**TITLE**

Concentric Tube Heat Exchanger

**INTRODUCTION**

A heat exchanger is a specialized device that assists in transfer of heat from one fluid to the other. In some cases, a solid wall may separate the fluids and prevent them from mixing. In other designs, the fluids may be in direct contact with each other. In the most efficient heat exchangers, the surface area of the wall between the fluids is maximized while simultaneously minimizing the fluid flow resistance. Fins or corrugations are sometimes used with the wall in order to increase the surface area and induce turbulence.

The types of heat exchangers to be tested in this experiment are called parallel-flow and counter-flow concentric tube heat exchangers. In a parallel-flow heat exchanger, the working fluid flow in the same direction as it is for counter-flow but, at opposite direction. The figure below briefly explains the fluid flowing path from both heat exchangers.



**Concentric Tube Heat Exchangers – Fluid Flow Direction**

There are some important variables or properties that influence the performance of a heat exchanger. Those variables include the physical properties, the mass flow rates, and the inlet temperature of the fluids, the physical properties of the heat exchanger materials, the configuration and area of the heat transfer surfaces, and the extent of scale or deposits on the heat transfer surfaces, and the ambient conditions.

Common appliances containing a heat exchanger include air conditioners, refrigerators, and space heaters. Heat exchangers are also used in chemical processing and power production. Perhaps the most commonly known heat exchanger is a car radiator, which cools the hot radiator fluid by taking advantage of airflow over the surface of the radiator.

**OBJECTIVE**

Demonstrate the effect of flow variation on the performance characteristics of a counter-flow concentric tube heat exchanger.

**THEORETICAL BACKGROUND**

There are several important formulas or equations to calculate the performance characteristics for both parallel-flow and counter flow concentric tube heat exchangers. The performance required are power emitted, power absorbed, power lost efficiency (*Ƞ*), logarithmic mean temperature difference ($∆T$*m*), and overall heat transfer coefficient (*U*).

The **Efficiency** for the **Cold Medium** is:

$$η\_{c}=\frac{T\_{c,out}-T\_{c,in}}{T\_{h,in}-T\_{c,in}}×100$$

The **Efficiency** for the **Hot Medium** is:

$$η\_{h}=\frac{T\_{h,in}-T\_{h,out}}{T\_{h,in}-T\_{c,in}}×100$$

The **Mean Temperature Efficiency** is:

$$η\_{mean}=\frac{η\_{c}+η\_{h}}{2}$$

The **Power Emitted** is given below (where $\dot{V}$**h** is the **Volumetric Flow Rate of the hot fluid**):

$$Power Emitted=\dot{V}\_{h}ρ\_{h}C\_{ph}(T\_{h,in}-T\_{h,out})$$

The **Power Absorbed** is given below (where $\dot{V}$**c** is the **Volumetric Flow Rate** **of the cold fluid**):

$$Power Absorbed=\dot{V}\_{c}ρ\_{c}C\_{pc}(T\_{c,out}-T\_{c,in})$$

The **Power Lost** is therefore:

$$Power Lost=Power Emitted-Power Absorbed$$

The **Overall Efficiency (**$η$**)** is:

$$η=\frac{Power Absorbed}{Power Emitted}×100$$

The **Logarithmic Mean Temperature Difference (**$∆T$**m)** is:

$$∆T\_{m}=\frac{∆T\_{1}-∆T\_{2}}{ln\left[\frac{∆T\_{1}}{∆T\_{2}}\right]}=\frac{\left(T\_{h,m}-T\_{c,out}\right)-(T\_{h,out}-T\_{c,in})}{ln\left[\frac{(T\_{h,in}-T\_{c,out})}{(T\_{h,out}-T\_{c,in})}\right]}$$

The **Overall Heat Transfer Coefficient (*U*)** is:

$$U=\frac{Power Absorbed}{A\_{s}∆T\_{m}}$$

Where the **Surface Area (*As*)** for this heat exchanger is **0.067 m2**

To obtain the value of **Density for both hot water and cold water (**$ρ$**h &** $ρ$**c)** and **Specific Heat of Hot Water (*Cph*),** the method of **interpolation** is required. As for the **Specific Heat of Cold Water (*Cpc*)**, the value is given in the **Property Tables**.

**EXPERIMENTAL PROCEDURE**

1. Configure the experiment for counter-flow heat exchanger operation. Set the required hot water inlet temperature to $T\_{h,in}$ **= 600C** with the decade switch. Set the cold water volumemtric flow rate ($\dot{V}$**c**) to run at a constant 2000 cm3/min.
2. Initially set the hot fluid volumetric flow rate ($\dot{V}$**h**) to 1000 cm3/min. Hold for a sufficient time of 5 minutes to stabilized the readings. Repeat this for volumetric flow rates of 2000, 3000, and 4000 cm3/min.
3. Look up for values for density ($ρ$**h &** $ρ$**c**) and constant pressure specific heat (***Cpc* & *Cph***) for the cold fluids at a temperature of $T\_{c,in}$and for the hot fluids at a temperature of $T\_{h,in}$.
4. Using this data, calculate the following heat exchanger performance factors:
5. Power Emitted
6. Power Absorbed
7. Power Lost
8. Efficiency
9. Logarithmic Mean Temperature
10. Overall Heat Transfer Coefficient

Record the results in the table.

**RESULT**

* Density of hot water,$ρ$h

$\frac{ρh-988}{975-988}$ = $\frac{60-50}{75-50}$

$\frac{ρh-988}{-13}$ = $\frac{10}{25}$

 $ρ$h = 982.8kg/m3

* Specific heat of hot water,Cph

$\frac{Cph-4.18}{4.19-4.18}$ = $\frac{60-50}{75-50}$

$\frac{Cph-4.18}{0.01}$ = $\frac{10}{25}$

 Cph = 4.184kJ/kg.K

* Density of cold water,$ρ$c

$\frac{ρc-997}{988-997}$ = $\frac{28-25}{50-25}$

$\frac{ρc-997}{-9}$ = $\frac{3}{25}$

 $ρ$c = 995.92kg/m3

* Specific heat of cold water,Cpc = 4.18kJ/kg.K because specific heat of temperature between 25°C-50°C is the same, 4.18kJ/kg.K. So, we don’t need to interpolate the value specific heat of cold water.
* Constant volumetric flow rate ($\dot{V}$c = 2000cm3/min)

$\dot{V}$h = $\frac{2000×1×10^{-6}}{60s}$

 = 3.333x10-5 m3/s

* The surface area(As) for this heat exchanger is given, 0.067m2.
1. **Counter flow**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| $\dot{V}$**h(cm3/min)** | **Th,in (°C)** | **Th,mid (°C)** | **Th,out (°C)** | **Tc,in (°C)** | **Tc,mid (°C)** | **Tc,out (°C)** |
| 1000 | 60 | 53 | 48 | 29.5 | 32 | 36.5 |
| 2000 | 60 | 56 | 51 | 29.5 | 34 | 39 |
| 3000 | 60 | 57 | 53 | 29.5 | 35 | 40.5 |
| 4000 | 60 | 58 | 54 | 29.5 | 35.5 | 41 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| $\dot{V}$**h****(cm3/min)** | **Power Emitted (W)** | **Power Absorbed (W)** | **Power Lost (W)** | **Efficiency (%)** | $∆$**T1 (°C)** | $∆$**T2 (°C)** | $∆T$**m (°C)** | **U (W/m2°C)** |
| 1000 | 821.62 | 971.257 | -149.63 | 118.21 | 23.5 | 18.5 | 20.9 | 693.61 |
| 2000 | 1232.31 | 1318.13 | -85.83 | 106.92 | 21 | 21.5 | 21.25 | 682.18 |
| 3000 | 1437.84 | 1526.26 | -88.43 | 106.15 | 19.5 | 23.5 | 21.44 | 1062.41 |
| 4000 | 1643.32 | 1595.64 | 47.69 | 97.1 | 19 | 24.5 | 21.63 | 1101.04 |

1. **Parallel flow**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| $\dot{V}$**h(cm3/min)** | **Th,in (°C)** | **Th,mid (°C)** | **Th,out (°C)** | **Tc,in (°C)** | **Tc,mid (°C)** | **Tc,out (°C)** |
| 1000 | 60 | 53 | 48 | 30.5 | 34 | 31 |
| 2000 | 60 | 54.5 | 51 | 30.5 | 35 | 38 |
| 3000 | 60 | 56 | 53 | 30.5 | 36 | 39 |
| 4000 | 60 | 56.5 | 54 | 30.5 | 36.5 | 40.5 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| $\dot{V}$**h** **(cm3/min)** | **Power Emitted (W)** | **Power Absorbed (W)** | **Power Lost (W)** | **Efficiency (%)** | $∆$**T1 (°C)** | $∆$**T2 (°C)** | $∆T$**m (°C)** | **U (W/m2°C)** |
| 1000 | 821.62 | 69.38 | 752.24 | 4.225 | 29 | 17.5 | 13.66 | 37.93 |
| 2000 | 1232.31 | 1040.63 | 191.68 | 84.45 | 22 | 20.5 | 21.24 | 731.25 |
| 3000 | 1437.84 | 1179.38 | 258.46 | 82.02 | 21 | 22.5 | 21.74 | 806.9 |
| 4000 | 1643.32 | 1387.51 | 255.81 | 84.43 | 19.5 | 23.5 | 21.43 | 966.36 |

**SAMPLE OF CALCULATION**

1. For counter flow ( $\dot{V}$h$ $= 1000cm3/min)

$\dot{V}$h = $\frac{1000×1×10^{-6}}{60s}$

 = 1.667x10-5 m3/s

Power Emitted = $\dot{V}$h$ρ$hCph (Th,in - Th,out)

 = 1.667x10-5 x 982.8 x 4.18k x (60-48)

 = 821.62 W

Power Absorbed = $\dot{V}$c$ρ$cCpc (Tc,out – Tc,in)

 = 3.333x10-5 x 995.92 x 4.18k x (36.5-29.5)

 = 971.257 W

Power lost = Power Emitted - Power Absorbed

 = 821.62 – 971.257

 = -149.636 W

Overall efficiency, Ƞ = $\frac{Power Absorbed}{Power Emitted} x 100\%$

 = $\frac{971.257}{821.62} x 100\%$

 = 118.21%

$∆$T1 = Th,in - Tc,out

 = 60 – 36.5

 = 23.5°C

$∆$T2 = Th,out - Tc,in

 = 48 – 29.5

 = 18.5°C

$∆T$m = $\frac{∆T1-∆T2}{ln\frac{ΔT1}{ΔT2}}$

 = $\frac{23.5-18.5}{ln\frac{23.5}{18.5}}$

 = 20.9°C

U = $\frac{Power Absorbed }{As∆Tm}$

 = $\frac{971.257}{0.067 x 20.9}$

 = 693.61 W/m2°C

1. For parallel flow ( $\dot{V}$h$ $= 1000cm3/min)

$\dot{V}$h = $\frac{1000×1×10^{-6}}{60s}$

 = 1.667x10-5 m3/s

Power Emitted = $\dot{V}$h$ρ$hCph (Th,in - Th,out)

 = 1.667x10-5 x 982.8 x 4.184k x (60-48))

 = 821.62 W

Power Absorbed = $\dot{V}$c$ρ$cCpc (Tc,out – Tc,in)

 = 3.333x10-5 x 995.92 x 4.18k x (31-30.5)

 = 69.38W

Power lost = Power Emitted - Power Absorbed

 = 821.62-69.38

 = 752.24W

Overall efficiency, Ƞ = $\frac{Power Absorbed}{Power Emitted} x 100\%$

 = $\frac{69.38}{821.62} x 100\%$

 = 8.44%

$∆$T1 = Th,in - Tc,out

 = 60 – 31

 = 29°C

$∆$T2 = Th,out - Tc,in

 = 48 – 30.5

 = 17.5°C

$∆T$m = $\frac{∆T1-∆T2}{ln\frac{ΔT1}{ΔT2}}$

 = $\frac{29-17.5}{ln\frac{29}{17.5}}$

 = 22.76°C

U = $\frac{Power Absorbed }{As∆Tm}$

 = $\frac{69.38}{0.067 x 22.67}$

 = 45.68 W/m2°C

**REFERENCES**

1. Thermodynamics, An Engineering Approach Sixth Edition (SI Units), Yunus A. Cengel & Michael A. Boles)
2. <http://www.engineersedge.com/heat_exchanger/heat_exchanger_application.htm>
3. <http://www.wisegeek.com/what-is-a-heat-exchanger.htm>
4. <http://www.fivesgroup.com/FivesCryogenie/EN/Expertise/Products/HeatExchangerApplications/Pages/Applicationsofheatexchangers.aspx>