Experimental study and statistical data analysis on cooling of electronic components

Aim:

To study the cooling nature of electronic components with and without forced air and also the experimental observations has to be correlated.

Apparatus required:

1. Hot plate
2. Electronic component – Heat sink materials such as aluminium, ,copper – Size 100mm×100mm×10mm
3. Electric table fan with speed regulator
4. Thermo Anemometer
5. RTD sensor with digital temperature indicator
6. Stop watch
7. Computer
8. Ordinary glass thermometer to measure atm. temperature
9. Table stand to hang the hot test specimen rigidly while exposing to the moving air.
10. Tongs

Theory:

The temperature difference between the system and surroundings leads to energy flow either from the system or to the system.The direction of energy flow purely depends on the level of heat energy or degree ofhotness of the system and surrendings.As for as the system (Electronic components) is considered, in heating process - the thermal energy has to be transfered to the system where as in cooling process the system liberates the heat towards the surroundings.

Newton’s Law of Cooling states that “the rate of temperature of the body is proportional to the difference between the temperature of the body and that of the surrounding medium”. This statement leads to the classic equation of exponential decline over time which can be applied to many phenomena in science and engineering. Newton's Law of Cooling is useful for studying electronic cooling and packaging because it can tell us how fast the high temperature electronic components in the printed circuit board (PCB) cools off when you turn off the breaker. Suppose that a body with initial temperature T_1°C, is allowed to cool in air which is maintained at a constant temperature T_2°C.Let the temperature of the body be T°C at time t.

Apply Newton’s Law of Cooling,

$$\frac{dT}{dt} = -k(T - T_2) \text{ ------- (1)}$$

Where k is the positive proportionality constant, since the temperature of the body is higher than the temperature of the surroundings then (T-T_2) is positive. Also the temperature of the body is decreasing i.e. it is cooling down and rate of change of temperature is negative.

$$\frac{dT}{dt} < 0$$

The constant ‘k’ depends upon the surface properties of the material being cooled.

$$k = (hA_S)/(\rho CV)$$

Where,

h - Convective heat transfer coefficient

A_s -Surface area of electronic component

ρ -Density of electronic component

C -Specific heat capacity of electronic component

V – Volume of electronic component

Initial condition is given by $T=T_1$ at t=0

Solving equation (1)

-kt = ln (T-T_2)+ln C -------(2)

$$T - T_2 = Ce^{-kt} \text{ ----------- (3)}$$

Applying initial condition

$$C = T_1 - T_2$$

Substituting the value of C in equation (3) gives

$$T = T_2 + (T_1 - T_2)e^{-kt} \text{ ---------- (4)}$$

From equation(2),

ln(T-T_2) = -kt + ln C --------(5)

This equation represents Newton’s law of cooling.

If $k<0$, lim$t$ --> ∞, $e^{-kt} = 0$ and $T= T_2$ or we can say that the temperature of the body approaches that of its surroundings as time goes.The graph drawn between the temperature of the body and time is known as cooling curve. The slope of the tangent to the curve at any point gives the rate of fall of temperature.

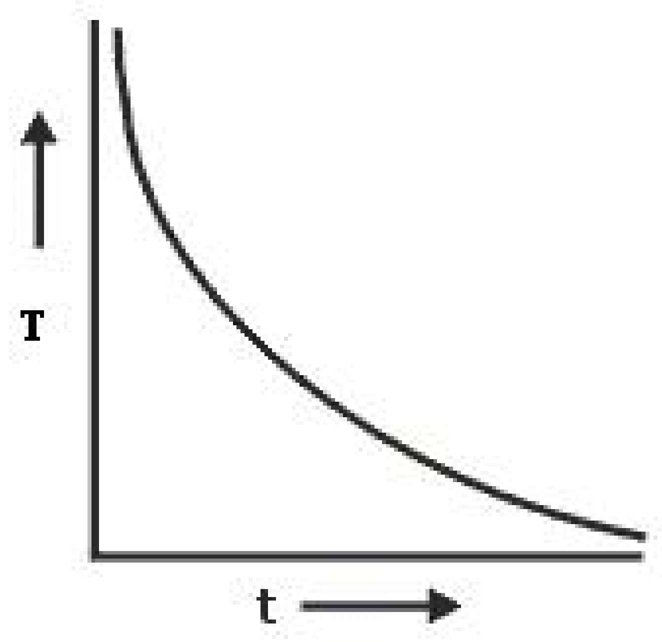

Figure 1: Cooling curve of the given test specimen

Other Applications:

1. In general, to predict how long it takes for a hot object to cool down at a certain temperature.
2. To find the temperature of a food placed in a refrigerator by a certain amount of time.
3. It helps to indicate the time of death which can be calculated using the probable body temperature at the time of death and current body temperature.

Procedure:

1. Clean the deposites on surface of the hot plate and test specimen.Then switch on the hot plate and set the required temperature (around 150°C) using thermostat.

2. Place the three speed setting table fan away from the hot plate and measure the air temperature (*T_2*) and velocity at any one speed settingof fan using thermo anemometer.
3. Place the test specimen on hot surface and wait untill it reaches the required set temperature.
4. Once it reaches the temperature fix rigidly on table stand using tongs and measure the initial temperature (T_1) of hot surface using Resistance Temperature Deductor (RTD).
5. Then expose the test specimen for moving air at any one speed of table fan.
6. Simultaneously, switch on the stop watch and note down the instantaneous surface temperature[*T(t)*] of test specimen at the equal time interval of every 30 seconds.This has to be continued untill the the test specimen reaches the temperature very closure to the atmospheric temperature.
7. Similarly, Switch off the table fan and repeate the above procedure and also tabulate the experimental data.
8. From the table 1, 2 calculate *k* value using Newton's law expression .
9. Calculate convective heat transfer coefficient (h) using *k* value at three different speeds.
10. Plot the graph between ln($T-T_2$) and time .Get the value of k from the slope.
11. Finally compare convective heat transfer coefficients and record your inference through this experimental study.Also correlate the data with acceptable (95% and above) goodness of fit.

Note:

The material properties (Test specimen and air) can be referred at any "Heat and Mass Transfer Data Book"

Tabulation:-

Table 1: Forced cooling of electronic component at fan speed-------------------.

S.No	**Initial temp.(T_1) when *t* =0 (°C) (Fixed value)**	**Ambient Temp.(T_2) (°C) (Fixed value)**	**Cooling Time *t* in Sec.**	**Instantaneous temp.*T(t)* (°C)**	***k*(Calculated from Newton's law)**
1.			**0**		

2.			**30**		
3.			**60**		
4.			**.**		
5.			**.**		
6.			**.**		
7.					
8.					
9.					
10.					
11.					
12.				**~ 60°C**	
K Average					

Table 2:Natural cooling of electronic component

S.No	**Initial temp.(T_1) when t =0 (°C) (Fixed value)**	**Ambient Temp.(T_2) (°C) (Fixed value)**	**Cooling Time t in Sec.**	**Instantaneous temp.$T(t)$ (°C)**	**k (Calculated from Newton's law)**
1.					
2.					
3.					
4.					
5.					
6.					

7.					
8.					
9.					
10.					
11.					
12.					

Graph:

Take cooling time alon *X* - axis and intanteneous temperature of test specimen on *Y*- axis and plot the cooling curves using Microsoft EXCEL.

Results and discussions:

1. Convective heat transfer coefficients (*h*) in w m^{-2} k^{-1}.
Natural cooling = -----------------
Forced cooling = -----------------

2.Compare the convective heat transfer coefficients and comment on the observations made.

3.Correlation for instanteneous temperature of the given components using MATLAB/Excel.

Self Study:

Rate of heat lost by a body due to change in temperature = mc dT/dt = $hA_s(T - T_2)$

h – Convective heat transfer coefficient due to the process of conduction and convection.The heat loss due to radiation is neglected in this case.