ภาคผนวก ง.

โปรแกรม Engineering Equation Solver (EES) สำหรับการออกแบบขนาดอุปกรณ์แลกเปลี่ยนความร้อนที่เหมาะสมในการเพิ่มสมรรถนะระบบการทำความเย็นแบบอัดไอ

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"The Engineering Equation Solver (EES) program calculates the length of a counter-flow liquid-suction heat exchanger in vapor-compression refrigeration system "

{SI Unit System , Pressure(MPa), Temperture(C), Mass(kg)}

" Analysis COP and superheat ratio value in Normal refrigeration system"

"input" "Pressure & Temperature of R22 @ states in vapor-compression refrigeration system"

$IfNot DiagramWindow

P_1 = 0.49[MPa]   {P_1,Pressure of R22 ,Superheat vapor enter to the Compressor }

T_1 = 7.6 [C]   {T_1Temperature of R22 ,Superheat vapor enters the Compressor }

P_2 = 1.93[MPa]   {P_2,Pressure of R22 ,Superheat vapor leaves the Compressor}

T_2 = 95.4[C]   {T_2, Temperature of R22 ,Superheat vapor leaves the Compressor}

P_3 = 1.92 [MPa]   {P_3,Pressure of R22 , Subcool Liquid leaves the Condenser}

T_3 = 46.4[C]   {T_3,Pressure of R22 , Subcool Liquid leaves the Condenser}

"Q_evap_n = 12,000 [BTU/h]"

fluid$ = 'R22'

m_dot = 0.022[kg/s]   {mass flow rate of R22 in system}

$Endif

{Vapor-Compression Refrigeration Cycle Analysis}

"Specific Enthalpy in Property for states of R22"

h_1 = Enthalpy(fluid$,T=T_1,P=P_1)

h_2 = Enthalpy(fluid$,T=T_2, P=P_2)

h_3 = Enthalpy(fluid$,T=T_3,P=P_3)

h_3 = h_4   "energy balance on throttle - isenthalpic"

h_g_n = Enthalpy(fluid$,x=1,P=P_1)   { Saturated vapor Enthalpy in state 1}

vs_n = Volume(fluid$,T=T_1,P=P_1)

"Isentropic Efficiency (eta_isen)"

s_1 = Entropy(fluid$,T=T_1, P=P_1)

s_2 = Entropy(fluid$,T=T_2, P=P_2)

s_1 = s_2_isen

h_2_isen = Enthalpy(fluid$,P=P_2, s=s_2_isen)

eta_isen = (h_2_isen - h_1)/(h_2-h_1)

DELTAs_n = (s_2-s_1)

superheat_n = h_1-h_g_n   { Superheat value in system superheat_inc_will not over 20 C}

"Condensed saturated Temp. @ condenser (T_C_n) "

T_C_n = Temperature(fluid$,P=P_3, x=0)

" Evaporated saturated Temp. @ Evaporator (T_E_n)"

T_E_n = Temperature(fluid$,P=P_1,x=1)

DELTATemp_Subcool_n   = T_C - T_3

DELTATemp_Superheat_n = T_1 - T_E

{input data}

$IfNot DiagramWindow

T_a_in = 28[C]   { T_a_in is air temp. into Fan Coil Unit}

$Endif

superheat_ratio_n = (T_1-T_E_n)/(T_a_in-T_E_n) { superheat_ratio design optimized at 0.65}

"refrigerant effect per mass unit"

{q_e = h_suc - h_4}

{mass flow rate in refrigeration system}

{Q_dot_evap_si = Q_evap*convert(BTU/h,kW)

m_dot = Q_dot_evap_si/q_e}

"Volume flow rate of refrigerant 22 in suction tube"

Vol_n = m_dot /vs_n

"the compressor power, in kW"

W_dot_comp_n = m_dot*(h_2-h_1)

"Thermal flow rate for condenser in kW"

Q_dot_cond_n   = m_dot*(h_2 - h_3)

"Thermal flow rate for evaporator in kW"

Q_dot_evap_n   = m_dot*(h_1-h_4)

" refrigerant effect , in BTU/h "

refrigerant_effect_n = Q_dot_evap_n*convert(kW,BTU/h)

" the refrigeration capacity, in tons "

capacity_n = Q_dot_evap_n*convert(kW,Ton)

"the coefficient of performance, COP"

COP_n = Q_dot_evap_n/W_dot_comp_n

"EER (energy efficiency ratio)"

EER_n =refrigerant_effect_n/(W_dot_comp_n*convert(kW,W))

"The length size design of the Liquid-Suction heat exchanger in the air conditions system"
{input data}
$IfNot DiagramWindow
d_o_in = 9.525[mm]; d_i_in = 7.75 [mm]   {Dimeter inner tube ,cold fluid R-22 is flow}
d_o_out = 15.88 [mm]; d_i_out = 13.84 [mm]   {Dimeter outer tube ,hot fluid R-22 is flow}
d_o_inner = d_o_in*convert(mm,m)
d_i_inner   = d_i_in *convert(mm,m)
d_o_outer   = d_o_out*convert(mm,m)
d_i_outer   = d_i_out *convert(mm,m)
k_copper = 382 [W/mC]   {k_copper is thermal conductivity of copper}
$Endif

{ Analysis hot fluid flow in a outer tube of heat exchanger}

"input"

$IfNot DiagramWindow

P_h_i = 1.92+ (T_subcool*0.001)

T_h_i = 46 [C]

T_subcool = 4 [C]

{P_h_i &T_h_i is Pressure &Temperature of R22 ,Subcool liquid phase leaves the condenser or enters the heat exchanger in outer tube}

$Endif

T_h_o = T_h_i - T_subcool

T_f_h   = (T_h_i + T_h_o)/2

{Property of R22 (Hot Fluid) in the outer tube of Heat Exchanger}

k_h_i   = Conductivity(Fluid$,T=T_f_h,P=P_h_i)

rho_h_i = Density(Fluid$,T=T_f_h,P=P_h_i)

{h_h_i = Enthalpy(Fluid$,T=T_f_h,P=P_h_i)}

mu_h_i = Viscosity(Fluid$,T=T_f_h,P=P_h_i)

cp_h_i = Cp(Fluid$,T=T_f_h,P=P_h_i)

"calculation Reynolds number ,Re_d_o "

d_h   = d_i_outer - d_o_inner   "d_h = Hydraulic Diameter(m)"

u_o   = (4*m_dot)/(rho_h_i*pi*(d_i_outer^2-d_o_inner^2))

{u_o is mean velocity of hot fluid flow R22 }

Re_d_o = (rho_h_i*u_o*d_h)/mu_h_i

"calculation Prandtl numbers "

Pr_o = cp_h_i*convert(kJ/kg-C,J/kg-C)*mu_h_i/k_h_i

{FUNCTION Nusselt number(Re_d ,Pr)}

"{condition}"

{IF Re> 4000   , 0.7 < Pr <160 , L/d_i_inner >60   THEN Turbulent flow }

"calculation Nusselt number (Turbulent flow) from Dittus-Boetler equation "

N_u_o = 0.023*(Re_d_o^0.8)*(Pr_o^0.3)   "Turbulent flow" { 0.3 is "cooling" }

{Heat Transfer Coefficient, h}

"Calculation Heat Transfer Coefficient of outer tube,h_o"

h_o = N_u_o*k_h_i/d_h   {[W/m^2C]}

{Analysis Cold fluid flow in a inner tube of heat exchanger}

"input"

$IfNot DiagramWindow

P_c_i   = 0.49+(T_subcool*0.005) { P_c_i is Pressure of R22 ,Superheat vapor leaves the evaporator or enters the heat exchanger }

T_c_i = (T_subcool*1.1)+T_1   { T_c_i is Temperature of R22 ,Superheat vapor leaves the evaporator or enters the heat exchanger }

$Endif

T_cs_o = (T_subcool*2) + T_c_i

T_f_c =(T_c_i+T_cs_o)/2 { film temperature}

{Property of R22 (Cold Fluid) in the Inner tube of Heat Exchanger }

k_c_i   = Conductivity(Fluid$,T=T_f_c,P=P_c_i)

rho_c_i = Density(Fluid$,T=T_f_c,P=P_c_i)

{h_c_i = Enthalpy(Fluid$,T=T_f_c,P=P_c_i)}

mu_c_i = Viscosity(Fluid$,T=T_f_c,P=P_c_i)

cp_c_i = Cp(Fluid$,T=T_f_c,P=P_c_i)   "Cp = specific heats"

"calculation Reynolds number ,Re_d_i "

u_i = (4*m_dot)/(rho_c_i *(pi*(d_i_inner^2))) {u_i is average velocity of Cold fluid flow R22 }

Re_d_i = (rho_c_i*u_i*d_i_inner)/mu_c_i

"calculation Prandtl numbers "

Pr_i   = cp_c_i*convert(kJ/kg-C,J/kg-C)*mu_c_i/k_c_i

"calculation Nusselt number "

N_u_i = 0.023*(Re_d_i^0.8)*(Pr_i^0.4)   "Turbulent flow" { 0.4 is "heating" }

"Calculation Heat Transfer Coefficient of inner tube, h_i"

h_i = N_u_i*k_c_i/d_i_inner   {[W/m^2C]}

{ calculation Overall Heat Transfer Coefficient ,U }

U = 1/ ((1/h_i)+(((1/(2*k_copper))*(d_i_inner)*ln(d_o_inner/d_i_inner)))

+(((d_i_inner/d_o_inner)*(1/h_o))))

"Analysis heat exchanger Design by NTU method"

C_dot_h = m_dot*cp_h_i   "hot R22 heat capacity rate[W/C]"

C_dot_c = m_dot*cp_c_i   "cold R22 heat capacity rate[W/C] "

"Energy balances on hot and cold of R22"

Q_dot_h   = C_dot_h*(T_h_i-T_h_o)

Q_dot_h   = Q_dot_hex

Q_dot_hex = Q_dot_c

T_c_o   = (Q_dot_c/C_dot_c) +T_c_i

"Definition of heat exchanger effectiveness"

Q_dot_max = (min(C_dot_h,C_dot_c))*(T_h_i-T_c_i)

Epsilon   = Q_dot_hex /Q_dot_max   {Epsilon is heat exchanger effectiveness}

C = (min(C_dot_h,C_dot_c))/(max(C_dot_h,C_dot_c))   {C is Capacity Ratio}

NTU   = (1/(C-1))*LN((Epsilon-1)/((Epsilon*C)-1))   {NTU=Number of heat transfer Unit}

A = ((NTU *(min(C_dot_h,C_dot_c))*convert(kW/C,W/C))/U)

" A is heat transfer surface area of tube"

L   = A/(pi*d_i_inner)   "the length of the tube in meter"

L_cm = L*convert(m,cm)   "the length of the tube in centimeter"

" CALCULATION COP & Superheat ratio after the installation of a liquid-suction heat exchanger into the refrigeration system"

{Caiculate P_h_o , P_c_o in refrigeration system}

"Pressure drop in Heat Exchanger (Delta_P)"

"major losses in inner tube"

$IfNot DiagramWindow

e = 0.0015[mm]   "e = epsilon is roughness height on the inside wall of the pipe"

$Endif

rough_i = e /(d_i_inner*convert(m,mm))   "Relative roughness"

f_i   = MoodyChart(Re_d_i,rough_i)   "calculation friction factor on MoodyChart"

" and/or calculation friction factor from Colebrook equation "

{f_i   = 1.325/(LN((rough_i/3.7)+(5.74/Re_d_i ^0.9))^2)}

DELTAP_i = ((f_i*L*rho_c_i*u_i^2)/(2*d_i_inner))*convert(Pa,MPa)   {MPa}

Power_i   = (m_dot*DELTAP_i / rho_c_i)*convert(MPa,Pa)   {W}

"major losses in outer tube"

rough_o   = e /(d_h*convert(m,mm))   "Relative roughness"

f_o   = MoodyChart(Re_d_o,rough_o)

{f_o   = 1.325/(LN((rough_o/3.7)+(5.74/Re_d_i ^0.9))^2)}

DELTAP_o_maj = (rho_h_i*u_o^2)/2*(((f_o*L)/d_h)+1)*convert(Pa,MPa)

"minor losses in outer tube"

$IfNot DiagramWindow

K=0.9*4   {K is loss coefficient}

$Endif

DELTAP_o_min   = (K*rho_h_i*u_o^2/2)*convert(Pa,MPa)

DELTAP_o   = DELTAP_o_maj + DELTAP_o_min

Power_o   = m_dot*DELTAP_o / rho_h_i*convert(MPa,Pa)   {W}

P_c_o =P_c_i - DELTAP_i

P_h_o =P_h_i - DELTAP_o

"Q_superheat =Q_subcool "

Q_subcool   = m_dot*cp_h_i*(T_h_i-T_h_o)

Q_superheat = m_dot*cp_c_i*(T_c_o-T_c_i)

"Condensed saturated Temp. @ condenser"

T_C = Temperature(fluid$,P=P_h_o,x=0)

DELTATemp_Subcool = T_C-T_h_o

"Evaporated saturated Temp. @ Evaporator"

T_E = Temperature(fluid$,P=P_c_o,x=1)

DELTATemp_Superheat = T_c_o -T_E   " DELTATemp superheat is Not over 20 C "

superheat_ratio = (T_c_o-T_E)/(T_a_in-T_E){ superheat_ratio design 0.5-0.7(optimized at 0.65)}

"Calculated R22 Temp. , Pressure and Enthalpy of Discharge tube compressor "

P_d   = P_h_i+(T_subcool*0.0025)   "Pressure R22 of Discharge tube compressor from experiment "

s_suc   = Entropy(fluid$,T=T_c_o,P=P_c_o)

s_dis   = (s_suc+(DELTAs_n))

vs   = Volume(fluid$,T=T_c_o,P=P_c_o)

T_d   = Temperature(fluid$,P=P_d,s=s_dis)

h_dis   = Enthalpy(fluid$,T=T_d, P=P_d)

"Property of R22 @ states in vapor-compression refrigeration system"

h_suc = Enthalpy(fluid$,T=T_c_o,P=P_c_o)

h_h_i = Enthalpy(fluid$,T=T_h_i,P=P_h_i)

h_h_o = Enthalpy(fluid$,T=T_h_o,P=P_h_o)

h_c_i = Enthalpy(fluid$,T=T_c_i,P=P_c_i)

h_th   = h_h_o   "energy balance on throttle - isentropic"

h_g   = Enthalpy(fluid$,x=1,P=P_c_o)

DELTAs = s_dis - s_suc

Superheat   = h_suc-h_g

superheat_inc = superheat/(h_suc-h_th)*100

"the compressor power, Wcomp in kW"

W_dot_comp = m_dot*(h_dis-h_suc)

W_dot_comp_Transition = (W_dot_comp-W_dot_comp_n)/W_dot_comp_n *100

"Thermal flow rate for evaporator in kW"

Q_dot_evap   = m_dot*(h_c_i-h_th)

Q_dot_evap_inc = (Q_dot_evap - Q_dot_evap_n)/Q_dot_evap_n *100

"Thermal flow rate for condenser in kW"

Q_dot_cond   = Q_dot_evap+W_dot_comp

Q_dot_cond_inc = (Q_dot_cond -Q_dot_cond_n)/Q_dot_cond_n*100

" refrigerant effect , in BTU/h "

refrigerant_effect = Q_dot_evap*convert(kW,BTU/h)

" the refrigeration capacity, in tons "

capacity = Q_dot_evap*convert(kW,Ton)

"the coefficient of performance, COP"

COP   = Q_dot_evap/W_dot_comp

COP_inc = (COP-COP_n)/COP_n*100

"EER (energy efficiency ratio)"

EER   = refrigerant_effect/(W_dot_comp*convert(kW,W))

EER_inc =(EER-EER_n)/EER_n*100