HEAT TRANSFER PRACTICUM MODULE

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Conduction is the transfer of heat without being accompanied by the transfer of any part of the medium, where the heat energy is transferred from one molecule to another molecule of an object. For example, heat transfer through a piece of iron from one end to the other. The mechanism of conduction can be seen in the image below.

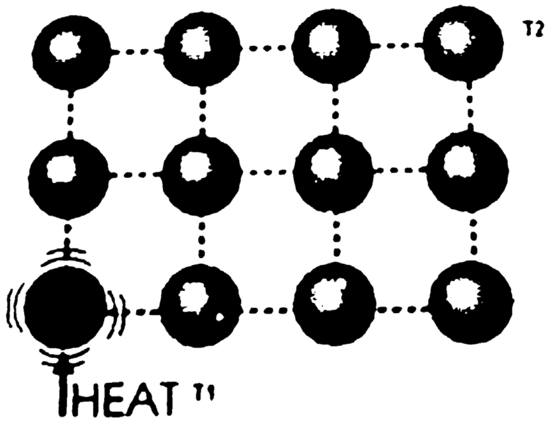


Figure 1. Molecular activity by conduction heat transfer

In the condition that the value of T1> T2, particles that close to T1 move randomly (rotate and vibrate) and collide with other particles so that energy transfer occurs, namely in the form of heat from T1 to T2. The amount of heat transfer rate can be expressed in terms of heat flux, q" (W/m^2), which is heat transfer per unit area that direction is perpendicular to the area and the magnitude is proportional to the temperature gradient. In general, the amount of the heat transfer value is:

$$q_n^{"} = -k\frac{dT}{dn} \tag{2.1}$$

In the x direction is

$$q_x^{"} = -k\frac{dT}{dx} \tag{2.2}$$

k is a property known as thermal conductivity ($\frac{W}{m.K}$). Assuming steady state conditions, the temperature distribution in conduction is linear. The temperature distribution can be expressed:

$$\frac{dT}{dx} = \frac{T_{2-T_1}}{L}$$

$$q^{"} = -k\frac{T_{2-T_1}}{L}$$

$$q^{"} = k\ \frac{T_{2-T_1}}{L} = k\ \frac{\Delta T}{L} \tag{2.3}$$

The conduction heat rate on a plane wall with area A is q = q". A (watt). The ability of a material to store heat energy is called volumetric heat capacity. Most solids and liquids are good heat energy storage media which have a comparative value of heat capacity($\rho.cp > 1\ {}^{MJ}/_{m^3.K}$), while gases are poor heat energy storage ($\rho.cp \approx 1\ {}^{MJ}/_{m^3.K}$). The ratio of thermal conductivity to heat capacity is called the thermal diffusivity,

$$\alpha = \frac{k}{\rho\ cp}\ [{}^{m^2}/_{s} \qquad (2.4)$$

Convection is a form of heat transfer in which the molecules of an object carry heat energy from one point to another.

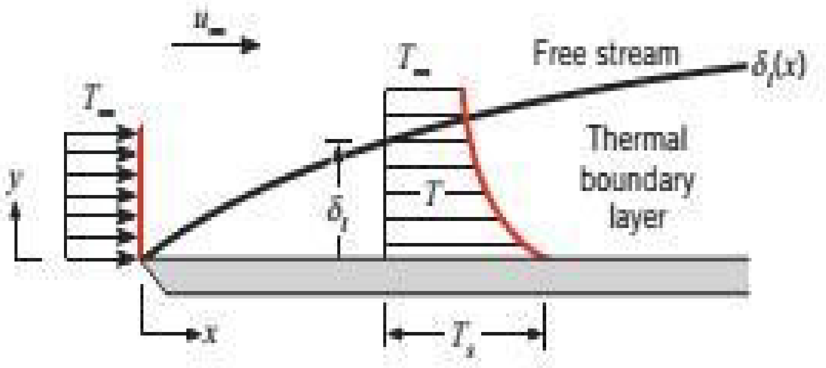


Figure 2. Thermal boundary layer on flat plate isotherms

Usually occurs in liquids and gases. Convection flow is influenced by several factors:

a. Horizontal and vertical flow
b. Laminar or turbulent flow
c. Flat or curved surface
d. The type of fluid, liquid or gas
e. Fluid properties such as viscosity, specific heat etc.

Convection heat transfer can be divided into two:

a. Force convection, namely heat transfer due to external work factors on intermediary fluids, for example convection with the help of fans, blowers, air conditioning and so on.
b. Free convection, namely heat transfer without any external factors but due to buoyancy force. In general, the amount of the convection heat transfer rate can be formulated:

$$q'' = h\ (T_\infty - T_s),\ T_s > T_\infty \qquad (2.1)$$

$$q'' = h\ (T_\infty - T_s),\ T_\infty > T_s \qquad (2.2)$$

Where h is the heat transfer coefficient by convection (W/m^2K), Ts is the surface temperature of the solid, and T∞ is the temperature of the fluid flowing around the solid wall. While q" is the convection heat flux (W/m^2).

Heat exchanger is a production support tool that functions to transfer heat energy from one fluid stream to another. There are many types and sizes of heat exchangers, depending on the needs specified by the user. One type of this equipment is the shell and tube type, in which a fluid flows inside the tube and another fluid flows through the sleeve across the outside of the tube. This cause heat transfer from the fluid flow with higher temperature to another fluid with lower temperature. To obtain greater heat transfer, baffles are installed inside the sleeve. The application of heat exchangers is often used in the industrial world such as chemical factories, power plants, natural gas processing, and others. Besides that, in the automotive world, heat exchangers are in the form of car radiators where the coolant transfers engine heat to the surrounding air.

CONDUCTION

CONDUCTION

Purposes

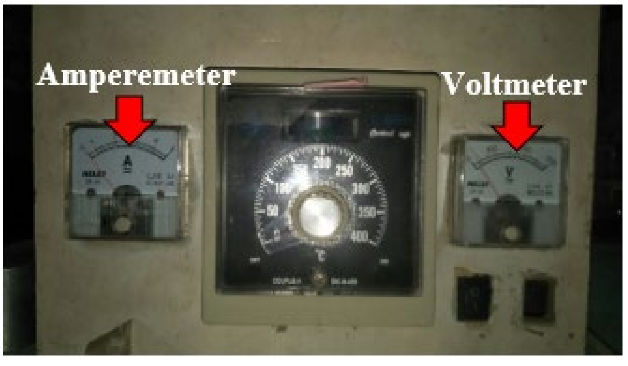
1. Increase understanding of the basic concept of heat transfer by conduction.
2. Be able to compare and estimate the conductivity and overall heat transfer coefficient values of a type of material through data processing.
3. Determine the effect of the heat transfer distance on the temperature distribution that occurs and also the effect of increasing the temperature of the specimen on the conductivity value.

Scope of The Problem

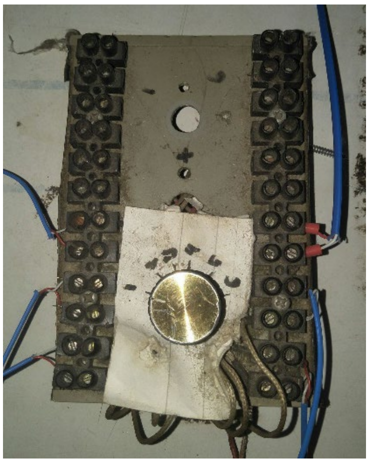
1. Steady state
   The properties of the specimen do not change with time.
2. No heat generation
   The test specimen has no generated energy because it is considered a pure metal in which there are no residual stresses in the working process.
3. No contact resistance
   The contact resistance between the two surfaces is neglected because the contact area between the specimen and the conducting metal is assumed to be even.
4. The heat source is assumed to be constant
   The heat generated by the current and voltage is set constant.
5. One dimensional conduction
   Conduction is assumed to be one-way only because the surroundings of the test object are isolated.

Equipment and Workpieces

1. Multimeter



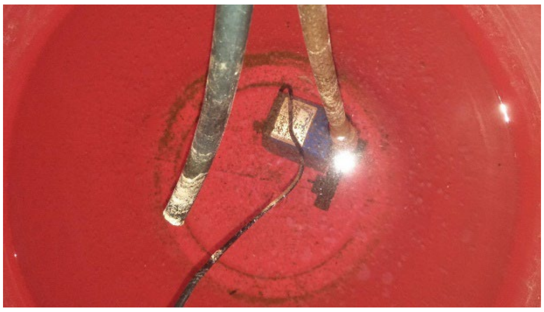
2. Thermocouple selector



3. Thermocouple (1,2,3,4,5, and 6)

4. Setpoint adjuster

5. Pump

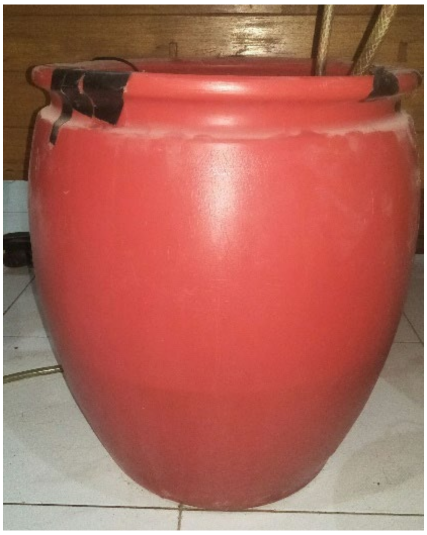


6. Thermocontrol reference

7. Heat element

8. Intermediate metal (1 and 2)

9. Water reservoir



10. Isolator

11. Thermocontrol

12. Specimen (iron, aluminium, stainless steel)

Practicum Installation

Equipment installation in this conduction practicum is as follows:

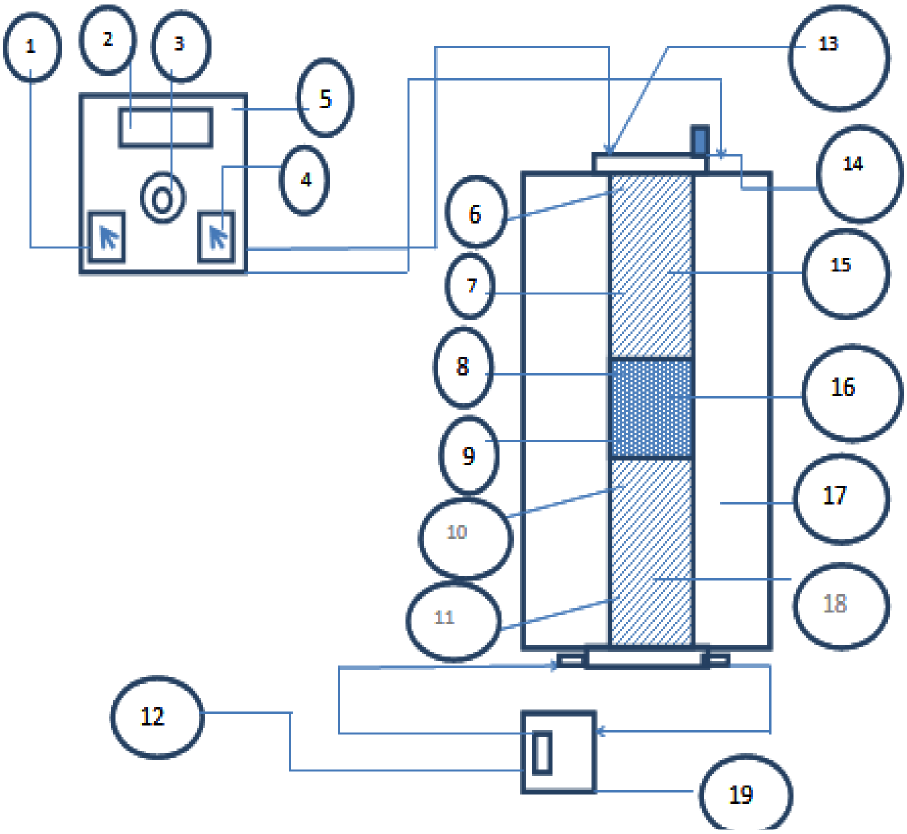


Figure 3. Conduction Equipment Installation

Description number:

1. Amperemeter
2. Thermocouple selector
3. Set point adjuster
4. Voltmeter
5. Thermocontrol
6. Thermocouple 1 (TC 1)
7. Thermocouple 2 (TC 2)
8. Thermocouple 3 (TC 3)
9. Thermocouple 4 (TC 4)
10. Thermocouple 5 (TC 5)
11. Thermocouple 6 (TC 6)
12. Pump
13. Thermocontrol reference
14. Heat element
15. Intermediate metal 1
16. Specimen

17. Isolator
18. Intermediate metal 2
19. Water reservoir

Practicum Procedure

1. Preparation Stage
    a. Gloves are always used as equipment and personal safety measures.
    b. The conduction test equipment system is ensured to have been installed properly and correctly in accordance with the conduction equipment installation scheme.
    c. The voltage regulator is ensured at a value of 0 volts, and the thermocontrol set point at 0 ^{o} C.
    d. The thermocouple is properly installed by checking the value shown on the digital thermocouple display. If the digital thermocouple does not display the relevant temperature value, the installation of the thermocouple on the specimen is checked, or the conducting cable between the thermocouple selector and the digital thermometer is adjusted.
    e. The thermocouple on the specimen in the conduction test equipment system is installed, the insulator is closed and sealed, then the heater with conducting metal is installed at the top of the conduction test equipment system and tightened.
    f. The reference thermocouple on the heater is installed.
    g. On the digital thermocouple, the temperature reading is rechecked. If the digital thermocouple does not display the relevant temperature value, repeat step (a).
2. Data Collection Stage
    a. Voltage regulator voltage at a value of 220 volts is regulated.
    b. The pump is ensured to circulate the cooling water properly.
    c. The thermocontrol is turned on by pressing the thermocontrol voltage switch to the ON position.
    d. The thermocontrol set point is set at 100 ^{o} C.
    e. Data is ready to be collected with a minimum waiting time of 10 minutes after the procedure (d). The data taken is contained in the conduction practicum data sheet. Retrieval of current data can be seen on the amperemeter, voltage data can be seen on the voltmeter, and temperature data for each point can be seen on the digital thermometer by setting the thermoselector set point.
    f. Data collection was carried out for each specimen with an increase in the thermocontrol set point of 25 ^{o} C until the thermocontrol set point reached a value of 150 ^{o} C. Minimum waiting time for data retrieval is 5 minutes for each increase in the thermocontrol set point value.
    g. After data collection is complete, the thermocontrol set point is set to 0 ^{o} C and the thermocontrol is turned off by pressing the thermocontrol voltage switch to the OFF position.
    h. The preparation procedure was carried out until data collection was carried out for each specimen, starting from stainless steel, iron, then aluminium, and with a

minimum cooling time of 5 minutes. Cooling of the test equipment system is carried out with cooling water still circulating. The specimen that have been collected is released.

i. After data collection was carried out for the last specimen, namely aluminium, the voltage regulator was turned off by adjusting the voltage to 0 volts. Then the supply cable for the pump is disconnected.
j. The conduction test equipment system is returned and tidied up to its original condition.

Keyword for Theoretical Foundations

1. Definition of Conduction
2. Heat Diffusion Equation for Cartesian Coordinates
3. Thermal Resistance on Plane Wall
4. Overall Heat Transfer Coefficient
5. Thermal Conductivity in Solids

Convection

Convection

Purposes

1. Increase understanding of the basic concept of heat transfer by convection.
2. Determine the effect of fluid velocity on the value of the convection coefficient.

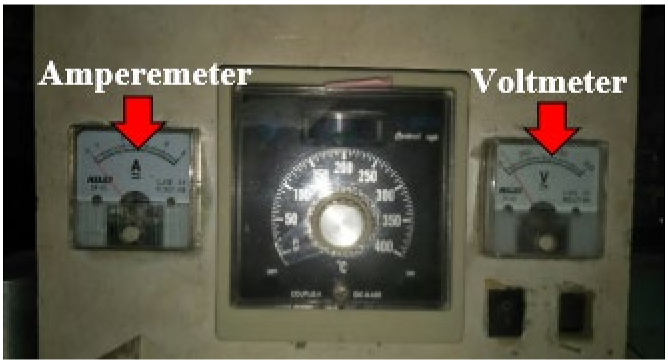
Scope of The Problem

1. Steady state
   a state in which the properties do not change with time.
2. No heat generation
   The test specimen has no generated energy because the specimen is considered a pure metal so no chemical reactions that produce energy occur.
3. Neglected radiation
   The radiation can be neglected because the difference between the surface temperature of the specimen and the environment is very small.
4. Heat Transfer is assumed to be constant
   The heater used is one and the voltage and current are set constant.

Equipment and Workpieces

1. Test object (conducting element and heater)


2. Multimeter



3. Voltage Regulator

4. Thermocontrol

5. Thermometer

6. Fan

7. Gloves

Practicum Installation

Convection practicum is carried out by heating through the heater to the conducting elements, then observing the influence of the surrounding air on the heat transfer process by convection, which is accompanied by an increase in air velocity with the fan. The convection equipment installation scheme can be seen in the image below:

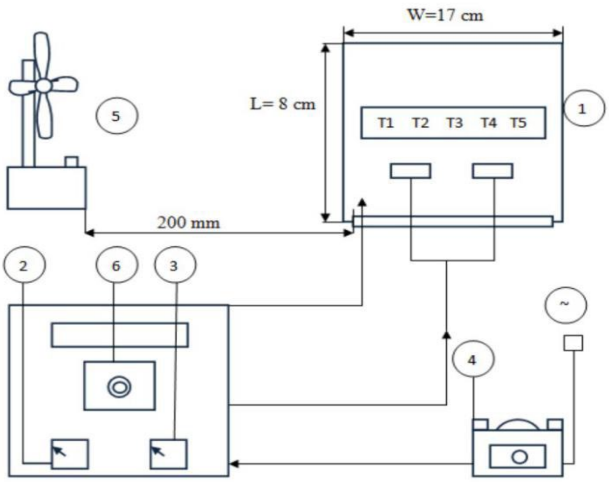


Figure 4. Convection Equipment Installation

Number description:

1. Test specimen
2. Amperemeter
3. Voltmeter
4. Voltage regulator
5. Fan
6. Thermocontrol

Practicum Procedure

1. Preparation Stage
   a. Always use gloves as equipment and personal safety measures.
   b. The convection test equipment system is ensured to have interacted properly and correctly according to the equipment scheme.
   c. The voltage regulator voltage is ensured at a value of 0.
   d. Thermocontrol set point is confirmed at a value of 0^{o} C.

e. The reference thermocouple is installed on the heater.

2. Data Collection Stage
   a. Voltage regulator is set at a value of 150 volts.
   b. The thermocontrol is turned on by holding the thermocontrol voltage switch in the ON position.
   c. The thermocontrol set point is set at 75^{o} C.
   d. The fan is started at speed level 1, with a minimum waiting time of 5 minutes after procedure (c).
   e. Data collection was carried out by varying the fan speed from level 1 to level 3. Waiting time for data retrieval is a minimum of 5 minutes for each fan speed level. Retrieval of current data can be seen on the voltmeter. Temperature data for each point can be known using an infrared thermometer.
   f. The data collection procedure step (e) is carried out with an increase in the voltage regulator voltage value of 25 volts until the voltage reaches a value of 200 volts.
   g. After all data collection is complete, set the thermocontrol set point to a value of 0^{o} C then turn off the thermocontrol by pressing the thermocontrol voltage switch to the OFF position.
   h. The convection test equipment system is returned and tidied up to its original condition.

Keyword For Theoretical Foundations

1. Definition of Convection
2. Thermal Resistance
3. Convection on Flat Plates in Parallel Flow
   a. Laminar flow over on isothermal plate
   b. Turbulent flow over on isothermal plate
   c. Mixed Boundary Layer Condition
   d. Unheated Starting Length
   e. Flat plate with constant heat flux condition
   f. Limitation on use convection coefficient

HEAT EXCHANGER

HEAT EXCHANGER

Purposes

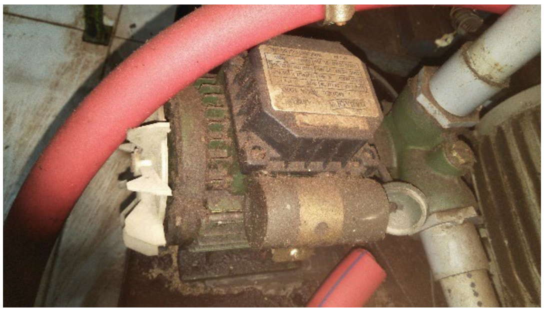
1. Understand the physical phenomenon of heat exchangers.
2. Understand the physical phenomenon of heat exchangers.

Scope of The Problem

1. Steady state
   The fluid properties at all points do not change with time.
2. Incompressible Flow
   Fluid with a density variation of less than 5% and a mach number of less than 0.3.
3. Fully Developed Flow
   A fluid flow that has stabilized direction and magnitude of velocity along the pipe is relatively the same for a distance y from the wall.
4. Radiasi is neglected
   Radiation heat transfer is neglected because the temperature difference is small and the magnitude of q radiation when compared to q convection between the two fluids is very small.
5. Changes in potential energy and kinetic energy are ignored
   The difference in potential and kinetic energy is neglected. This is because there is no difference in height between the inlet and outlet and because the surface area of the pipe (A) and the amount of discharge (Q) are constant, the velocity is also constant.
6. overall heat transfer coefficient is considered constant
   This is because the value of the pipe diameter is fixed so that the value of A (area) is fixed and the pipe material is uniform, so the value of thermal resistance does not change. So, the magnitude of overall heat transfer coefficient does not change.
7. Heat transfer occurs only between two fluids
   Heat transfer only occurs between the two fluids because the pipe walls are very thin.
8. No Fouling Factor
   The presence of fouling in the piping system is ignored because it can affect the heat transfer value.

Equipment and Workpieces

1. Fluid pump



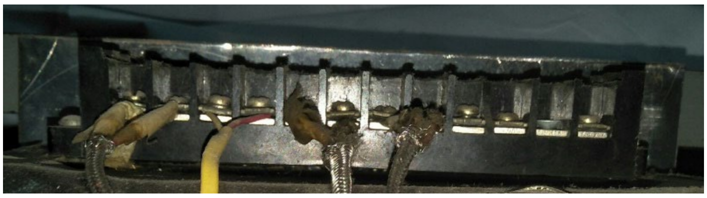
2. Motor

3. Heating element
4. Pressure gage

5. Flowmeter

6. Thermocontrol

7. Thermocouple



8. Digital thermometer

Practicum Instalation

Schematic installation of heat exchanger equipment can be seen in the image below:

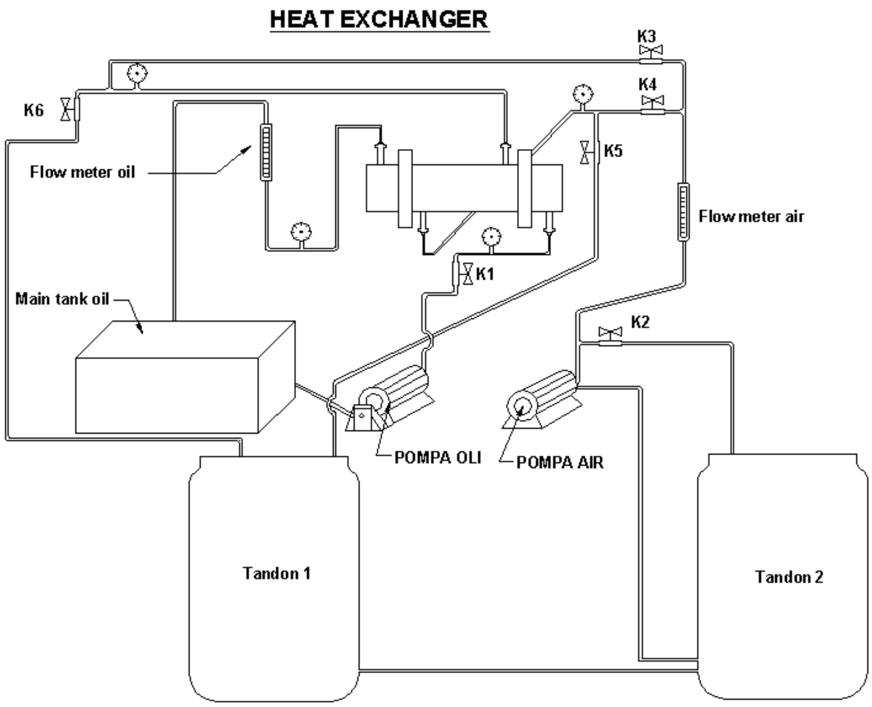


Figure 5. Heat Exchanger Installation Scheme

Practicum Procedure

1. Preparation Stage
   a. The installation switch is turned on so that the main panel shows the temperature on the thermocontrol.
   b. The cold fluid inlet valve is set to select parallel or counter flow type.
      - Paralel flow

Opening the K-4 valve; K-6, closing valve K-3; K-5

- Counter

  Opening the K-3 valve; K-5, closing valve K-4; K-6

c. Leakage in the cold fluid channel is checked by turning on the pump. The K-2 valve is ensured to be open. The discharge is regulated by setting the valve to maximum condition.
d. The cold fluid pump is turned off and if a leak still occurs it must be repaired and the procedure repeated.
e. Valve K-1 is confirmed to be open. Procedures c and d for the hot fluid are carried out with the tank pressure being maintained at ± 0.8 bar and control level height at ± 3/4.
f. If there is no leakage in both channels, the two pumps are started simultaneously.
g. The thermocontrol is set as desired, namely 60°C.
h. Data retrieval is ready to be done when it is stable.

2. Data Collection Stage
   a. The cold fluid flow rate is set, for the beginning it is 400 L/h with an increase of 50 L/h up to a discharge of 800 L/h.
   b. Data is ready to be taken with a time hold of 10 minutes after the procedure.
   c. The thermocouple control panel button is pressed according to the description on the selector, which are T_{in} Cold, T_{out} Cold, T_{in} Hot, T_{out} Hot.
   d. If necessary, the treatment of the hot fluid temperature is carried out according to the step b.
   e. When finished, turn off the thermocontrol setting, the cold and hot fluid pumps, the main switch is turned off, and the K-1 valve is opened.
   f. The heat exchanger equipment system is returned to its original condition.

Keyword for theoretical foundation

1. Type of Heat Exchanger
2. Shell and Tube Heat Exchanger
   a. Codification of Shell and Tube Heat Exchanger
   b. Types of Baffles
3. Type of Heat Exchanger
   a. Logarithmic Mean Temperature Difference (LMTD) Method
   b. Number of Transfer Unit (NTU) Method
   c. Pressure Drop