In [26]:

```
import numpy as np
##Pipe Diamters for a double pipe heat exchange. Smaller pipe is locate
d inside of a larger pipe. Each pipe carries
##different fluids (fluid 1 and fluid 2). Fluid 1 and 2 are not pre-det
ermined to be in a designated pipe, and instead
##are determined using criteria found below.
#T1 is HOT fluid inlet
#T2 is HOT fluid outlet
#t1 is COLD fluid inlet
#t2 is COLD fluid outlet

L = 1 ## Length of Pipe in feet
numPipes= 18 ##number of pipes
IPOD = 0.0499 ## Inside Pipe, Outter Diameter (in ft)
IPID = 0.0417## Inside Pipe, Inner Diameter (in ft)
Flow_IPA = (np.pi*IPID**2)/(4)##Flow area of the Inner Pipe

#Inside pipe surface area of heat transfer
Ao = np.pi*IPOD*L*numPipes

OPOD = 0.1041666 ## Outside Pipe, Outter Diameter (in ft)
OPID = 0.08333 ## Outside Pipe, Inner Diameter (in ft)
Flow_OPA = (np.pi*(OPID**2-IPOD**2)/(4))

#Properties of liquid with the HIGHER mass flow rate (WATER)
densityw = 62.4 ## Density (lb/ft3)
vw = .000020919 ## Viscocity
cpw = 1.01 ## Specific heat
Prw = 7.02 ## Prandtl number
mfrw = 0.6955 ## Mass flow rate (in lbs) #Make sure this is the higher
mass flow rate of the 2 fluids
kw = .597
Tw = 70 ##Temp of water in farenheit
#Tw = 32 ##Temp of water in farenheit
Rdi = 0.0002 #fouling

#Properties of liquid with the LOWER mass flow rate (BEER WORT)
densityo = 62.4 ## Density (lb/ft3)
vo = .000020919 ## Viscocity
cpo = 1.01 ## Specific heat at __ 140 degrees celcius__ (use problem st
atement to determine temp and Cp)
Pro = 7.02 ## Prandtl number of the heavier density fluid at __ 140 deg
rees celcius __(use problem statement to determine temp and Pr)
mfro = 0.04349 ## Mass flow rate (in lbs)
ko = .597
To = 192 ##Temp of water in farenheit
Rdo = 0.0002 #fouling


#Properties of liquid with the LOWER mass flow rate (BEER WORT)
#densityo = 66.45 ## Density (lb/ft3)
#vo = .000021599 ## Viscocity
#cpo = 1.01 ## Specific heat at __ 140 degrees celcius__ (use problem s
tatement to determine temp and Cp)
```

```
#Pro = 5.26 ## Prandtl number of the heavier density fluid at __ 140 de
grees celcius __(use problem statement to determine temp and Pr)
#mfro = 0.07 ## Mass flow rate (in lbs)
#ko = .538
#To = 205 ##Temp of beer wort in farenheit
#Rdo = 0.0002 #fouling

#Ratio of specific heat for each fluid * the mass flow rate of each
R = ((mfrw*cpw)/(mfro*cpo))
```

In [27]:

```
if Tw < To:
    Cc = cpw*mfrw
else:
    Cc = cpo*mfro
```

In [28]:

```
if Flow_IPA > Flow_OPA: ## If the flow area of the inner pipe is less t
han the outter piper flow area
#Assign the properties of Water to fluid 1 in the outter pipe
    density1 = densityw
    v1 = vw
    cp1 = cpw
    Pr1 = Prw
    mfr1 = mfrw
    k1 = kw
    t1 = Tw
    Vel1 = ((mfrw)/(densityw*Flow_IPA)) ##Fluid 1 is in the outter pipe
#Assign the properties of Oil to fluid 2 in the inner pipe
    density2 = densityo
    v2 = vo
    cp2 = cpo
    Pr2 = Pro
    mfr2 = mfro
    k2 = ko
    T1 = To
    Vel2 = ((mfro)/(densityo*Flow_OPA)) ##Fluid 2 is in the inner pipe

else:
#Assign the properties of Beer Wort to fluid 1 in the outter pipe
    density1 = densityo
    v1 = vo
    cp1 = cpo
    Pr1 = Pro
    mfr1 = mfro
    k1 = ko
    T1 = To
    Cw = cpo*mfro
    Vel1 = ((mfro)/(densityo*Flow_IPA)) ##Fluid 1 is in the inner pipe
#Assign the properties of Water to fluid 2 in the outter pipe
    density2 = densityw
    v2 = vw
    cp2 = cpw
    Pr2 = Prw
    mfr2 = mfrw
    k2 = kw
    t1 = Tw
    Cc = cpw*mfrw
    Vel2 = ((mfrw)/(densityw*Flow_OPA)) ##Fluid 2 is in the outter pipe
```

In [29]:

```
Dh = (OPID - IPOD) ##Friction diameter
De = (OPID**2 - IPOD**2)/IPOD ##Equivalent
```

In [30]:

```
Re_ip = ((Vel1*IPID)/(v1))
if Re_ip>10000:
    ip="turbulent"
    Nu_ip=0.023*Re_ip**(4/5)*Pr1**0.3
    hi = (Nu_ip*k1)/(IPID)
    h1 = hi*(IPID/IPOD)
elif Re_ip<2100:
    ip="laminar"
    Nu_ip= 1.86*(((IPID*Re_ip*Pr1)/L)**(1/3))
    hi = (Nu_ip*k1)/(IPID)
    h1 = hi*(IPID/IPOD)
else:
    ip="transitional"
    Nu_ip=((0.023*Re_ip**(4/5)*Pr1**0.4)+(1.86*(((De*Re_ip*Pr1)**(1/
3)/(L)))))/2
    h1 = (((Nu_ip*k1)/(IPID))+((Nu_ip*k1)/(IPID)))/2

Re_op = ((Vel2*De)/(v2))
if Re_op>10000:
    op="turbulent"
    Nu_op=0.023*Re_op**(4/5)*Pr2**0.4
    h2=Nu_op*k2/(De)
elif Re_op<2100:
    op="laminar"
    Nu_op= 1.86*(((De*Re_op*Pr2)**(1/3)/(L)))
    h2=Nu_op*k2/(De)
else:
    op="transitional"
    Nu_op=((0.023*Re_op**(4/5)*Pr2**0.4)+(1.86*(((De*Re_op*Pr2)**(1/
3)/(L)))))/2
    h2= ((Nu_op*k2/(De))+((Nu_op*k2)/(IPOD)))/2
```

In [31]:

```
##Exchanger Coefficient
Uo = (1/((1/h1)+(1/h2)))+Rdi+Rdo

##Effectiveness
Ec = (np.exp(Uo*Ao*((R-1)/(Cc*3600))))

#Outlet temperatures
T2 = ((T1*(1-R))+(R*t1*(1-Ec)))/(1-(R*Ec))
t2 = t1 + (T1 - T2)/R
```

Reynold's and Friction Factor

```
In [32]: print(f"Reynold's Pipe          =    {Re_ip:.2f} and is {ip}")
         print(f"Reynold's Annulus       =    {Re_op:.2f} and is {op}")
         #print(f"Friction Factor Pipe     =    {f1:.4f}")
         print(f"Friction Factor Annulus =    {f2:.4f}")
```

```
Reynold's Pipe          =    1017.27 and is laminar
Reynold's Annulus       =    13595.06 and is turbulent
Friction Factor Annulus =    0.0150
```

Nusselt

```
In [33]: print(f"Pipe    =   {Nu_ip:.2f}")
         print(f"Annulus =   {Nu_op:.2f}")
```

```
Pipe    =   12.42
Annulus =   101.62
```

Convection Coefficient

```
In [34]: print(f"Pipe    =    {h1:.2f} btu/ft f")
         print(f"Annulus =    {h2:.2f} btu/ft f")
```

```
Pipe    =    148.60 btu/ft f
Annulus =    679.68 btu/ft f
```

Temperature Inlet / Outlet

```
In [35]: print(f"Inlet Pipe      = {T1:.2f} f")
         print(f"Inlet Annulus   =  {t1:.2f} f")
         print(f"Outlet Pipe     =  {T2:.2f} f")
         print(f"Outlet Annulus =  {t2:.2f} f")
```

```
Inlet Pipe      = 192.00 f
Inlet Annulus   =  70.00 f
Outlet Pipe     =  84.99 f
Outlet Annulus =  76.69 f
```

R, Cc, Uo, Ec

In [36]:
```
print(f"R      = {R:.4f}")
print(f"Cc     = {Cc:.4f}")
print(f"Uo     = {Uo:.4f}")
print(f"Ec     = {Ec:.4f}")
```

```
R      = 15.9922
Cc     = 0.7025
Uo     = 121.9415
Ec     = 7.6902
```

Annulus Hydraulic Diameter and Equivalent Diameter

In [37]:
```
print(f"Dh      = {Dh:.6f} ft ")
print(f"De      = {De:.6f} ft")
```

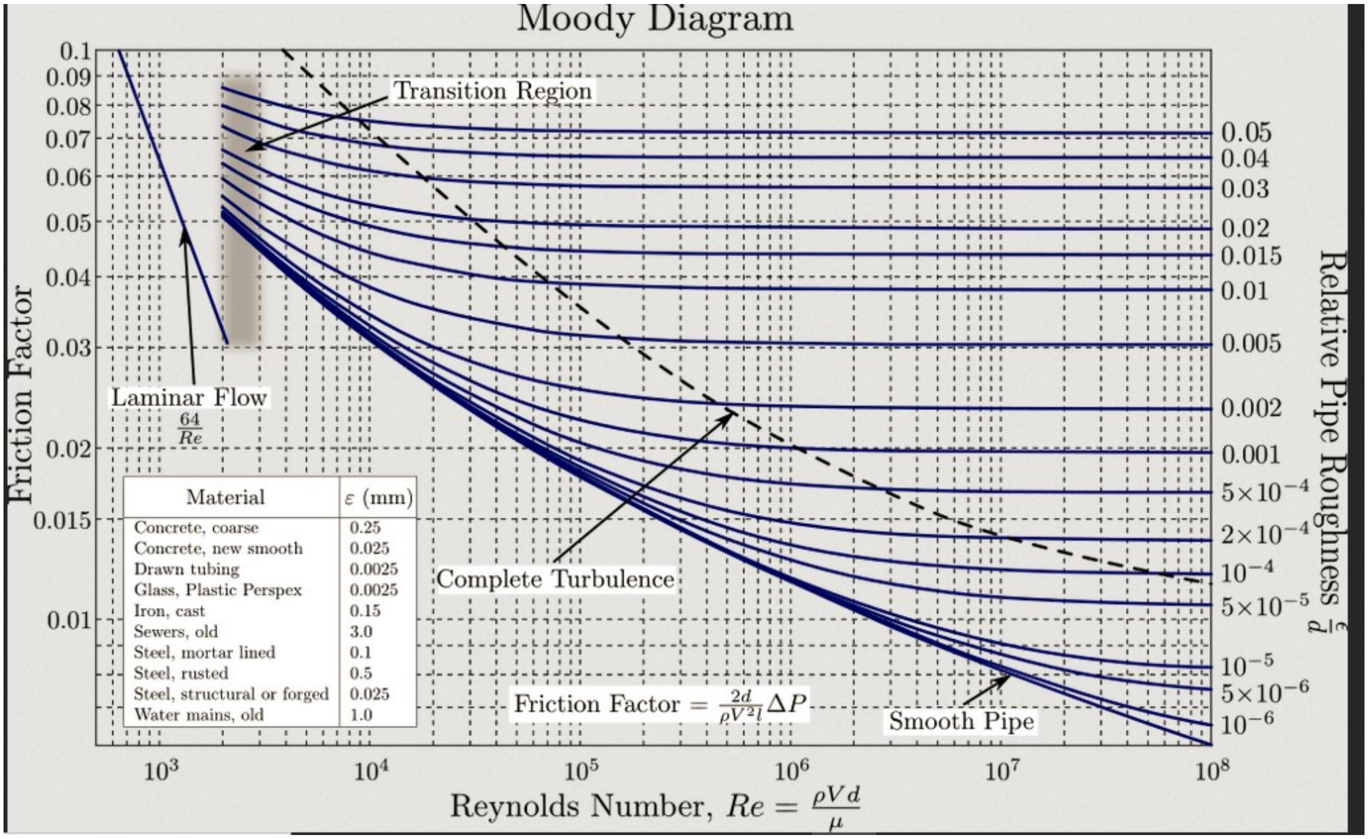
```
Dh      = 0.033430 ft
De      = 0.089256 ft
```

Fluid Velocity

In [38]:
```
print(f"Pipe Velocity        = {Vel1:.2f} ft/s")
print(f"Annulus Velocity     = {Vel2:.2f} ft/s")
```

```
Pipe Velocity        = 0.51 ft/s
Annulus Velocity     = 3.19 ft/s
```

Pressure Drop



Miscellaneous		
Brass, Copper, Glass, Lead, Plastic, Tin	0.000005	0.000 15
Galvanized	0.0002–0.0008	0.006–0.025

$$\Delta p_p = \frac{f_p L}{ID_p} \frac{\rho_p V_p^2}{2g_c}$$

$$\Delta p_a = \left(\frac{f_a L}{D_h} + 1\right) \frac{\rho_a V_a^2}{2g_c}$$

In [39]:
```
Roughness_p= 0.0000015/IPID #E from table
Roughness_a= 0.0000015/Dh #E from table
#friction factor from moody diagram
#print(Roughness_p,Roughness_a)
f1=64/Re_ip #laminar
f2=0.015 #from moody diagram

delP=((f1*L*numPipes)/(IPID))*((density1*(Vel1)**2)/(2*1000))
delA=(((f2*L*numPipes)/(Dh))+1)*((density2*(Vel2)**2)/(2*1000))
print(f"Pipe Pressure drop    = {delP:.4f}psi")
print(f"Annulus Presure drop = {delA:.4f}psi")
```

```
Pipe Pressure drop    = 0.2207psi
Annulus Presure drop = 2.8750psi
```

LMTD

$$Counterflow \qquad LMTD = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln\left[(T_1 - t_2)/(T_2 - t_1)\right]} =$$

In [24]:
```
LMTD = (((T1-t2)-(T2-t1))/(np.log((T1-t2)/(T2-t1))))
print(f"LMTD Temp = {LMTD:.2f}f")
```

```
LMTD Temp = 49.18f
```

Heat Transfer Rate

$$q = U_o A_o LMTD$$

In [25]:
```
q = Uo*Ao*LMTD
print(f"Heat Transfer rate = {q:.2f} BTUs")
```

```
Heat Transfer rate = 16920.77 BTUs
```

In [ ]:

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In [ ]: