Problema y sistema

Para su tratamiento en una planta, 20500 kg.hr-1 de una salmuera de NaCl al 15% debe ser calentada desde 10°C a 40°C por intercambio de calor con una corriente de agua, la que será enfriada desde los 80°C hasta 45°C. Dimensionar un STHE 1-2 (TEMA: arreglo triangular) Se dispone de tubos 6 m, 3/4" y 1" BWG 14, Acero SS (conductividad térmica: 16.27 W.m-1.°C-1), por los que circula la salmuera. Asumir: que los factores de ensuciamiento son de 0.0005 m2.°C.W-1 y 0.0001 m2.°C.W-1 para los fluidos que circulan por los tubos y el shell respectivamente; que el costo de un STHE cumple con la siguiente ecuación CSHTE=1000Areq0.8 *um* (*um:* unidad monetaria); un interés anual del 3%; que el costo de energía de bombeo es de 0.15 um.kWh-1; que la planta funciona 335 días al año. Puede despreciarse el efecto de la temperatura de pared. Dimensione comparativamente con los métodos de Kern y Delaware. Efectúe un análisis de sensibilidad al modificar el espaciado de los bafles, 0.2, 0.4, 0.6, 0.8 del diámetro de shell y corte de deflectores 0.15, 0.20, 0.25 y 0.30 del diámetro de shell.

DATOS

$Q_{ms} := 20500 \; \frac{kg}{hr}$ $\quad ws := 0.15$ $\quad Temp_{Cin} := 10$ $\quad Temp_{Cout} := 40$

Intercambiador de coraza y tubo 1:2 (1 paso por coraza, 2 por tubo)
Arreglo triangular
tubos BWG 14 ACERO SS (inoxidable)
Por tubos salmuera, coraza agua
fluido de servicio: agua
fluido de trabajo: salmuera

$Temp_{Hin} := 80$ $\quad Temp_{Hout} := 45$

$L_t := 6 \; m$ $\quad L_h := 2 \cdot L_t = 12 \; m$ $\quad \varepsilon := 2 \cdot 10^{-6} \; m$

tubo 1 $\quad D_{in1} := \frac{3}{4} \; in - 2 \cdot 2.11 \; mm = 0.584 \; in$ $\quad D_{o1} := \frac{3}{4} \; in = 0.75 \; in$

tubo 2 $\quad D_{o2} := 1 \; in = 0.025 \; m$ $\quad P_{T2} := 1.25 \cdot D_{o2} =$

$D_{in2} := 1 \; in - 2 \cdot 2.11 \; mm = 0.834 \; in$

$k_{ac} := 16.27 \; \frac{W}{m \cdot \Delta°C}$ $\quad R_{ad} := \left(0.0005 \; \frac{m^2 \cdot \Delta°C}{W} + 0.0001 \; \frac{m^2 \cdot \Delta°C}{W}\right.$

n° de pasos por tubos npi $\quad n_{pi} := 2$ $\quad n_{pe} := 1$

DESARROLLO

INCISO A método de Kern- dimensionamiento

ecuaciones

$$\delta_w(Temp) := \frac{999.83952 + 16.945176 \cdot (Temp) - 7.9870401 \cdot 10^{-3} \cdot (Temp)^2 - 46.170461 \cdot 10^{-6} \cdot (Temp)^3}{1 + 16.87950 \cdot 10^{-3} \cdot (Temp)}$$

$$B(Temp) := \frac{1.3272 \cdot (20 - Temp) - 0.001053 \cdot (Temp - 20)^2}{Temp + 105}$$

$$\mu_w(Temp) := 1.002 \cdot 10^{-3} \cdot 10^{B(Temp)} \cdot Pa \cdot s$$

$$C_1 := \frac{276370}{18.0153} = 1.534 \cdot 10^4 \qquad C_2 := \frac{-2090.1}{18.0153} = -116.018 \qquad C_3 := \frac{8.125}{18.0153} = 0.451$$

$$C_4 := \frac{-0.014116}{18.0153} = -7.836 \cdot 10^{-4} \qquad C_5 := \frac{9.3701 \cdot 10^{-6}}{18.0153} = 5.201 \cdot 10^{-7}$$

$$cP_w(Temp) := \left(C_1 + C_2 \cdot Temp + C_3 \cdot Temp^2 + C_4 \cdot Temp^3 + C_5 \cdot Temp^4\right) \frac{J}{kg \cdot \Delta°C}$$

$$C_1 := -0.432 \qquad C_2 := 0.0057255 \qquad C_3 := -0.000008078 \qquad C_4 := 1.861 \cdot 10^{-9} \qquad C_5 := 0$$

$$k_w(Temp) := \left(C_1 + C_2 \cdot Temp + C_3 \cdot Temp^2 + C_4 \cdot Temp^3 + C_5 \cdot Temp^4\right) \frac{W}{m \cdot \Delta°C}$$

$$C_0 := -0.003241 \qquad C_1 := 0.063635 \qquad C_2 := 1.013714 \qquad C_3 := 0.014595 \qquad C_4 := 3317.349$$

$$\delta_{ap}(ws, Temp) := \frac{\left(ws \cdot C_0 + C_1\right) \cdot e^{\left(1 \cdot 10^{-6} \cdot (Temp + C_4)^2\right)}}{\left(ws + C_2 + Temp \cdot C_3\right)} \cdot \left(\frac{kg}{m^3}\right)$$

$$\delta_{sol}(ws, \delta_{ap}, Temp) := \left(\left(\frac{ws}{\delta_{ap}(ws, Temp)}\right) + \frac{(1 - ws)}{\delta_w(Temp)}\right)^{-1}$$

$$V_1 := 16.221789 \qquad V_2 := 1.322931 \qquad V_3 := 1.484860 \qquad V_4 := 0.007469 \qquad V_5 := 30.780201 \qquad V_6$$

$$\mu_{ap}(ws,Temp):=\frac{e^{\left(\frac{V_1\cdot ws^{V_2}+V_3}{Temp\cdot V_4+1}\right)}}{\left(V_5\cdot ws^{V_6}+1\right)}$$

$$\mu_{sol}(ws,Temp):=\mu_{ap}(ws,Temp)^{ws}\cdot\left(\mu_w(Temp)\cdot 1000\ \frac{m\cdot s}{kg}\right)^{(1-ws)}\cdot 10^{-3}\ \frac{kg}{m\cdot s}$$

$a_1:=-0.06936$ $a_2:=-0.07821$ $a_3:=3.847985$ $a_4:=-11.2762$ $a_5:=8.731877$ $a_6:=1.8124$

$$\alpha(ws,Temp):=a_2\cdot Temp+a_3\cdot e^{(0.01\cdot Temp)}+a_4\cdot ws$$

$$cPi(Temp,ws):=\left(a_1\cdot e^{(\alpha(ws,Temp))}+a_5\cdot ws^{a_6}\right)\ \frac{J}{kg\cdot\Delta°C}$$

$$cPsol(Temp,ws):=(1-ws)\cdot cP_w(Temp)+ws\cdot cPi(Temp,ws)$$

$$Mnacl:=\frac{58.44277}{1000}$$

$$b:=\left(Mnacl\cdot\left(\frac{1}{ws}-1\right)\right)^{-1}$$

$$ksal(Temp,b):=\left(\left(0.5621-0.01394\cdot b+0.00177\cdot b^2\right)+\left(0.00199-0.000294\cdot b-6.3\cdot 10^{-5}\cdot b^2\right)\cdot Tem\right.$$

Para el tubo 1

$D_{o1}=0.019\ m$ $D_{in1}=0.015\ m$ $P_{T1}=0.024\ m$

$$Temp_{proH}:=\frac{Temp_{Hin}+Temp_{Hout}}{2}=62.5 \qquad Temp_{proHk}:=Temp_{proH}+273.2=335.7$$

$$Temp_{proC}:=\frac{Temp_{Cin}+Temp_{Cout}}{2}=25 \qquad Temp_{proCk}:=Temp_{proC}+273.2=298.2$$

$$\delta_a:=\delta_w\left(Temp_{proH}\right)=981.905\ \frac{kg}{m^3} \qquad \delta_s:=\delta_{sol}\left(ws,\delta_{ap},Temp_{proC}\right)=\left(1.107\cdot 10^3\right)$$

$$\mu_a:=\mu_w\left(Temp_{proH}\right)=\left(4.495\cdot 10^{-4}\right)\ \frac{kg}{m\cdot s} \qquad \mu_s:=\mu_{sol}\left(ws,Temp_{proC}\right)=0.001201\ \frac{kg}{m\cdot s}$$

$$cP_a:=cP_w\left(Temp_{proHk}\right)=\left(4.182\cdot 10^3\right)\ \frac{m^2}{} \qquad cPsol(Temp,ws):=(1-ws)\cdot cP_w(Temp$$

$$s^2 \cdot K$$

$$cP_s := cPsol(Temp_{proC}, ws) = (3.557 \cdot 10^3)$$

$$k_a := k_w(Temp_{proHk}) = 0.65 \frac{kg \cdot m}{s^3 \cdot K}$$

$$k_s := ksal(Temp_{proC}, b) = 0.542 \frac{kg \cdot m}{s^3 \cdot K}$$

Como se está diseñando se va a elegir un coeficiente global de diseño de tabla y luego se va a verificarlo - En la tabla no hay un valor para los fluidos que tenemos, entonces se extrae un valor de un paper específico

$$U_{gdiseño} := (600) \cdot \frac{W}{m^2 \cdot \Delta°C} = 600 \frac{kg}{s^3 \cdot K}$$

$$q := (Q_{ms} \cdot cP_s \cdot (Temp_{Cout} - Temp_{Cin})) \cdot K$$

$$q = 607.612\ kW$$

Con el servicio y el U diseñado obtengo un área de diseño

Valores de prueba

$$Q_{ma} := 1 \frac{kg}{hr}$$

Solver Restricciones

$$q = (Q_{ma} \cdot cP_a \cdot (Temp_{Hin} - Temp_{Hout})) \cdot K$$

$$Q_{ma} := \text{find}(Q_{ma}) = (1.494 \cdot 10^4) \frac{kg}{hr}$$

$$LMTD_{ctc} := \left(\frac{(Temp_{Hout} - Temp_{Cin}) - (Temp_{Hin} - Temp_{Cout})}{\ln\left(\frac{(Temp_{Hout} - Temp_{Cin})}{(Temp_{Hin} - Temp_{Cout})}\right)} \right) \cdot \Delta°C = 37.444\ K$$

$$\Delta T_{max} := (Temp_{Hin} - Temp_{Cin}) \cdot K = 70\ K$$

$$P := \frac{(Temp_{Cout} - Temp_{Cin}) \cdot K}{\Delta T_{max}}$$

$$C_H := cP_a \cdot Q_{ma} = (1.736 \cdot 10^4) \frac{kg \cdot m^2}{}$$

$$s^3 \cdot K$$

$$C_C := cP_s \cdot Q_{ms} = \left(2.025 \cdot 10^4\right) \frac{kg \cdot m^2}{s^3 \cdot K}$$

$$R = \frac{C_C}{C_H} \qquad R := \frac{\left(Temp_{Hin} - Temp_{Hout}\right)}{\left(Temp_{Cout} - Temp_{Cin}\right)} = 1.167$$

$$S := \frac{\sqrt[2]{R^2 + 1}}{R - 1} = 9.22$$

$$W := \left(\frac{1 - P \cdot R}{1 - P}\right)^{\frac{1}{n_{ps}}} = 0.875$$

$$F_t := \frac{S \cdot \ln(W)}{\ln\left(\frac{1 + W - S + S \cdot W}{1 + W + S - S \cdot W}\right)} = 0.859$$

el valor es mayor a 0.75 así que es aceptable y no es necesario aumentar el número de pasos por coraza

$$A_{tdiseño} := \frac{q}{U_{gdiseño} \cdot LMTD_{ctc} \cdot F_t}$$

$$A_{tdiseño} = 31.473\ m^2$$

área que el equipo necesitaría

$$N_{t1} := \text{ceil}\left(\frac{A_{tdiseño}}{\pi \cdot D_{o1} \cdot L_t}\right) = 88 \qquad N_{t2} := \text{ceil}\left(\frac{A_{tdiseño}}{\pi \cdot D_{o2} \cdot L_t}\right) = 66$$

Con el número de tubos se puede obtener el D de coraza Ds quw también se pueden obtener de tabla

$$CTP := 0.9$$

$$CL := \frac{\sqrt[2]{3}}{2} = 0.866$$

donde CTP cobertura i empaqueta EL 90%

$$D_{s1diseño} := \frac{2 \cdot P_{T1}}{\pi} \cdot \sqrt[2]{\left(\frac{CL}{CTP}\right) \cdot \frac{A_{tdiseño}}{D_{o1} \cdot L_t}} \qquad D_{s2diseño} := \frac{2 \cdot P_{T2}}{\pi} \cdot \sqrt[2]{\left(\frac{CL}{CTP}\right) \cdot \frac{A_{tdiseño}}{D_{o2} \cdot L_t}}$$

$$D_{s1diseño} = 0.247\ m \qquad D_{s2diseño} = 0.285\ m$$

De tabla se puede obtener el diámetro de coraza según tema

$D_{s1dis} := 12\ in = 0.305\ m$ $D_{s2dis} := 13.25\ in = 0.337\ m$

$N_{t1} := 94$ $N_{t2} := 62$ escogidos de tabla, usando el criterio de elegir los más cercanos

Cálculo del área de empaquetamiento y del diámetro mínimo de la coraza

$$A_{tube}(P_T) := P_T^{\ 2} \cdot CL$$

$$A_{bundle}(N_t, D_o, P_T) := 2 \cdot \left(\frac{N_t \cdot A_{tube}(P_T)}{\pi}\right)^{0.5} \cdot D_o \cdot (n_{pi} - 1) + N_t \cdot A_{tube}(P_T)$$

$$D_{smin}(N_t, D_o, P_T) := 2 \cdot \left(\frac{A_{bundle}(N_t, D_o, P_T)}{\pi}\right)^{0.5} + 2 \cdot D_o$$

$A_{bundle1} := A_{bundle}(N_{t1}, D_{o1}, P_{T1}) = 0.051\ m^2$ $A_{bundle2} := A_{bundle}(N_{t2}, D_{o2}, P_{T2}) = 0.061\ m^2$

$D_{smin1} := D_{smin}(N_{t1}, D_{o1}, P_{T1}) = 11.511\ in$ $D_{smin2} := D_{smin}(N_{t2}, D_{o2}, P_{T2}) = 12.954\ in$

A partir de confirmar que el diámetro de coraza sea mayor que el diámetro mínimo necesario, y de tener el n° de tubos de tabla, se calcula el área disponible

$$A_{dispo}(N_t, D_o) := \pi \cdot D_o \cdot L_t \cdot N_t$$

$A_{disp1} := A_{dispo}(N_{t1}, D_{o1}) = 33.754\ m^2$ $A_{disp2} := A_{dispo}(N_{t2}, D_{o2}) = 29.684\ m^2$

Se proponen los diferentes espaciados y cortes y se verifica

$B_1 := 0.2$

$c(P_T, D_o) :=$

$A_s(P_T, D_o,$

$G_s(Q_m, P_T$

$D_{eq\Delta}(P_T, L$

$$A_{tp}(D_{in}, N_t) := \frac{\pi \cdot D_{in}^{\ 2}}{4} \cdot N_t$$

$$G_i(D_{in}, N_t, Q_m) := \frac{Q_m \cdot 4 \cdot n_{pi}}{\pi \cdot D_{in}^{\ 2} \cdot N_t}$$

$$Rey_i(D_{in}, N_t, Q_m, \mu) := \frac{D_{in} \cdot G_i(D_{in}, N_t, Q_m)}{\mu}$$

$$Pr(\mu, k, cP) := \frac{cP \cdot \mu}{}$$

$$k$$

$$f\left(D_{in},N_t,Q_m,\mu\right):=\left(1.821\cdot\log\left(Rey_i\left(D_{in},N_t,Q_m,\mu\right)-1.64\right)\right)^{-2}$$

$Rey_s\left(Q_m,\ldots\right.$

$$Nu\left(D_{in},N_t,Q_m,\mu,k,cP\right):=\left(\frac{\left(\frac{f\left(D_{in},N_t,Q_m,\mu\right)}{8}\right)\cdot\left(Rey_i\left(D_{in},N_t,Q_m,\mu\right)-1000\right)\cdot Pr\left(\mu,k,cP\right)}{1+12.7\cdot\left(\frac{f\left(D_{in},N_t,Q_m,\mu\right)}{8}\right)^{\frac{1}{2}}\cdot\left(Pr\left(\mu,k,cP\right)^{\frac{2}{3}}-1\right)}\right)$$

$$f_{Di}\left(D_{in},N_t,Q_m,\mu\right):=\frac{1}{\left(-2\cdot\log\left(\frac{\frac{\varepsilon}{D_{in}}}{3.7065}-\frac{5.0452}{Rey_i\left(D_{in},N_t,Q_m,\mu\right)}\cdot\log\left(\frac{1}{2.8257}\cdot\left(\frac{\varepsilon}{D_{in}}\right)^{1.1098}+\frac{5.8\ldots}{Rey_i\left(D_{in},N\ldots\right.}\right.\right.\right.}$$

$$\Delta P_i\left(D_{in},N_t,Q_m,\mu,\delta\right)=f_{Di}\left(D_{in},N_t,Q_m,\mu\right)\cdot n_{pi}\cdot\frac{L_t}{D_{in}}\cdot\frac{G_i\left(D_{in},N_t,Q_m\right)^2}{2\cdot\delta}\cdot\left(\frac{\mu}{\mu_{wall}}\right)^{-\gamma}$$

$$\Delta P_r\left(D_{in},N_t,Q_m\right)=4\cdot n_{pi}\cdot\frac{G_i\left(D_{in},N_t,Q_m\right)^2}{2\cdot\delta}$$

$$\Delta P_{Ti}\left(D_{in},N_t,Q_m,\mu,\delta\right):=\frac{G_i\left(D_{in},N_t,Q_m\right)^2}{2\cdot\delta}\cdot\left(f_{Di}\left(D_{in},N_t,Q_m,\mu\right)\cdot n_{pi}\cdot\frac{L_t}{D_{in}}+4\cdot n_{pi}\right)$$

Cálculo de coeficientes peliculares para el tubo 1

$$Nu\left(D_{in1},N_{t1},Q_{ms},\mu_s,k_s,cP_s\right)=51.428$$

$Nu_s\left(Q_{ma},P_{T1},D\ldots\right.$

$$h_i\left(D_{in},N_t,Q_m,\mu,k,cP\right):=\frac{Nu\left(D_{in},N_t,Q_m,\mu,k,cP\right)\cdot k}{D_{in}}$$

$h_o\left(Q_m,P_T,D_o,\ldots\right.$

$$h_i\left(D_{in1},N_{t1},Q_{ms},\mu_s,k_s,cP_s\right)=\left(1.88\cdot10^3\right)\frac{kg}{s^3\cdot K}$$

$h_{o11}:=h_o\left(Q_{ma},P\ldots\right.$

$$h_{io}\left(D_{in},N_t,Q_m,\mu,k,cP,D_o\right):=h_i\left(D_{in},N_t,Q_m,\mu,k,cP\right)\cdot\frac{D_{in}}{D_o}$$

$h_{o12}:=h_o\left(Q_{ma},P\ldots\right.$

$$h_{io1}:=h_{io}\left(D_{in1},N_{t1},Q_{ms},\mu_s,k_s,cP_s,D_{o1}\right)=\left(1.464\cdot10^3\right)\frac{kg}{s^3\cdot K}$$

$h_{o13}:=h_o\left(Q_{ma},P_{T1},\ldots\right.$

$h_{o14} := h_o(Q_{ma}, P$

$$U_g(h_{io}, h_o, D_o, D_{in}) := \left(\frac{1}{h_{io}} + \frac{1}{h_o} + R_{ad} + \frac{D_o}{2 \cdot k_{ac}} \cdot \ln\left(\frac{D_o}{D_{in}}\right)\right)^{-1}$$

$U_{g11} := U_g(h_{io1}, h_{o11}, D_{o1}, D_{in1}) = 640.505 \ \frac{kg}{s^3 \cdot K}$

$U_{g13} := U_g(h_{io1}, h_{o13}, D_{o1}, D_{in1}) = 598.67 \ \frac{kg}{s^3 \cdot K}$

$U_{g12} := U_g(h_{io1}, h_{o12}, D_{o1}, D_{in1}) = 616.416 \ \frac{kg}{s^3 \cdot K}$

$U_{g14} := U_g(h_{io1}, h_{o14}, D_{o1}, D_{in1}) = 584.245 \ \frac{kg}{s^3 \cdot}$

$$A_{tdisp}(h_{io}, h_o, D_o, D_{in}) := \frac{q}{U_g(h_{io}, h_o, D_o, D_{in}) \cdot LMTD_{ctc} \cdot F_t}$$

En realidad es área necesaria o requerida, me olvidé cambiar el nombre cuando copié la ecuación

$A_{t11} := A_{tdisp}(h_{io1}, h_{o11}, D_{o1}, D_{in1}) = 29.483 \ m^2$

$A_{t13} := A_{tdisp}(h_{io1}, h_{o13}, D_{o1}, D_{in1}) = 31.543 \ m^2$

$A_{t12} := A_{tdisp}(h_{io1}, h_{o12}, D_{o1}, D_{in1}) = 30.635 \ m^2$

$A_{t14} := A_{tdisp}(h_{io1}, h_{o14}, D_{o1}, D_{in1}) = 32.322 \ m^2$

$\Delta P_{Ti1} := \Delta P_{Ti}(D_{in1}, N_{t1}, Q_{ms}, \mu_s, \delta_s) = 7.583 \ kPa$

$\Delta P_{s11} := \Delta P_s(Q_{ma}, P_{T1}, D$

$\Delta P_{s12} := \Delta P_s(Q_{ma}, P_{T1}, D$

$\Delta P_{s13} := \Delta P_s(Q_{ma}, P_{T1}, D$

$\Delta P_{s14} := \Delta P_s(Q_{ma}, P_{T1}, D$

Cálculo de coeficientes peliculares para el tubo 2

$Nu(D_{in2}, N_{t2}, Q_{ms}, \mu_s, k_s, cP_s) = 54.522$

$Nu_s(Q_{ma}, P_{T2}, D$

$$h_i(D_{in}, N_t, Q_m, \mu, k, cP) := \frac{Nu(D_{in}, N_t, Q_m, \mu, k, cP) \cdot k}{D_{in}}$$

$h_o(Q_m, P_T, D_o, D$

$h_i(D_{in2}, N_{t2}, Q_{ms}, \mu_s, k_s, cP_s) = (1.396 \cdot 10^3) \ \frac{kg}{}$

$h_{o21} := h_o(Q_{ma}, P$

$$h_{io}(D_{in}, N_t, Q_m, \mu, k, cP, D_o) := h_i(D_{in}, N_t, Q_m, \mu, k, cP) \cdot \frac{D_{in}}{D_o}$$

$h_{o22} := h_o(Q_{ma}, P$

$$h_{io2} := h_{io}(D_{in2}, N_{t2}, Q_{ms}, \mu_s, k_s, cP_s, D_{o2}) = (1.164 \cdot 10^3)\ \frac{kg}{s^3 \cdot K}$$

$h_{o23} := h_o(Q_{ma}, P_{T2},$

$h_{o24} := h_o(Q_{ma}, P$

$$U_g(h_{io}, h_o, D_o, D_{in}) := \left(\frac{1}{h_{io}} + \frac{1}{h_o} + R_{ad} + \frac{D_o}{2 \cdot k_{ac}} \cdot \ln\left(\frac{D_o}{D_{in}}\right)\right)^{-1}$$

$$U_{g21} := U_g(h_{io2}, h_{o21}, D_{o2}, D_{in2}) = 565.632\ \frac{kg}{s^3 \cdot K}$$

$$U_{g23} := U_g(h_{io2}, h_{o23}, D_{o2}, D_{in2}) = 524.545\ \frac{kg}{s^3 \cdot}$$

$$U_{g22} := U_g(h_{io2}, h_{o22}, D_{o2}, D_{in2}) = 541.895\ \frac{kg}{s^3 \cdot K}$$

$$U_{g24} := U_g(h_{io2}, h_{o24}, D_{o2}, D_{in2}) = 510.527\ \frac{kg}{s^3 \cdot}$$

$$A_{tdisp}(h_{io}, h_o, D_o, D_{in}) := \frac{q}{U_g(h_{io}, h_o, D_o, D_{in}) \cdot LMTD_{ctc} \cdot F_t}$$

$$A_{t21} := A_{tdisp}(h_{io2}, h_{o21}, D_{o2}, D_{in2}) = 33.386\ m^2$$

$$A_{t23} := A_{tdisp}(h_{io2}, h_{o23}, D_{o2}, D_{in2}) = 36.001\ m^2$$

$$A_{t22} := A_{tdisp}(h_{io2}, h_{o22}, D_{o2}, D_{in2}) = 34.848\ m^2$$

$$A_{t24} := A_{tdisp}(h_{io2}, h_{o23}, D_{o2}, D_{in2}) = 36.001\ m^2$$

$$\Delta P_{Ti2} := \Delta P_{Ti}(D_{in2}, N_{t2}, Q_{ms}, \mu_s, \delta_s) = 3.189\ kPa$$

$\Delta P_{s21} := \Delta P_s(Q_{ma}, P_{T2}, D$

$\Delta P_{s22} := \Delta P_s(Q_{ma}, P_{T2}, D$

$\Delta P_{s23} := \Delta P_s(Q_{ma}, P_{T2}, D$

$\Delta P_{s24} := \Delta P_s(Q_{ma}, P_{T2}, D$

INCISO b método Delaware- dimensionamiento

sólo delaware indica qu
corte y el espaciado de

$P_{Tef}(P_T) := P_T \cdot CL$ $\quad L_{c1} := 0.15 \quad L_{c2} := 0.20 \quad L_{c3} := 0.25 \quad L_{c4} := 0.30$

Number

$J_l := 0.75 \qquad J_b := 0.80 \qquad J_s := 0.925$

$a := 0.249 \qquad b := 2.207$

$$D_{bdl}\left(D_o, N_t\right) := D_o \cdot \left(\frac{N_t}{a}\right)^{\frac{1}{b}}$$

$$\phi\left(D_o, N_t, D_s, L_c\right) := \frac{\left(D_s - 2 \cdot L_c \cdot D_s\right)}{D_{bdl}\left(D_o, N_t\right)}$$

$$\theta\left(D_o, N_t, D_s, L_c\right) := 2 \cdot \text{acos}\left(\phi\left(D_o, N_t, D_s, L_c\right)\right)$$

$$F_c\left(D_o, N_t, D_s, L_c\right) := \frac{1}{\pi} \cdot \left(\pi + 2 \cdot \phi\left(D_o, N_t, D_s, L_c\right) \cdot \sin\left(\frac{\theta\left(D_o, N_t, D_s, L_c\right)}{2}\right) - \theta\left(D_o, N_t, D_s, L_c\right)\right)$$

$$J_c\left(D_o, N_t, D_s, L_c\right) := 0.55 + 0.72 \cdot F_c\left(D_o, N_t, D_s, L_c\right)$$

$$J_c\left(D_{o1}, N_{t1}, D_{s1dis}, L_{c1}\right) \cdot J_l \cdot J_b \cdot J_s = 0.651$$

$$A_{sD}\left(D_s, P_T, N_t, D_o, B\right) := B \cdot D_s \cdot \left(\left(D_s - D_{bdl}\left(D_o, N_t\right)\right) + \frac{\left(D_{bdl}\left(D_o, N_t\right) - D_o\right)}{P_{Tef}\left(P_T\right)} \cdot \left(P_T - D_o\right)\right)$$

$$G_{sD}\left(D_s, P_T, N_t, D_o, B\right) := \frac{Q_{ma}}{A_{sD}\left(D_s, P_T, N_t, D_o, B\right)}$$

$$Pr\left(\mu, k, cP\right) := \frac{cP \cdot \mu}{k}$$

$$Rey_s\left(D_o, D_s, P_T, N_t, \mu, B\right) := \frac{D_o \cdot G_{sD}\left(D_s, P_T, N_t, D_o, B\right)}{\mu}$$

Para el tubo 1

$$Rey_{11} := Rey_s\left(D_{o1}, D_{s1dis}, P_{T1}, N_{t1}, \mu_a, B_1\right) = 3.4 \cdot 10^4$$

$$Rey_{12} := Rey_s\left(D_{o1}, D_{s1dis}, P_{T1}, N_{t1}, \mu_a, B_2\right) = 1.7 \cdot 10^4$$

$$Rey_{13} := Rey_s\left(D_{o1}, D_{s1dis}, P_{T1}, N_{t1}, \mu_a, B_3\right) = 1.133 \cdot 10^4$$

$$Rey_{14} := Rey_s\left(D_{o1}, D_{s1dis}, P_{T1}, N_{t1}, \mu_a, B_4\right) = 8.499 \cdot 10^3$$

El Reynolds está entre 10 a la cuarta y al cubo, se escoge un layout angle de 30°: por lo que se escogen las constantes:

$a_1 := 0.321 \qquad a_2 := -0.388 \qquad a_3 := 1.450 \qquad a_4 := 0.519 \qquad b_1 := 0.486 \qquad b_2 := -0.152$

Triangula

Square pi

Pitch = 1.2

Compa

Cómputo de

$j_{id} = a_1$

Layout Angle

30°

45°

90°

$b_3 := 7 \qquad b_4 := 0.5$

$$a(D_o, D_s, P_T, N_t, \mu, B) := \frac{a_3}{1 + 0.14 \cdot Rey_s(D_o, D_s, P_T, N_t, \mu, B)^{a_4}}$$

$$j_{id}(D_o, D_s, P_T, N_t, \mu, B) := a_1 \cdot \left(\frac{1.33 \cdot D_o}{P_T}\right)^{a(D_o, D_s, P_T, N_t, \mu, B)} \cdot Rey_s(D_o, D_s, P_T, N_t, \mu, B)^{a_2}$$

$$h_{id}(D_s, P_T, N_t, \mu, k, cP, D_o, B) = j_{id}(D_o, D_s, P_T, N_t, \mu, B) \cdot cP \cdot G_{sD}(D_s, P_T, N_t, D_o, B) \cdot Pr(\mu, k, cP)^{\frac{-2}{3}}$$

$$h_{id}(D_s, P_T, N_t, \mu, k, cP, D_o, B) := j_{id}(D_o, D_s, P_T, N_t, \mu, B) \cdot cP \cdot G_{sD}(D_s, P_T, N_t, D_o, B) \cdot Pr(\mu, k, cP)^{\frac{-2}{3}}$$

$$h_s(D_s, P_T, N_t, \mu, k, cP, D_o, B, L_c) := h_{id}(D_s, P_T, N_t, \mu, k, cP, D_o, B) \cdot J_c(D_o, N_t, D_s, L_c) \cdot J_l \cdot J_b \cdot J_s$$

$$h_{s11} := h_s(D_{s1dis}, P_{T1}, N_{t1}, \mu_a, k_a, cP_a, D_{o1}, B_1, L_{c1}) = (6.044 \cdot 10^3)\ \frac{kg}{s^3 \cdot K}$$

$$h_{s13} := h_s(D_{s1dis}, P_{T1}, N_{t1},$$

$$h_{s12} := h_s(D_{s1dis}, P_{T1}, N_{t1}, \mu_a, k_a, cP_a, D_{o1}, B_2, L_{c2}) = (3.721 \cdot 10^3)\ \frac{kg}{s^3 \cdot K}$$

$$h_{s14} := h_s(D_{s1dis}, P_{T1}, N_{t1},$$

$$U_g(h_{io}, h_s, D_o, D_{in}) := \left(\frac{1}{h_{io}} + \frac{1}{h_s} + R_{ad} + \frac{D_o}{2 \cdot k_{ac}} \cdot \ln\left(\frac{D_o}{D_{in}}\right)\right)^{-1}$$

$$U_{g11} := U_g(h_{io1}, h_{s11}, D_{o1}, D_{in1}) = 626.86\ \frac{kg}{s^3 \cdot K}$$

$$U_{g13} := U_g(h_{io1}, h_{s13}, D_{o1}, D_{in1}) = 555.327\ \frac{kg}{s^3 \cdot}$$

$$U_{g12} := U_g(h_{io1}, h_{s12}, D_{o1}, D_{in1}) = 588.752\ \frac{kg}{s^3 \cdot K}$$

$$U_{g14} := U_g(h_{io1}, h_{s14}, D_{o1}, D_{in1}) = 522.776\ \frac{kg}{s^3 \cdot}$$

$$A_{tdisp}(h_{io}, h_s, D_o, D_{in}) := \frac{q}{U_g(h_{io}, h_s, D_o, D_{in}) \cdot LMTD_{ctc} \cdot F_t}$$

$$A_{t11} := A_{tdisp}(h_{io1}, h_{s11}, D_{o1}, D_{in1}) = 30.125\ m^2$$

$$A_{t13} := A_{tdisp}(h_{io1}, h_{s13}, D_{o1}, D_{in1}) = 34.005\ m^2$$

$A_{t12} := A_{tdisp}\left(h_{io1}, h_{s12}, D_{o1}, D_{in1}\right) = 32.075\ m^2$

$A_{t14} := A_{tdisp}\left(h_{io1}, h_{s14}, D_{o1}, D_{in1}\right) = 36.123\ m^2$

$\Delta P_{Ti1} := \Delta P_{Ti}\left(D_{in1}, N_{t1}, Q_{ms}, \mu_s, \delta_s\right) = 7.583\ kPa$

Caída de presión en la coraza

$L_{c1} := 0.15 \qquad L_{c2} := 0.20 \qquad L_{c3} := 0.25 \qquad L_{c4} := 0.30$

$$\phi\left(D_o, N_t, D_s, L_c\right) := \frac{\left(D_s - 2 \cdot L_c \cdot D_s\right)}{D_{bdl}\left(D_o, N_t\right)}$$

$$\theta\left(D_o, N_t, D_s, L_c\right) := 2 \cdot \text{acos}\left(\phi\left(D_o, N_t, D_s, L_c\right)\right)$$

$$F_{tw}\left(D_o, N_t, D_s, L_c\right) := \frac{\theta\left(D_o, N_t, D_s, L_c\right) - \sin\left(\theta\left(D_o, N_t, D_s, L_c\right)\right)}{2 \cdot \pi}$$

$$N_{tw}\left(D_o, N_t, D_s, L_c\right) := F_{tw}\left(D_o, N_t, D_s, L_c\right) \cdot N_t$$

$$A_{wt}\left(D_o, N_t, D_s, L_c\right) := N_{tw}\left(D_o, N_t, D_s, L_c\right) \cdot \frac{\pi \cdot D_o^2}{4}$$

$$A_{wg}\left(D_o, N_t, D_s, L_c\right) := \frac{\pi \cdot D_s^2}{8} \cdot \theta\left(D_o, N_t, D_s, L_c\right) - \sin\left(\frac{\theta\left(D_o, N_t, D_s, L_c\right)}{2}\right) \cdot \left(\frac{D_s}{2}\right) \cdot \left(\frac{D_s}{2} - L_c \cdot D_s\right)$$

$$A_{win}\left(D_o, N_t, D_s, L_c\right) := A_{wg}\left(D_o, N_t, D_s, L_c\right) - A_{wt}\left(D_o, N_t, D_s, L_c\right)$$

$R_l := 0.45 \qquad R_b := 0.65$

Rl: corrección por fuga en deflector
Rb: correción por bypass

$$N_{cw}\left(P_T, D_s, L_c\right) := \frac{0.8 \cdot L_c \cdot D_s}{P_{Tef}\left(P_T\right)} \qquad N_B\left(B, D_s\right) := \frac{L_t}{B \cdot D_s} - 1$$

Ncw n° efect de tubos en ca
ventana

$$\Delta P_{wind}\left(D_s, P_T, N_t, D_o, B, L_c, Q_m, \delta\right) := n_{ps} \cdot \left(\frac{Q_m^{\ 2} \cdot \left(2 + 0.6 \cdot N_{cw}\left(P_T, D_s, L_c\right)\right)}{2 \cdot \delta \cdot A_{sD}\left(D_s, P_T, N_t, D_o, B\right) \cdot A_{win}\left(D_o, N_t, D_s, L_c\right)}\right) \cdot N_B\left(B\right.$$

$$b\left(D_o, D_s, P_T, N_t, \mu, B\right) := \frac{b_3}{1 + 0.14 \cdot Rey_s\left(D_o, D_s, P_T, N_t, \mu, B\right)^{b_4}}$$

$$f_{id}(D_o, D_s, P_T, N_t, \mu, B) := b_1 \cdot \left(\frac{1.33 \cdot D_o}{P_T}\right)^{b(D_o, D_s, P_T, N_t, \mu, B)} \cdot Rey_s(D_o, D_s, P_T, N_t, \mu, B)^{b_2}$$

$$\Delta P_{bi} = n_{ps} \cdot 4 \cdot f_{id}(D_o, D_s, P_T, N_t, \mu, B) \cdot \frac{G_{sD}(D_s, P_T, N_t, D_o, B)^2}{2 \cdot \delta} \cdot \left(\frac{\mu}{\mu_{wall}}\right)^{-0.14}$$

$$\Delta P_{bi}(D_o, D_s, P_T, N_t, \mu, B, \delta) := n_{ps} \cdot 4 \cdot f_{id}(D_o, D_s, P_T, N_t, \mu, B) \cdot \frac{G_{sD}(D_s, P_T, N_t, D_o, B)^2}{2 \cdot \delta}$$

$$\Delta P_{cf}(D_o, D_s, P_T, N_t, \mu, B, \delta) := \Delta P_{bi}(D_o, D_s, P_T, N_t, \mu, B, \delta) \cdot (N_B(B, D_s) - 1) \cdot R_l \cdot R_b$$

$$\Delta P_s(D_o, D_s, P_T, N_t, \mu, B, \delta, L_c, Q_m) := \Delta P_{cf}(D_o, D_s, P_T, N_t, \mu, B, \delta) + \Delta P_{wind}(D_s, P_T, N_t, D_o, B, L_c, Q_m$$

$$\Delta P_{s11} := \Delta P_s(D_{o1}, D_{s1dis}, P_{T1}, N_{t1}, \mu_a, B_1, \delta_a, L_{c1}, Q_{ma}) = 9.562\ kPa$$

$$\Delta P_{s12} := \Delta P_s(D_{o1}, D_{s1dis}, P_{T1}, N_{t1}, \mu_a, B_2, \delta_a, L_{c2}, Q_{ma}) = 1.794\ kPa$$

$$\Delta P_{s13} := \Delta P_s(D_{o1}, D_{s1dis}, P_{T1}, N_{t1}, \mu_a, B_3, \delta_a, L_{c3}, Q_{ma}) = 0.682\ kPa$$

$$\Delta P_{s14} := \Delta P_s(D_{o1}, D_{s1dis}, P_{T1}, N_{t1}, \mu_a, B_4, \delta_a, L_{c4}, Q_{ma}) = 0.345\ kPa$$

tubo 2

$$h_{s21} := h_s(D_{s2dis}, P_{T2}, N_{t2}, \mu_a, k_a, cP_a, D_{o2}, B_1, L_{c1}) = (4.819 \cdot 10^3)\ \frac{kg}{s^3 \cdot K} \qquad h_{s23} := h_s(D_{s2dis}, P_{T2}, N_{t2},$$

$$h_{s22} := h_s(D_{s2dis}, P_{T2}, N_{t2}, \mu_a, k_a, cP_a, D_{o2}, B_2, L_{c2}) = (2.967 \cdot 10^3)\ \frac{kg}{s^3 \cdot K} \qquad h_{s24} := h_s(D_{s2dis}, P_{T2}, N_{t2},$$

$$U_g(h_{io}, h_s, D_o, D_{in}) := \left(\frac{1}{h_{io}} + \frac{1}{h_s} + R_{ad} + \frac{D_o}{2 \cdot k_{ac}} \cdot \ln\left(\frac{D_o}{D_{in}}\right)\right)^{-1}$$

$$U_{g21} := U_g(h_{io2}, h_{s21}, D_{o2}, D_{in2}) = 552.929\ \frac{kg}{s^3 \cdot K} \qquad U_{g23} := U_g(h_{io2}, h_{s23}, D_{o2}, D_{in2}) = 483.959\ \frac{kg}{s^3 \cdot}$$

$U_{g22} := U_g(h_{io2}, h_{s22}, D_{o2}, D_{in2}) = 515.98\ \frac{kg}{s^3 \cdot K}$

$U_{g24} := U_g(h_{io2}, h_{s24}, D_{o2}, D_{in2}) = 453.117\ \frac{kg}{s^3 \cdot}$

$$A_{tdisp}(h_{io}, h_s, D_o, D_{in}) := \frac{q}{U_g(h_{io}, h_s, D_o, D_{in}) \cdot LMTD_{ctc} \cdot F_t}$$

$A_{t21} := A_{tdisp}(h_{io2}, h_{s21}, D_{o2}, D_{in2}) = 34.153\ m^2$

$A_{t23} := A_{tdisp}(h_{io2}, h_{s23}, D_{o2}, D_{in2}) = 39.02\ m^2$

$A_{t22} := A_{tdisp}(h_{io2}, h_{s22}, D_{o2}, D_{in2}) = 36.598\ m^2$

$A_{t24} := A_{tdisp}(h_{io2}, h_{s24}, D_{o2}, D_{in2}) = 41.676\ m^2$

$\Delta P_{Ti2} := \Delta P_{Ti}(D_{in2}, N_{t2}, Q_{ms}, \mu_s, \delta_s) = 3.189\ kPa$

$\Delta P_s(D_o, D_s, P_T, N_t, \mu, B, \delta, L_c, Q_m) := \Delta P_{cf}(D_o, D_s, P_T, N_t, \mu, B, \delta) + \Delta P_{wind}(D_s, P_T, N_t, D_o, B, L_c, Q$

$\Delta P_{s21} := \Delta P_s(D_{o2}, D_{s2dis}, P_{T2}, N_{t2}, \mu_a, B_1, \delta_a, L_{c1}, Q_{ma}) = 5.65\ kPa$

$\Delta P_{s22} := \Delta P_s(D_{o2}, D_{s2dis}, P_{T2}, N_{t2}, \mu_a, B_2, \delta_a, L_{c2}, Q_{ma}) = 1.042\ kPa$

$\Delta P_{s23} := \Delta P_s(D_{o2}, D_{s2dis}, P_{T2}, N_{t2}, \mu_a, B_3, \delta_a, L_{c3}, Q_{ma}) = 0.391\ kPa$

$\Delta P_{s22} := \Delta P_s(D_{o2}, D_{s2dis}, P_{T2}, N_{t2}, \mu_a, B_4, \delta_a, L_{c4}, Q_{ma}) = 0.196\ kPa$

$\Delta P_T(\Delta P_{Ti}, \Delta P_s) := \Delta P_{Ti} + \Delta P_s$

COSTO

$i := 0.03$ $\quad n := 10$

$$a := \left(\frac{i \cdot (1+i)^n}{(i+1)^n - 1}\right) \frac{1}{yr} = 0.117\ \frac{1}{yr}$$

Donde
i:interés
n: vida útil
a: amortización, en éste caso es a 10 años (vida útil)

Costo de la energía por bombeo

$$C_{ener} := \left(\frac{0.15}{1000 \cdot 3600}\right) \frac{¤}{J} = \left(4.167 \cdot 10^{-8}\right) \frac{¤}{J}$$

$$t := 335 \frac{day}{yr} \cdot 24 \frac{hr}{day} = \left(8.04 \cdot 10^{3}\right) \frac{hr}{yr}$$

cOSTO FIJO- COSTO DEL INTERCAMBIADOR (lo que se paga ahora)

$$C_{fijo}\left(A_t\right) := 1000 \cdot A_t \cdot 0.8 \frac{¤}{m^2}$$

donde At es el área requerida del intercambiador

Para el tubo 1

$$C_{fi11} := C_{fijo}\left(A_{t11}\right) = 24099.85 \text{ ¤} \qquad C_{fi12} := C_{fijo}\left(A_{t12}\right) = 25659.765 \text{ ¤}$$

$$C_{fi13} := C_{fijo}\left(A_{t13}\right) = 27204.211 \text{ ¤} \qquad C_{fi14} := C_{fijo}\left(A_{t14}\right) = 28898.108 \text{ ¤}$$

Para el tubo 2

$$C_{fi21} := C_{fijo}\left(A_{t21}\right) = 27322.206 \text{ ¤} \qquad C_{fi22} := C_{fijo}\left(A_{t22}\right) = 29278.727 \text{ ¤}$$

$$C_{fi23} := C_{fijo}\left(A_{t23}\right) = 31215.956 \text{ ¤} \qquad C_{fi24} := C_{fijo}\left(A_{t24}\right) = 33340.714 \text{ ¤}$$

Costo amortizado, lo que voy a pagar en 10 años

$$C_{amor}\left(C_{fi}\right) := C_{fi} \cdot a$$

Para el tubo 1

$$C_{am11} := C_{amor}\left(C_{fi11}\right) = 2825.238 \frac{¤}{yr} \qquad C_{am13} := C_{amor}\left(C_{fi13}\right) = 3189.163 \frac{¤}{yr}$$

$$C_{am12} := C_{amor}\left(C_{fi12}\right) = 3008.107 \frac{¤}{yr} \qquad C_{am14} := C_{amor}\left(C_{fi14}\right) = 3387.74 \frac{¤}{yr}$$

Para el tubo 2

$$C_{am21} := C_{amor}\left(C_{fi21}\right) = 3202.996 \frac{¤}{yr} \qquad C_{am23} := C_{amor}\left(C_{fi23}\right) = 3659.462 \frac{¤}{yr}$$

$$C_{am22} := C_{amor}\left(C_{fi22}\right) = 3432.36 \frac{¤}{yr} \qquad C_{am24} := C_{amor}\left(C_{fi24}\right) = 3908.549 \frac{¤}{yr}$$

Costo de la potencia para el bombeo

$$Pot\left(\Delta P_s, \Delta P_{Ti}\right) := \Delta P_s \cdot \frac{Q_{ma}}{\delta_a \cdot 0.8} + \Delta P_{Ti} \cdot \frac{Q_{ms}}{\delta_s \cdot 0.8}$$

Cada término corresponde a la potencia de una bomba diferente porque son fluidos diferentes

$$C_{bomb}\left(\Delta P_s, \Delta P_{Ti}\right) := C_{ener} \cdot Pot\left(\Delta P_s, \Delta P_{Ti}\right)$$

$$C_{bomb11} := C_{bomb}\left(\Delta P_{s11}, \Delta P_{Ti1}\right) = 130.579\ \frac{¤}{yr}$$

$$C_{bomb12} := C_{bomb}\left(\Delta P_{s12}, \Delta P_{Ti1}\right) = 76.596\ \frac{¤}{yr}$$

$$C_{bomb13} := C_{bomb}\left(\Delta P_{s13}, \Delta P_{Ti1}\right) = 68.871\ \frac{¤}{yr}$$

$$C_{bomb14} := C_{bomb}\left(\Delta P_{s14}, \Delta P_{Ti1}\right) = 66.531\ \frac{¤}{yr}$$

$$C_{bomb21} := C_{bomb}\left(\Delta P_{s21}, \Delta P_{Ti2}\right) = 66.227\ \frac{¤}{yr}$$

$$C_{bomb22} := C_{bomb}\left(\Delta P_{s22}, \Delta P_{Ti2}\right) = 28.329\ \frac{¤}{yr}$$

$$C_{bomb23} := C_{bomb}\left(\Delta P_{s23}, \Delta P_{Ti2}\right) = 29.686\ \frac{¤}{yr}$$

$$C_{bomb24} := C_{bomb}\left(\Delta P_{s24}, \Delta P_{Ti2}\right) = 50.93\ \frac{¤}{yr}$$

Costo total

$$C_T\left(C_{bomb}, C_{am}\right) := C_{bomb} + C_{am}$$

$$C_{T11} := C_T\left(C_{bomb11}, C_{am11}\right) = 2955.817\ \frac{¤}{yr}$$

$$C_{T12} := C_T\left(C_{bomb12}, C_{am12}\right) = 3084.703\ \frac{¤}{yr}$$

$$C_{T13} := C_T\left(C_{bomb13}, C_{am13}\right) = 3258.035\ \frac{¤}{yr}$$

$$C_{T14} := C_T\left(C_{bomb14}, C_{am14}\right) = 3454.27\ \frac{¤}{yr}$$

$$C_{T21} := C_T\left(C_{bomb21}, C_{am21}\right) = 3269.223\ \frac{¤}{yr}$$

$$C_{T22} := C_T\left(C_{bomb22}, C_{am22}\right) = 3460.689\ \frac{¤}{yr}$$

$$C_{T23} := C_T\left(C_{bomb23}, C_{am23}\right) = 3689.149\ \frac{¤}{yr}$$

$$C_{T24} := C_T\left(C_{bomb24}, C_{am24}\right) = 3959.479\ \frac{¤}{yr}$$

$$B_{t1} := \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{bmatrix} \cdot D_{s1dis} \qquad B_{t2} := \begin{bmatrix} B_1 \\ B_2 \\ B_3 \\ B_4 \end{bmatrix} \cdot D_{s2dis} \qquad L_{ct1} := \begin{bmatrix} L_{c1} \\ L_{c2} \\ L_{c3} \\ L_{c4} \end{bmatrix} \cdot D_{s1dis} \qquad L_{ct2} := \begin{bmatrix} L_{c1} \\ L_{c2} \\ L_{c3} \\ L_{c4} \end{bmatrix} \cdot D_{s2dis}$$

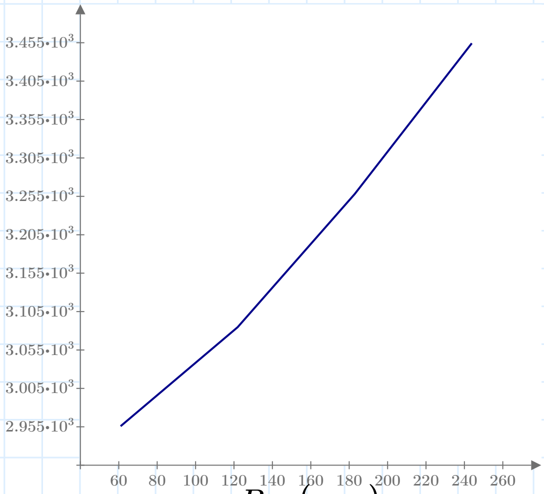
$$C_{T1} := \begin{bmatrix} C_{T11} \\ C_{T12} \\ C_{T13} \\ C_{T14} \end{bmatrix} \qquad C_{T2} := \begin{bmatrix} C_{T21} \\ C_{T22} \\ C_{T23} \\ C_{T24} \end{bmatrix}$$

$$A_{t11} := A_{tdisp}\left(h_{io1}, h_{s11}, D_{o1}, D_{in1}\right) = 30.125\ m^2$$

$$A_{t12} := A_{tdisp}\left(h_{io1}, h_{s12}, D_{o1}, D_{in1}\right) = 32.075\ m^2$$

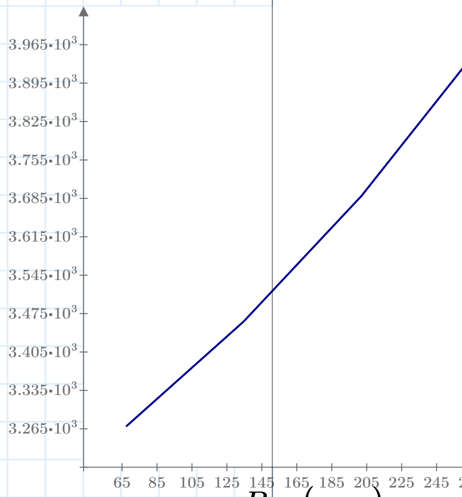
$$A_{t21} := A_{tdisp}\left(h_{io2}, h_{s21}, D_{o2}, D_{in2}\right) = 34.153\ m^2$$

$$A_{t22} := A_{tdisp}\left(h_{io2}, h_{s22}, D_{o2}, D_{in2}\right) = 36.598\ m^2$$

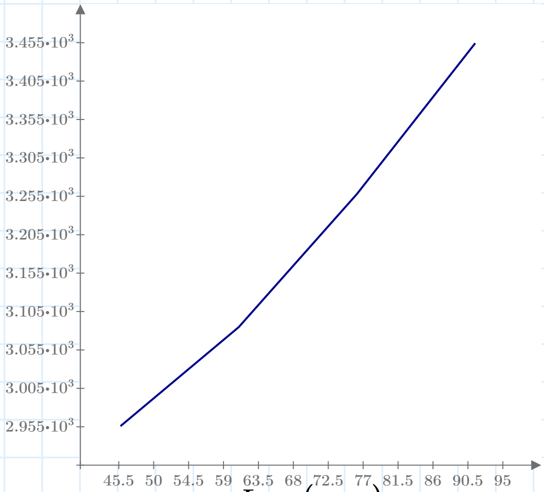


$C_{T1}\ \left(\frac{¤}{yr}\right)$

$B_{t1}\ (mm)$

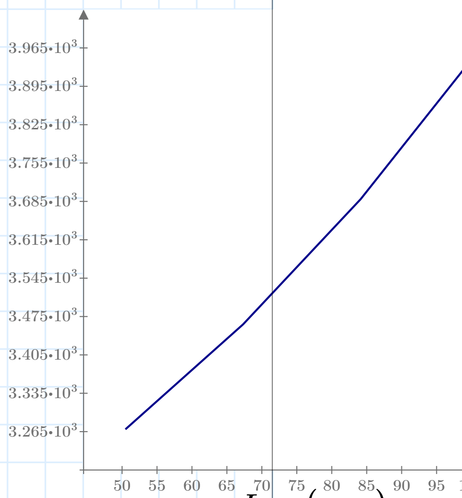


$B_{t2}\ (mm)$



$C_{T1}\ \left(\frac{¤}{yr}\right)$

$L_{ct1}\ (mm)$



$L_{ct2}\ (mm)$

VIDA ÚTIL

Cálculo de coeficiente global disponible

$$U_{disp1} := \frac{q}{A_{disp1} \cdot F_t \cdot LMTD_{ctc}} = 559.463\ \frac{kg}{s^3 \cdot K}$$

$$U_{disp2} := \frac{q}{A_{disp2} \cdot F_t \cdot LMTD_{ctc}} = 636.163\ \frac{kg}{s^3 \cdot K}$$

Cálculo de Rd disponible o calculado

$$R_{d1}\left(U_g\right) := \left(\frac{1}{U_{disp1}} - \frac{1}{U_g}\right)$$

$$R_{d11} := R_{d1}\left(U_{g11}\right) = \left(1.922 \cdot 10^{-4}\right)\ \frac{s^3 \cdot K}{kg} \qquad R_{d12} := R_{d1}\left(U_{g12}\right) = \left(8.892 \cdot 10^{-5}\right)\ \frac{s^3 \cdot K}{kg}$$

$$R_{d13} := R_{d1}\left(U_{g13}\right) = -1.331 \cdot 10^{-5}\ \frac{s^3 \cdot K}{kg} \qquad R_{d14} := R_{d1}\left(U_{g14}\right) = -1.254 \cdot 10^{-4}\ \frac{s^3 \cdot K}{kg}$$

$$R_{dT1} := \left(0.0005\ \frac{m^2 \cdot \Delta°C}{W} \cdot \frac{D_{o1}}{D_{in1}} + 0.0001\ \frac{m^2 \cdot \Delta°C}{W}\right) = \left(7.423 \cdot 10^{-4}\right)\ \frac{s^3 \cdot K}{kg}$$

Cálculo de la vida Útil

$$VU_1\left(R_{d1}\right) := \frac{R_{d1}}{R_{dT1}} \cdot 12$$

$$VU_1\left(R_{d11}\right) = 3.107 \qquad VU_1\left(R_{d12}\right) = 1.438$$

$$VU_1\left(R_{d13}\right) = -0.215 \qquad VU_1\left(R_{d14}\right) = -2.028$$

Que la vida útil de negativa, es indicativo de que el coeficiente global requerido es mayor al disponible, por lo que el área requerida es mayor a la disponible
Con respecto a la vida útil, el intercambiador que habría que elegir es el de At12 porque su vida útil sobrepasa a 1 año de uso, luego de eso hay que limpiarlo, pero no está muy sobredimensionado como el de At11

$R_{d2}($

$R_{d21}:$

$R_{d23}:$

$R_{dT2} := ($

$VU_2\left(R_{d2}\right):$

$VU_2\left(R_{d21}\right)$

$VU_2\left(R_{d23}\right)$