + 2 \cdot y_{l.m})$$

$$m_{is} = \rho_l \cdot n \cdot a_E \cdot 2 \cdot y_{l.m}$$

$$m_{l.req} = \rho_l \cdot n \cdot a_E \cdot 2 \cdot y_{l.req}$$

$$Q_{load} = m_{l.b} \cdot \left[- c_w \cdot T_{wi} - h_{sf} + c_l \cdot \left(\frac{T_{r.E.build} + T_{l.o}}{2} \right) \right]$$

$$INT_{ENERGY} = n \cdot (\mathbf{u}('R717', P=P_{rE}, x=0) \cdot 0.3 \cdot a_E \cdot y_{inner} \cdot \rho('R717', P=P_{rE}, x=0) + \mathbf{u}('R717', P=P_{rE}, x=1) \cdot 0.3 \cdot a_E \cdot y_{inner} \cdot \rho('R717', P=P_{rE}, x=1))$$

$$- Q_{load} + INT_{ENERGY} = m_r \cdot (h_{rl.v,Eo} - h_{rl,E})$$

$$m_{rdot} = \frac{m_r}{t \cdot 60}$$

$$m_{rdot,check} = (2.6943 - (\pi - 2.9781)) \cdot R_i^2 \cdot L_{PD} \cdot \frac{\rho('R717', P=Pn2, x=0)}{7 \cdot t_{pump}}$$

$$APP_{A10.4} = n \cdot \left[\frac{0.3 \cdot a_E \cdot y_{inner} \cdot \rho('R717', P=P_{rE}, x=0) + 0.3 \cdot a_E \cdot y_{inner} \cdot \rho('R717', P=P_{rE}, x=1)}{13.5 \cdot 60 \cdot m_{rdot}} \right] \cdot 100$$

$$Q_{PRD,E} = m_{l.req} \cdot (- c_w \cdot T_{wi} - h_{sf})$$

$$\Delta H_{rltrap,E} = - m_{rltrap,E,t2} \cdot (h_{rl.har} - h_{rfevap})$$

$$\Delta H_{r.s,E} = m_{s,E} \cdot c_s \cdot (T_{r.E.build} - T_{r.har})$$

$$m_{s,E} = n \cdot \rho_s \cdot a_E \cdot 2 \cdot y_s$$

$$\Delta H_{r.har.1} = -\Delta H_{r.s,E}$$

$$\Delta H_{r.har.2} = -m_{l.b} \cdot c_l \cdot \left[\frac{T_{r.E.build} + T_{l.o}}{2}\right]$$

$$\Delta H_{r.har.3} = \rho_{ice} \cdot n \cdot a_E \cdot 2 \cdot y_{l.m} \cdot h_{sf}$$

$$a_E \cdot y_{inner} = V_{rl,E} + V_{rv,E}$$

$$V_{rv,E} = 0.7 \cdot a_E \cdot y_{inner}$$

$$\Delta m_{rl.cont,E,to,ACC} = n \cdot (V_{rl,E} \cdot \rho_{rl} + V_{rv,E} \cdot \rho_{rv})$$

$$\Delta H_{rl.cont,E,to,ACC} = \Delta m_{rl.cont,E,to,ACC} \cdot (h_{rl,ACC} - h_{rl,E,to,ACC})$$

$$Q_{h5} = \Delta H_{r.har.1} + \Delta H_{r.har.2} + \Delta H_{r.har.3}$$

$$Q_{h5} = m_{rlc} \cdot (h_{rv.har} - h_{rl.har})$$

$$\Delta H_{rv,PD.f,to,ACC} = 2.9781 \cdot R_i^2 \cdot \frac{L_{PD}}{\mathbf{v}('R717', x=1, P=Pn2)} \cdot (h_{rv.ACC} - h_{rv,PD.f,to,ACC}) \cdot 3 \cdot 2$$

$$\Delta H_{rlc} = m_{rlc} \cdot (h4l - h_{rl.har})$$

$$\Delta_{H,rv.trap,E} = -m_{rvtrap,E,t2} \cdot (1 - ptrap) \cdot (h_{rv.har} - h_{rv.ACC})$$

$$\Delta H_{rv.vent,PD.p,to,ACC} = -m_{rv.vent,PD.p,to,ACC} \cdot (h_{rv,PD.p} - h_{rv.ACC}) \cdot 3 \cdot 2$$

$$\Delta H_{r.s,ACC} = -m_{s,ACC} \cdot c_{s,ACC} \cdot delT_{ACC} \cdot 3 \cdot 2$$

$$\Delta H_{r.s,PD} = -m_{s,PD} \cdot c_{s,PD} \cdot delT_{PD} \cdot 3 \cdot 2$$

$$\Delta H_{rl.circ,PD,to,E} = m_{rl.circ,PD,to,E} \cdot (hn2l - h_{rl.circ,PD,to,E}) \cdot \frac{5.4}{7}$$

$$h_{rl.circ,PD,to,E} = \mathbf{h}\left['R717', x=0, T=Tn2 + \frac{del_T}{2}\right]$$

$$T_{w,PRCi} = 22.2$$

$$T_{w,PRCo} = 12$$

$$c_{w,PRC} = \mathbf{Cp}('Water', T=19, P=Patm)$$

$$Q_{PRD,PRC} = -m_{l.req} \cdot c_{w,PRC} \cdot (T_{w,PRCi} - T_{w,PRCo})$$

$$\Delta H_{total,URD,per,mod,HG} = \Delta H_{r.s,E} + \Delta H_{rl.cont,E,to,ACC} + \frac{\Delta H_{rv,PD.f,to,ACC}}{8} + \Delta H_{rlc} + \Delta H_{rltrap,E} + \Delta_{H,rv.trap,E} + \frac{\Delta H_{rv.vent,PD.p,to,ACC.HG}}{8} + \frac{\Delta H_{r.s,ACC,HG}}{8} + \frac{\Delta H_{r.s,PD,HG}}{8} + \Delta H_{rl.circ,PD,to,E,HG} + Q_{load} - Q_{PRD,E}$$

$$\Delta H_{total,per,mod} = Q_{PRD,E} + \Delta H_{total,URD,per,mod} + Q_{PRD,PRC}$$

$$Q_{PRD} = -Q_{PRD,E} - Q_{PRD,PRC}$$

$$APer_{URD} = \frac{\Delta H_{total,URD,per,mod}}{\Delta H_{total,per,mod}} \cdot 100$$

$$\Delta H_{rv.vent,PD.p,to,ACC.HG} = -m_{rv.vent,PD.p,to,ACC.HG} \cdot (hn1v - h_{rv.ACC}) \cdot 3 \cdot 2$$

$$\Delta H_{rl.circ,PD,to,E,HG} = m_{rl.circ,PD,to,E,HG} \cdot (hn2l - h_{rl.circ,PD,to,E,HG}) \cdot \frac{5.4}{7}$$

$$h_{rl.circ,PD,to,E,HG} = \mathbf{h}\left['R717' , x=0 , T=Tn2 + \frac{delT_{T,hot}}{2} \right]$$

$$\Delta H_{r.s,PD,HG} = -m_{s,PD} \cdot c_{s,PD} \cdot delT_{PD,HG} \cdot 3 \cdot 2$$

$$\Delta H_{r.s,ACC,HG} = -m_{s,ACC} \cdot c_{s,ACC} \cdot delT_{ACC,HG} \cdot 3 \cdot 2$$

$$\Delta H_{total,URD,per,mod,HG} = \Delta H_{r.s,E} + \Delta H_{rl.cont,E,to,ACC} + \frac{\Delta H_{rv,PD.f,to,ACC}}{8} + \Delta H_{rlc} + \Delta H_{rltrap,E} + \Delta_{H,rv.trap,E} + \frac{\Delta H_{rv.vent,PD.p,to,ACC.HG}}{8} + \frac{\Delta H_{r.s,ACC,HG}}{8} + \frac{\Delta H_{r.s,PD,HG}}{8} + \Delta H_{rl.circ,PD,to,E,HG} + Q_{load} - Q_{PRD,E}$$

$$\Delta H_{total,per,mod,HG} = \Delta H_{total,URD,per,mod,HG} + Q_{PRD,E} + Q_{PRD,PRC}$$

$$Pow_{comp,hot,gas,per,module} = \Delta H_{total,per,mod,HG} \cdot \frac{96}{24 \cdot 3600} - Ins_{transm,losses,permod}$$

$$APer_{URD,HG} = \frac{\Delta H_{total,URD,per,mod,HG}}{\Delta H_{total,per,mod,HG}} \cdot 100$$

$$\Delta H_{rl,P} = -W_{P,MPS,mech} \cdot t \cdot 60$$

$$\Delta H_{r.s,ACC,p} = -m_{s,ACC} \cdot c_s \cdot delT_{ACC,p} \cdot 3 \cdot 2 \cdot 0$$

$$\Delta H_{total,URD,per,mod,P} = \Delta H_{r.s,E} + \Delta H_{rl.cont,E,to,ACC} + \Delta H_{rlc} + \Delta H_{rltrap,E} + \Delta_{H,rv.trap,E} + \frac{\Delta H_{r.s,ACC,p}}{8} + \Delta H_{rl,P} + Q_{load} - Q_{PRD,E}$$

$$\Delta H_{total,per,mod,P} = \Delta H_{total,URD,per,mod,P} + Q_{PRD,E} + Q_{PRD,PRC}$$

$$APer_{URDp} = \frac{\Delta H_{total,URD,per,mod,P}}{\Delta H_{total,per,mod,P}} \cdot 100$$

$$P_{pump.inlet} = P4$$

$$T_{filling} = \mathbf{T}\left('R717' , P=P_{pump.inlet} , x=0 \right)$$

$$P_{pump.outlet} = Pn2h$$

$$P_{pump.exit} = Pn5$$

$$T_{acc} = \mathbf{T}\left('R717' , P=P_{pump.inlet} , x=0 \right)$$

$$V_{dotrf,pump} = m_{rdot} \cdot \mathbf{v}\left('R717' , P=P_{pump.outlet} , x=0 \right) \cdot 7$$

$$\mu_{rf.pump} = \mathbf{Visc}\left('R717' , x=0 , P=P_{pump.exit} \right)$$

$$Vel_{thruplates,pump} = \frac{V_{dotrf,pump}}{\pi \cdot \frac{d_{outlet.piping}^{2}}{4}}$$

$$\rho_{ammonia} = \rho\left('R717' , x=0 , P=P_{pump.outlet} \right)$$

$$\rho_{rf.pump} = \rho\left('R717' , x=0 , P=P_{pump.outlet} \right)$$

$$d_{outlet.piping} = 0.25$$

$$Velocity_{pump} = \frac{V_{dotrf,pump}}{\pi \cdot \frac{d_{outlet.piping}^{2}}{4}}$$

$$Re_{pump} = Velocity_{pump} \cdot \frac{d_{outlet.piping}}{7} \cdot \frac{\rho_{ammonia}}{\mu_{rf.pump}}$$

$$minor.headloss_{pump} = (K_{valve} + 2 \cdot K_{elbow} + K_{exit}) \cdot \frac{Velocity_{pump}^{2}}{2 \cdot g}$$

$$frictional.headloss_{pump} = f \cdot Velocity_{pump}^{2} \cdot \frac{z_{height.pump}}{2 \cdot d_{outlet.piping} \cdot g}$$

$$z_{pump.inlet} = 3$$

$$z_{height.pump} = 4.5$$

$$f = 0.0285$$

$$f_{z} = 0.0285$$

$$K_{valve} = 5$$

$$K_{elbow} = 1.5$$

$$K_{exit} = 1$$

$$wu = \rho_{rf.pump} \cdot g$$

$$NPSH_{a} = \frac{P_{pump.inlet}}{wu} + z_{pump.inlet} - f \cdot Velocity_{pump}^{2} \cdot \frac{z_{pump.inlet}}{2 \cdot g \cdot d_{outlet.piping}} - \frac{P_{sat,pump}}{wu}$$

$$P_{sat,pump} = \mathbf{P}_{sat}\,('R717' , T = T_{acc})$$

$$Hor_{dist} = 7$$

$$d_{hor} = 0.095$$

$$K_{manifold} = 2$$

$$\frac{P_{pump.inlet}}{\rho\,('R717' , x = 0 , P = P_{pump.inlet}) \cdot g} \cdot 1000 + Head_{pump} + z_{pump.inlet} = \frac{P_{pump.exit}}{\rho\,('R717' , x = 0 , P = P_{pump.exit}) \cdot g} \cdot 1000 + z_{height.pump} + \left[f \cdot \frac{z_{height.pump}}{d_{outlet.piping}} + 2 \cdot K_{elbow} + K_{valve} + K_{exit} + 7 \cdot \left(f_{z} \cdot \frac{Hor_{dist}}{d_{hor}} + 2 \cdot K_{elbow} + K_{exit} + K_{manifold} \right) \right] \cdot \frac{Velocity_{pump}^{2}}{2 \cdot g}$$

$$a911 = \left[f \cdot \frac{z_{height.pump}}{d_{outlet.piping}} + 2 \cdot K_{elbow} + K_{valve} + K_{exit} + 7 \cdot \left(f_{z} \cdot \frac{Hor_{dist}}{d_{hor}} + 2 \cdot K_{elbow} + K_{exit} + K_{manifold} \right) \right] \cdot \frac{Velocity_{pump}^{2}}{2 \cdot g}$$

$$a912 = \frac{P_{pump.inlet}}{\rho\,('R717' , x = 0 , P = P_{pump.inlet}) \cdot g} \cdot 1000 + z_{pump.inlet} - \left[\frac{P_{pump.exit}}{\rho\,('R717' , x = 0 , P = P_{pump.exit}) \cdot g} \cdot 1000 + z_{height.pump} \right]$$

$$W_{P,MPS,mech} = wu \cdot \frac{Head_{pump}}{7} \cdot \frac{V_{dotrf,pump}}{\eta_{pump} \cdot 1000}$$

$$\eta_{pump} = 0.85$$

$$t_{FMPS} = 13 \cdot 60$$

$$m_{rlc,FMPS} \cdot (h_{rv.har} - h_{rl.har}) = \Delta H_{r.har.1} + \Delta H_{r.har.2} + \Delta H_{r.har.3}$$

$$\Delta H_{rlc,FMPS} = m_{rlc,FMPS} \cdot (h_{rl,ACC} - h_{rl.har})$$

$$\Delta H_{rl,P,FMPS} = - W_{P,FMPS} \cdot t_{FMPS}$$

$$\Delta H_{total,URD,per,mod,FPMS} = \Delta H_{r.s,E} + \Delta H_{rlc,FMPS} + \Delta_{H,rv.trap,E} + \frac{\Delta H_{r.s,ACC,p}}{8} + \Delta H_{rl,P} + \Delta H_{rl,P,FMPS} + Q_{load} - Q_{PRD,E}$$

$$\Delta H_{total,per,mod,FMPS} = \Delta H_{total,URD,per,mod,FPMS} + Q_{PRD,E} + Q_{PRD,PRC}$$

$$Pow_{comp,P.R,permod} = \Delta H_{total,per,mod,FMPS} \cdot \frac{96}{24 \cdot 3600} - Ins_{transm,losses,permod}$$

$$V_{module} = a_E \cdot y_{inner} \cdot n$$

$$V_{remain} = 0.3 \cdot V_{module}$$

$$V_{discharge} = V_{module}$$

$$V_{recharge} = V_{module}$$

$$\dot{V}_{discharge} = \frac{V_{remain}}{10}$$

$$\dot{V}_{pump.recharge} = 1 \cdot \frac{V_{module}}{13 \cdot 60}$$

$$m_{rdot,act,pump.recharge} = \dot{V}_{pump.recharge} \cdot \rho('R717', x=0, P=P4)$$

$$\dot{V}_{recharge} = \frac{V_{module}}{25}$$

$$\frac{\dot{V}_{pump.recharge}}{\pi \cdot \frac{d_{pump.recharge.piping}^{2}}{4}} = Velocity_{pump.recharge}$$

$$\mu_{rf.pump,FMPS} = \mathbf{Visc}('R717', x=0, P=P4)$$

$$\rho_{ammonia,FMPS} = \rho('R717', x=0, P=P4)$$

$$Re_{pump.recharge} = Velocity_{pump.recharge} \cdot d_{pump.recharge.piping} \cdot \frac{\rho_{ammonia,FMPS}}{\mu_{rf.pump,FMPS}}$$

$$d_{pump.recharge.piping} = 0.05$$

$$Head_{pump.recharge} + z_{pump.recharge.inlet} = z_{height.pump.recharge} + f_{FMPS} \cdot Velocity_{pump.recharge}^{2} \cdot \frac{z_{height.pump.recharge}}{2 \cdot g \cdot d_{pump.recharge.piping}} + (2 \cdot K_{elbow} + K_{valve} + K_{exit}) \cdot \frac{Velocity_{pump.recharge}^{2}}{2 \cdot g}$$

$$f_{FMPS} = 0.029$$

$$z_{pump.recharge.inlet} = 3$$

$$NPSH_{a2} = \frac{P_{rE}}{wu} \cdot 1000 + z_{pump.recharge.inlet} - f_{FMPS} \cdot Velocity_{pump.recharge}^{2} \cdot \frac{z_{pump.recharge.inlet}}{2 \cdot g \cdot d_{pump.recharge.piping}} - \frac{P_{sat,2}}{wu} \cdot 1000$$

$$P_{sat,2} = \mathbf{P}_{sat}(\text{'R717'}, T = T_{r.E.build})$$

$$z_{height.pump.recharge} = 8.5$$

$$W_{P,FMPS} = \rho_{ammonia,FMPS} \cdot g \cdot Head_{pump.recharge} \cdot \frac{\dot{V}_{pump.recharge}}{\eta_{pump} \cdot 1000}$$

$$APer_{URDP.R} = \frac{\Delta H_{total,URD,per,mod,FPMS}}{\Delta H_{total,per,mod,FMPS}} \cdot 100$$

$$W_{CR,elec} = (7696.885 - 7696.815) \cdot \frac{2400}{\frac{7}{60} \cdot 8} \cdot \frac{-\Delta H_{total,per,mod}}{770141}$$

$$W_{CR,elec,HG} = W_{CR,elec} \cdot \frac{\Delta H_{total,per,mod,HG}}{\Delta H_{total,per,mod}}$$

$$W_{CR,elec,P} = W_{CR,elec} \cdot \frac{\Delta H_{total,per,mod,P}}{\Delta H_{total,per,mod}}$$

$$W_{CR,elec,FMPS} = W_{CR,elec} \cdot \frac{\Delta H_{total,per,mod,FMPS}}{\Delta H_{total,per,mod}}$$

$$\eta_{motor} = 0.96$$

$$Cost_{kWh,Ophours} = 365 \cdot 24 \cdot \left[\frac{6}{12} \cdot 26 + \frac{5}{12} \cdot 55.34\right]$$

$$Cost_{CGPS} = W_{CR,elec} \cdot Cost_{kWh,Ophours} \cdot 8$$

$$Cost_{HGPS} = W_{CR,elec,HG} \cdot Cost_{kWh,Ophours} \cdot 8$$

$$Cost_{MPS} = \left[W_{CR,elec,P} + \frac{W_{P,MPS,mech}}{\eta_{motor}}\right] \cdot Cost_{kWh,Ophours} \cdot 8$$

$$Cost_{FMPS} = \left[W_{CR,elec,FMPS} + \frac{W_{P,MPS,mech} + W_{P,FMPS}}{\eta_{motor}}\right] \cdot Cost_{kWh,Ophours} \cdot 8$$

$$a555 = \frac{W_{P,MPS,mech}}{\eta_{motor}} \cdot 8$$

$$a556 = \frac{W_{P,FMPS}}{\eta_{motor}} \cdot 8$$

$$COP_{CGPS} = \frac{Q_{PRD}}{W_{CR,elec} \cdot \eta_{motor} \cdot 15 \cdot 60}$$

$$COP_{HGPS} = \frac{Q_{PRD}}{W_{CR,elec,HG} \cdot \eta_{motor} \cdot 15 \cdot 60}$$

$$COP_{MPS} = \frac{Q_{PRD}}{(W_{CR,elec,P} \cdot \eta_{motor} + W_{P,MPS,mech}) \cdot 15 \cdot 60}$$

$$COP_{FMPS} = \frac{Q_{PRD}}{(W_{CR,elec,FMPS} \cdot \eta_{motor} + W_{P,MPS,mech} + W_{P,FMPS}) \cdot 15 \cdot 60}$$

$$H_{CGPS} = -\Delta H_{total,per,mod}$$

$$H_{HGPS} = -\Delta H_{total,per,mod,HG}$$

$$H_{MPS} = -\Delta H_{total,per,mod,P}$$

$$H_{FMPS} = -\Delta H_{total,per,mod,FMPS}$$

$$m_{rdot,per,plate} = \frac{m_{rdot}}{35}$$

$$m_{rdotpertube} = \frac{m_{rdot,per,plate}}{30 \cdot 2}$$