CHME 302 CHEMICAL ENGINEERING LABORATORY - I

EXPERIMENT 302-6

RADIATIVE HEAT TRANSFER

OBJECTIVE

Objective of the experiment is to investigate the radiation basic radiation laws by thermal and optical radiation examples. Topics to be investigated in this experiment are listed below:

- Stefan Boltzman's Law
- Lambert's Distance Law
- Kirchoff's Law
- Lambert's Direction Law (Cosine)
- Transmittance of light

PRELIMINARY WORK

1. Study the basic principles of radiation especially the concepts listed in objective section.

2. Visit the lab. in advance to familiarize yourself with the experimental set-up with the consent of the teaching assistant.

BACKGROUND

a) Stefan Boltzmann's Law

Stefan Boltzmann's Law states that total emissive power form a black body changes with 4^{th} power of the temperature.

$$\frac{q}{A} = \sigma . T^4 \qquad (1)$$

where $\sigma = 5.670 \times 10^{-8}$ W/m^2.K^4 and temperature T is in K.

b) Lambert's Distance Law

Distance Law states that intensity of radiation from a point heat source decreases with square of distance. Since it is known that change in irradiance is related with a^{th} (should be found as 2) power of L, equation (2) can be written to define irradiance (E -W/m^2).

$$E(W/m^2) = k.L^a \quad (2)$$

c) Kirchhoff's Law

According to Kirchoff's Law, at thermal equilibrium emissivity and absorptivity of a surface are equal.

d) Lambert's Direction Law (Cosine Law)

Radiant intensity (flux per unit solid angle) emitted in any direction from a unit radiating surface varies as the cosine of the angle between the normal to the surface and the direction of the radiation..

$$E = E\,(0^0).\cos\theta \quad (3)$$

e) Transmittance

Radiation can be absorbed, transmitted or reflected from a surface. These phenomena are represented as absorbtivity (α), transmittance (τ) and emissivity (ε) where: $\alpha + \tau + \varepsilon = 1$. Transmittance is simply the portion of the light which is not either absorbed nor reflected from the surface.

EXPERIMENTAL SETUP

Experimental set-up is mainly composed of a heat source and a light source for the radiation experiments coupled with a thermopile and a luxmeter in order to measure heat emitted from the heat source and the intensity of the light radiated, respectively.

Absorption plates and color filters are also included in the set-up. Schematic view of experimental set-up is given in Figure 1.

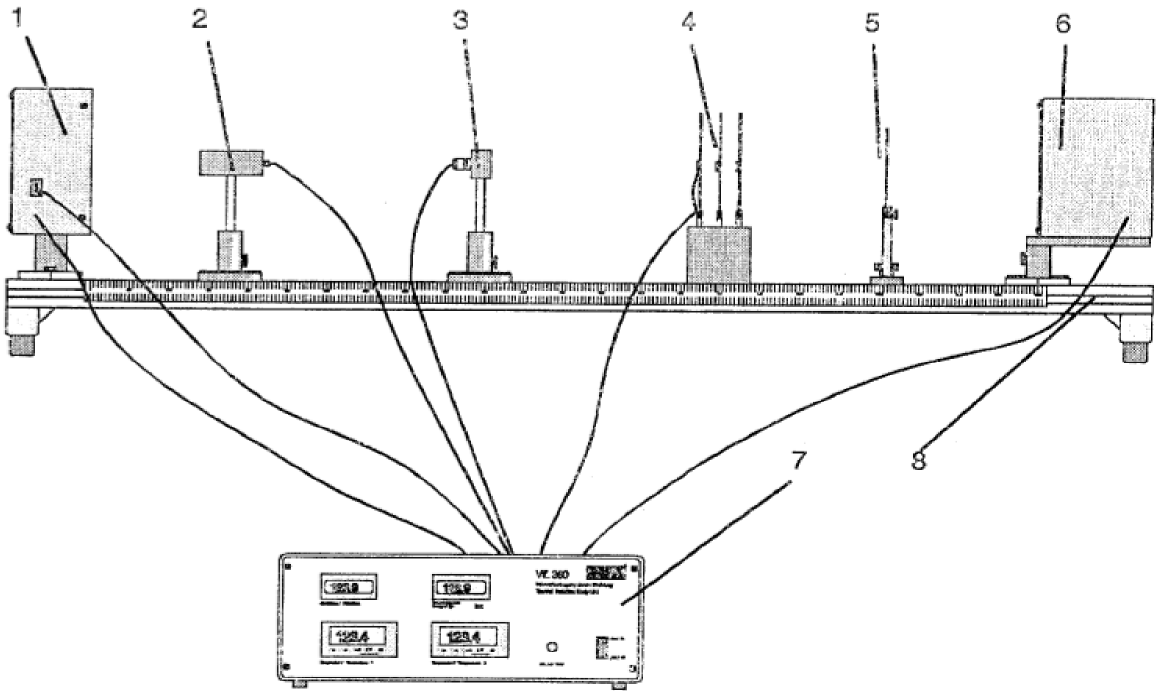

Figure 1. Schematic view of experimental set-up. 1:Heat source, 2: Thermopile, 3 : Luxmeter, 4: Absorption plates, 5: Color filters (red, green, indigo), 6: Light source

EXPERIMENTAL PROCEDURE

Experiments for thermal and optical radiation will be conducted separately. Thermal radiation experiments will be carried out first to investigate Lambert's Distance Law, Stefan Boltzmann's Law and Kirchoff's Law. After the first part optical experiments will follow to consider Cosine Law and transmittance of light through different colored filters. The experimental procedure is outlined below.

<u>Heat Source</u>

a) Stefan Boltzmann's Law

- Mount thermopile at a distance L = 130 mm from the heat source.
- Check connections of both heat source and thermopile.
- Switch on measuring amplifier note background radiation.

- Set power regulator on measuring amplifier to 70.
- Record Irradiance (W/m^2) at different temperatures.
- Continue until a constant temperature is reached.

b) Lambert's distance law

- Record the Irradiance values at different distances by lowering the distance with a reasonable step size.
- Note: Heat source can be considered as a point source as long as the distance from the source is higher than 300 mm.

c) Kirchhoff's Law

- Mount absorption plates instead of the thermopile.
- Place polished/black emission plate on the heat source.
- Mount black/polished absorption plate to a distance of 75 mm from the heat source.
- Record temperatures on heater and absorption plate.
- Mount absorption plate with a distance of 50 mm and repeat the procedure for Kirchhoff's Law.
- Repeat the same procedure this time with black side of the emission plate.

Light Source

a) Lambert's Direction Law (Cosine Law)

- Mount luxmeter at L = 350mm from the light source.
- Place light source to a position where $\theta = 0$.
- Check all connections.
- Switch on measuring amplifier (note irradiance from the surrounding).
- Switch on light source.
- Turn on the power regulator to full capacity.
- Record Illuminance (Lux) at different angles by increasing the angle of illuminance.

b) Transmittance

- Restore light source's position to $\theta = 0$.
- Install colored filters between luxmeter and light source.
- Record the irradiance before and after installing the colored filters.
- Repeat these steps by changing the power from the light source.

ANALYSIS

a) Stefan Boltzmann's Law

- Plot Temperature vs Irradiance diagram on a log-log scale and compare the power of temperature T you find with that of stated by Stefan Boltzman's law.
- Compute the emissivity (ε) for each irradiation measured

Note: Irradiance values are the net emission values including heat absorption from the surroundings (absorption has negative and emission has positive signs). Plotted diagrams should be based on surface emission so radiation absorbed from the surroundings should also be added to the radiation values read.

b) Lambert's Distance Law

- Plot irradiance vs. length on log-log scale.
- Calculate the slope.
- Comment on the value found.

c) Kirchhoff's Law

If the plates with bright and black surfaces are used alternately as emitters and absorbers and if the respective temperatures of the emitters and absorbers are equal, the ratio of the emission coefficient to the absorption coefficient of both surfaces should be constant.

d) Lambert’s Direction Law (Cosine Law)

Check the correlation between illuminance and incident angle by using least squares method or by plotting normalized illuminace values (normalized between 0 and 1) on a unit circle (circle having a diameter equals to 1) provided in software of the experimental setup.

e) Transmittance

Calculate the Transmittance (τ) value for each filter using the irradiation readings taken.