Name: Vishal Kumar **Roll no.:** B22339 **Group:** G5

Experiment 1

Determining the local heat transfer coefficient for a vertical tube losing heat by natural convection

Aim: It aims to figure out the local heat transfer coefficient for a vertical tube that loses heat through natural convection. Second, it looks to study how the tube's surface temperature, the temperature around it, and the rate of heat transfer are connected.

Overview/Introduction:When we place a hot object in calm air, it transfers heat to the nearby fluid through natural convection. The fluid touching the hot object heats up, becomes less dense, and moves upward. Cold fluid from the surroundings then rushes in to fill the space. This process keeps going, and heat moves because of the motion between hot and cold particles. We call this way of moving heat natural or free convection. Unlike forced convection, natural convection happens because of the temperature difference between the surface and the fluid, without any outside help. Natural convection plays a key role in how heat moves from pipes, cooling coils, hot radiators, and similar objects.

Theory:

Fluid moves in free convection because particles near a hot object heat up more than the surrounding fluid changing their density . Cooler fluid replaces the warmer fluid creating convection currents. These currents start when a body force (gravity centrifugal force, electrostatic force, etc.) acts on a fluid with density differences. Free convection flow speeds are much lower than forced convection speeds, so heat transfer rates are also lower. The force that causes these convection currents is called buoyancy force, which happens because of density differences in the fluid and a body force. The Grashof number (Gr) is crucial in natural convection. It compares the strength of buoyancy forces to viscous forces in the fluid. Newton's Law of Cooling says that heat transfer (Q) between a solid surface and the fluid around it is related to the temperature difference between them.

It is expressed as: $Q = h \cdot A \cdot (Ts - Tinf)$

where: h = local heat transfer coefficient, A = surface area of the tube, Ts = surface temperature of the tube, Tinf = ambient fluid temperature. This law forms the basis for calculating the heat transfer coefficient (h), which is the main objective of the experiment.

Observation Table and **Calculations**:

	All readings are in celsius							
Power (in Watts)	T1	T2	T3	T4	T5	T6	T7	T.amb
5.2	32.8	36.5	36.9	38.9	38.2	37.1	36.7	27.6
8.5	36	41.9	41.9	44.8	43.9	42.3	42	28
12	38.4	45.9	46.1	49.5	49.2	46.9	46.4	28.1

First we will find the average/mean temperature, ***Tavg = (T1+T2+T3+T4+T5+T6+T7) / 7***

Tmean 1 = (32.8+36.5+36.9+38.9+38.2+37.1+36.7) / 7 = 36.72 celsius
Tmean 2 = (36.0+41.9+41.9+44.8+43.9+42.3+42.0) / 7 = 41.83 celsius
Tmean 3 = (38.4+45.9+46.1+49.5+49.2+46.9+46.4) / 7 = 46.05 celsius

Area of surface = 3.14 x d x l = 3.14 x 0.025 x 0.7 = 0.0549 m^2

Now, we will calculate experimental coefficient of heat transfer using,

h = Q/[As(Ts-Tamb)]

→ h1exp = 5.2/ [0.0549 x (36.72 - 27.6)] = 10.38
→ h2exp = 8.5/ [0.0549 x (41.83 - 28)] = 11.19
→ h3exp = 12/ [0.0549 x (46.05 - 28.1)] = 12.18

Now, we will calculate the theoretical coefficient of local heat transfer.

First we will find Grashof number (Gr) = gß(L)^3(Ts-Tamb) / (ʋ)^2 —> 1
where : ß = coefficient of thermal expansion = 1/(Tf + 273);

Tf = (Ts + Tamb)/ 2 ;ʋ = Kinematic viscosity of air = [1.48 x (10)^-5] m^2 /s

Tf1 = (36.72+273 + 27.6+273) / 2 = 305.16K

ß = 1/(305.16) = 0.00327

Putting these values in 1 to find (Gr) number,

Gr = 9.81 x (0.00327) x (0.7)^3 x (36.72 - 27.6) / (1.48)^2 x 10^(-10) = 0.046 x 10^10

Now we will find Prundtl number, Pr = Cp/K
where: Cp = Specific heat of air = 1.005kJ/kg-K and K = Thermal conductivity of air = 2.557 x 10-4 W/m°C

So, Pr = 0.71 (Approx.) —> 2

Now we know that Rayleigh number = Gr.Pr = 0.046 x 0.71 x 10^10 = 0.325 x 10^9

So from the above conditions we will be using the 1st equation of Nusselt number. Nu = 0.59 x (3.25 x 10^8)^0.25 =79.52 Now, h x L / K = Nu —> h x 0.7/ 0.028 = 79.52 On solving this h-theoretical = 13.46 Similarly, we will solve for other readings as well.

<u>Result</u>:

S.no	Power(in watts)	h-experimental	h-theoretical
1	5.2	10.38	3.18
2	8.5	11.19	3.52
3	12	12.18	3.73

Sources of error:

1) Wrong Temperature Readings: Thermocouples have limits that lead to mistakes in measuring surface or surrounding temperatures.
2) Heat Escaping to Nearby Objects: Unexpected heat loss to things close by affects the actual rate of heat transfer through convection.
3) Uneven Surface Temperature: The tube's surface temperature changes in different spots causing heat transfer rates to vary along the tube.
4) Mistakes in Tool Setup: Tools that aren't set up right (like temperature sensors or heaters) cause wrong measurements. [This caused the most errors in our test, as the controller's dial kept moving.]
5) Room Conditions: Shifts in air movement or moisture in the room change how natural convection works.

Conclusions:

Researchers determined the local heat transfer coefficient for natural convection around a vertical tube, utilizing Grashof, Prandtl, and Rayleigh numbers to calculate the Nusselt number. Their findings revealed that natural convection is an effective method for cooling in heat dissipation applications. The study also highlighted how surface temperature and surrounding conditions significantly impact the heat transfer rate. Overall, the tests demonstrated that natural convection is highly effective in real-world heat management systems. This research underscores the potential of natural convection in optimizing thermal management strategies.