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# Heat Dissipation in Control Panel using Heat Pipe

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**ABSTRACT**

*This experiment consist design and develops of an add-on for a control panel which is fitted with heat pipes which helps in better heat dissipation inside the control panel obstructing failure of the control panel due to overheating and also due to fouling of the components inside the control panel. It can provide a better add-on for an industrial control panel that would not have frequent failures in which heat dissipation is achieved by using forced convection where fans suck out the air which blows over the hot end of the heat pipe thus bringing in a massive heat dissipation rate which is effective. This also helps in avoiding the fouling of the components which are fixed inside the control panel. The Modified Control panel are tested and it is more economical and efficient than the normal industrial control panel thus bringing down the rate of failures in control panel. This gets achieved by performing experimentation on a scale model, which would help in proving that the control panel which has been designed is much more efficient and competent than the conventional control panels being used in industries now-a-days.*

**Keywords: Minimum 7 Control panel, Compatibility, Effectiveness Fan, Formulas, Heat Pipe, Heat Dissipation, working.**

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## I. INTRODUCTION OF HEAT PIPE

Effective cooling of electronic components is an important matter for successful functionality and high reliability and authenticity of the electronic devices. The rapid developments in microprocessors challenge an enhanced processing power to ensure faster operations. The electronic devices have highly integrated circuits that produce a high heat flux, which leads to increase in the operating temperature of devices, and this result in the shortening of life time of the electronic devices. Consequently, the need for cooling techniques to dissipate the associated heat is obvious. Thus, heat pipes have been identified as one of the viable and promising options to achieve this purpose, prior to its simple structure, flexibility and high efficiency. The phase changes in the working fluid inside in order to facilitate the heat transport is utilized by heat pipes. Heat pipes are the best choice for cooling electronic devices, because depending on the length, the effective thermal conductivity of heat pipes can be up to several thousand times higher than that of a copper rod. Main perception of a heat pipe includes

passive two-phase heat transfer device that can transfer large quantity of heat with minimum temperature drop. This method offers the possibility of high local heat removal rates with the ability to dissipate heat uniformly. Heat pipes are used in a wide range of products such as refrigerators, air conditioners, heat exchangers, transistors, and capacitors. Heat pipes are also used for a better performance by decreasing the operating temperature in desktops and laptops.

Electronic cooling has adopted heat pipe dependable and cost-effective solution for sophisticated cooling applications. The fundamental of heat pipes is dependent of evaporation and condensation. At the hot side, the working liquid is evaporated and at the cool side it condenses. As every material has different properties, it's required to choose the set of material properly. At the source the cool fluid is evaporated, the hot vapour stream is a while later transported to the sink where the vapour condenses again and is transported back to the source. The thought of a Heat Pipe is presently to incorporate the complete convective transport in one channel, where the vapour stream is in the centre of the pipe and the flow happens to be on the outside of the barrel. Heat exchange is so efficient that fundamentally it is a direct result of the low heat resistance because of the convective stream, as explained earlier. This low heat resistance is because of little effective length of heat exchange through strong porous wick walls. Heat pipes are hollow metal tubes which is filled with working fluid. Heat pipe are used to transfer heat from one end to other end of heat pipe by evaporating and condensing in an endless cycle. Due to the ability of heat pipe to quickly transport heat energy, they can be used between the hot flue gases and fresh atmospheric air to increase the heat transfer rate.[3]

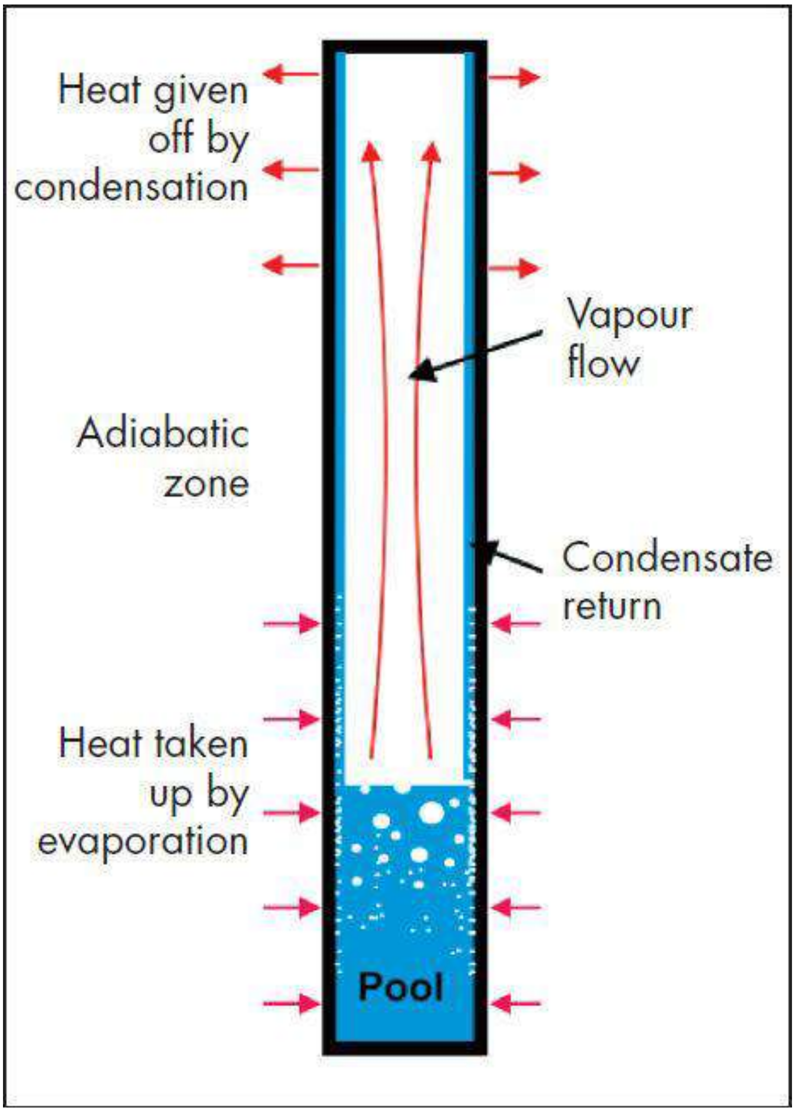



**Figure 1** – Heat Pipe.

## II. PROBLEM DEFINITION.

1. Effective cooling of electronic control panel.
2. Increase in the heat dissipation rate.
3. Avoid failure of control panel due to over heating.

## III. HEAT PIPE

A typical heat pipe consists of a sealed pipe or tube made of a material, that is compatible with the working fluid such as copper for water heat pipes, or aluminum for ammonia heat pipes. Typically, a vacuum pump is used to remove the air from the empty heat pipe. The heat pipe is partially filled with a working fluid and then sealed. The working fluid mass is chosen so that the heat pipe contains both vapor and liquid over the operating temperature range. Below the operating temperature, the liquid is too cold and cannot vaporize into a gas. Above the operating temperature, all the liquid has turned to gas, and the environmental temperature is too high for any of the gas to condense. Whether too high or too low, thermal is still possible through the walls of the heat pipe, but at a greatly reduced rate of thermal transfer. Working fluids are chosen according to the temperatures at which the heat pipe must operate, with examples ranging from liquid helium for extremely low temperature applications (2–4 K) to mercury (523–923 K), sodium (873–1473 K) and even indium (2000–3000 K) for extremely high temperatures. The vast majority of heat pipes for room temperature applications use ammonia (213–373 K), alcohol (methanol (283–403 K) or ethanol (273–403 K)) or water (298–573 K) as the working fluid. Copper/water heat pipes have a copper envelope, use water as the working fluid and typically operate in the temperature range of 20 to 150 °C. Water heat pipes are sometimes filled by partially filling with water, heating until the water boils and displaces the air, and then sealed while hot.For the heat pipe to transfer heat, it must contain saturated liquid and its vapor (gas phase). The saturated liquid vaporizes and travels to the condenser, where it is cooled and turned back to a saturated liquid. In a standard heat pipe, the condensed liquid is returned to the evaporator using a wick structure exerting a capillary action on the liquid phase of the working fluid. Wick structures used in heat pipes include sintered metal powder, screen, and grooved wicks, which have a series of grooves parallel to the pipe axis. When the condenser is located above the evaporator in a gravitational field, gravity can return the liquid. In this case, the heat pipe is a thermo syphon. Finally, rotating heat pipes use centrifugal forces to return liquid from the condenser to the evaporator. Heat pipes contain no mechanical moving parts and typically require no maintenance, though non-condensable gases that diffuse through the pipe's walls, resulting from breakdown of the working fluid or as impurities extant in the material, may eventually reduce the pipe's effectiveness at transferring heat.[3]

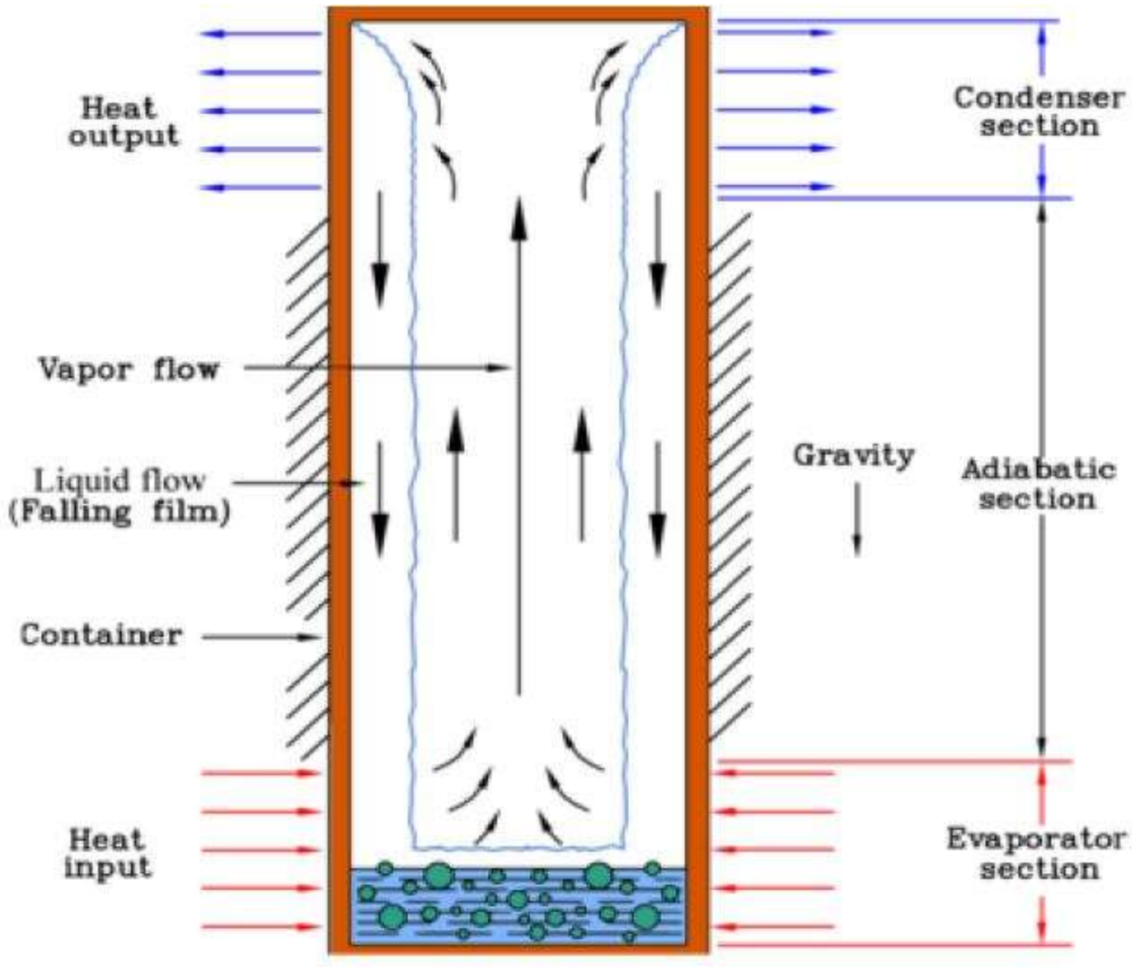



**Figure 2** – Structure of Thermosymphon Heat Pipe.

## IV. WORKING FLUID SELECTION CONSIDERATIONS.

A first consideration in the identification of a suitable working fluid is the operating vapour temperature range. Within the approximate temperature band, several possible working fluids may exist, and a variety of characteristics must be examined in order to determine the most acceptable of these fluids for the application considered. The prime requirements are –

- Compatibility with wick and wall materials
- Good thermal stability
- Wettability of wick and wall materials
- Vapor pressure not too high or low over the operating temperature range
- High latent heat

• High thermal conductivity
• Low liquid and vapor viscosities
• High surface tension
• Acceptable freezing or pour point

## V. COMPATIBILITY WITH WORKING FLUID AND HEAT PIPE

The compatibility between heat pipes and working fluid is very important because if it is not compatible it results in failure of heat pipes and ultimately resulted in failure of electronic devices. For instance, let us analyze the compatibility issue between aluminium and water. The two major results of incompatibility are corrosion and the generation of non-condensable gas. If the wall or wick material is soluble in the working fluid, mass transfer is likely to occur between the condenser and the evaporator, with solid material being deposited in the latter. This will result either in local hot spots or blocking of the pores of the wick. Non-condensable gas generation is probably the most common indication of heat pipe failure and, as the non-condensables tend to accumulate in the heat pipe condenser section, which gradually becomes blocked, it is easy to identify because of the sharp temperature drop that exists at the gas vapour interface. Some compatibility data is of course available in the general scientific publications and from trade literature on chemicals and materials. However, it has become common practice to carry out life tests on representative heat pipes, the main aim of these tests being to estimate long-term materials compatibility under heat pipe operating conditions. At the termination of life tests, gas analyses and metallurgical examinations as well as chemical analysis of the working fluid may be carried out. The main criteria to be satisfied in the heat pipe design are the selection of heat pipe and the working fluid.
• Heat pipe and working fluid should be compatible. For instance, water and aluminium have chemical reaction with each other and aluminium releases large amount of non condensable gasses. So that we prefer copper with water.
• The temperature of evaporator should be above melting point of the fluid to have the advantage of phase transition.
• The high temperature evaporator such as nuclear reactor needs working fluid which have high melting point.
• If the evaporator temperature is so high then the fluid will remain in vapour state.
• The amount of fluid in the heat pipe is less than the required level; there is a chance of entrainment of fluid. We have to fill the fluid to optimum quantity.

**5. Formula Used In Experimentation.**

5.1] Heat gained by aluminium block[1], Q= kA(T2-T1)

5.2] Temperature at other end of the aluminium block[2] Q= $kA(T2-T3)/x$

5.3] Total internal volume of heat pipe[1], $Vi=\pi/4*Di\text{^}2*h$

5.4] Design of optimum quantity of fluid[1]
The amount of fluid in the heat pipe is less than the required level; there is a chance of entrainment of fluid. We have to fill the fluid to optimum quantity.

$Vl$>0.001 ( $e$+$la$+$lc$)

Whereas, $Vl$ - Volume of liquid $Di$ - Internal diameter of heat tube , $le$ - Length of evaporator section, $la$ - Length of adiabatic section, $lc$- Length of condenser section, h- Height of heat pipe

5.5] Calculation of evaporation rate

$$q_{nuc}^{\cdot} = \mu_l h_{fg}\left[\frac{g(\rho_l-\rho_v)}{\sigma}\right]^{1/2}\left[\frac{C_{pl}\,(T_s-T_{sat})}{C_{sf}h_{fg}Pr_l^n}\right]^3$$

5.6] Calculation of Forced Convection with Fan and without and with Heat Pipes:

Reynolds number
Re = $\rho VL/\mu$

Nusselt number = $0.029Re^{0.8}Pr^{1/3}$

$Q_{gen} = Q_{loss} + Q_{carried\,by\,air} = hA\Delta T + (mCp\Delta T)$

## VI. PROCEDURES.

The following is a list of the procedures described above, which should be followed during heat pipe assembly:[2]

i. Select container material
ii. Select wick material and form
iii. Fabricate end caps.
iv. Outgas metal components
v. Insert wick and locate
vi. Weld end caps
vii. Leak check welds
viii. Select working fluid
ix. Purify working fluid (if necessary)
x. Degas working fluid
xi. Evacuate and fill heat pipe
xii. Seal heat pipe.

It may be convenient to weld the blank end cap before wick insertion, and in cases of sintered and diffusion bonded wicks, the outgassing may be done with the wick in place in the container. For the manufacturer considering the production of a considerable number of identical heat pipes, for example 50 or more units following prototype trials, a number of the manufacturing stages may be omitted. Outgassing of metal components may be unnecessary, and it may be found that, depending upon the filling and evacuation procedure used, the fluid degassing may be eliminated as a separate activity.[2]

## VII. RESULTS

Without Heat Pipe & Without Fan:

**Table 1** : Without Heat Pipe and Without Fan

| Sr. No. | Temperature | | | Time |
|---|---|---|---|---|
| | Enclosure Air Temperature (°C) | Aluminium Block (°C) | Wall Surface (°C) | |
| 1 | 65.57 | 76.8 | 34.6 | 1.15 PM |
| 2 | 99 | 110.1 | 41.1 | 2.15 PM |
| 3 | 104.7 | 141.4 | 53 | 3.15 PM |
| 4 | 107 | 183 | 61.7 | 4.15 PM |
| 5 | 107 | 190.7 | 67.3 | 5.15 PM |

**Table 2**: Without Heat Pipe and With Fan

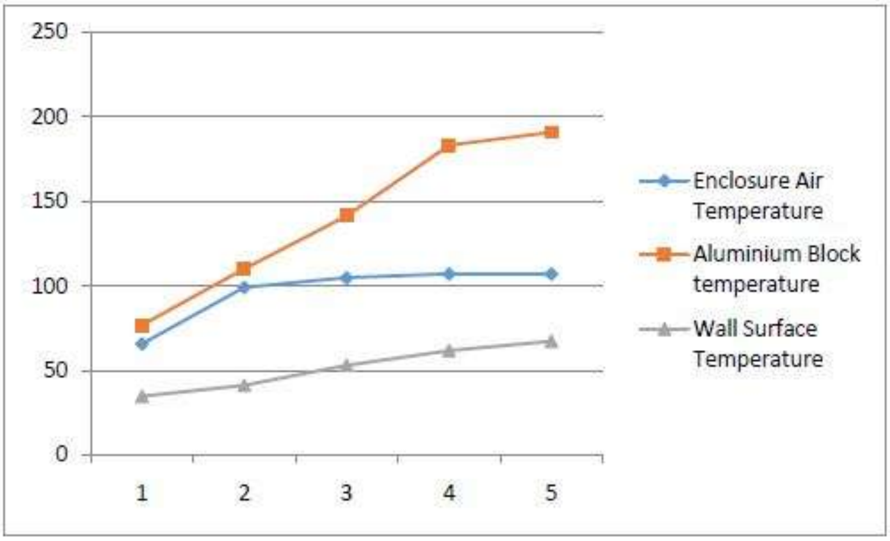
| Sr. No. | Temperature | | | Time |
|---|---|---|---|---|
| | Enclosure Air Temperature (°C) | Aluminium Block (°C) | Wall Surface (°C) | |
| 1 | 50 | 101 | 36.9 | 6.15 PM |
| 2 | 45 | 96.6 | 36.5 | 7.15 PM |
| 3 | 45 | 91.1 | 36.3 | 8.15 PM |

**Table 3** : With Heat Pipe and With Fan

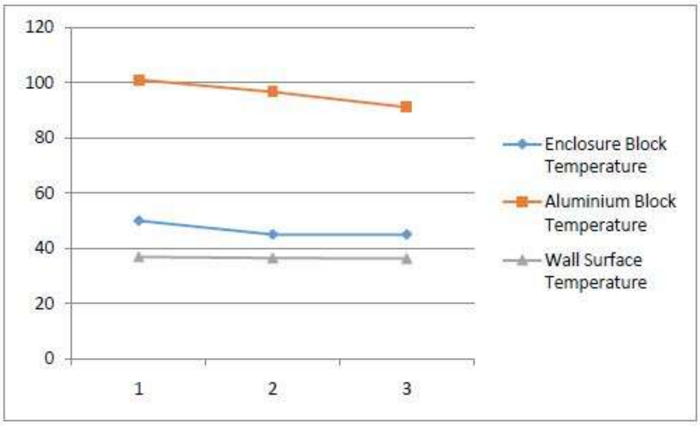
| Sr. No. | Temperature | | | Time |
|---|---|---|---|---|
| | Enclosure Air Temperature (°C) | Aluminium Block (°C) | Wall Surface (°C) | |
| 1 | 41.3 | 67.2 | 34.7 | 9.45 AM |
| 2 | 43 | 71 | 34.2 | 10.45 AM |
| 3 | 40 | 70 | 34.1 | 11.45 AM |
| 4 | 41 | 68 | 34 | 12.45 PM |
| 5 | 39.6 | 66.9 | 33.9 | 1.45 PM |
| 6 | 38.9 | 61.1 | 33.3 | 2.45 PM |
| 7 | 38.7 | 64 | 32 | 3.45 PM |
| 8 | 37.5 | 62.4 | 31.5 | 4.45 PM |
| 9 | 36.1 | 58.3 | 30.8 | 5.45 PM |
| 10 | 36.1 | 57.3 | 30.7 | 6.45 PM |

*EFFECTIVENESS:*

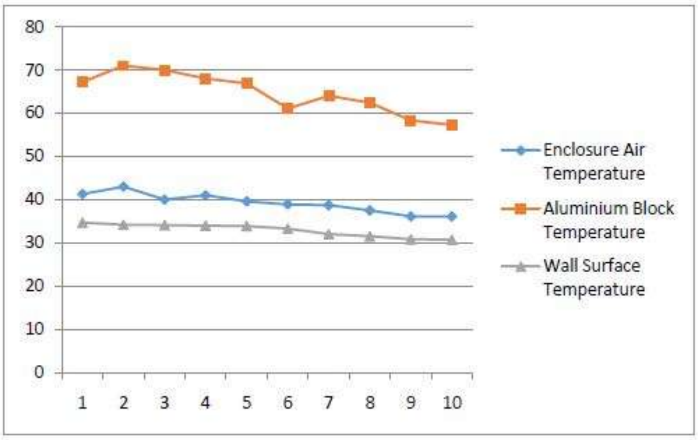
Without Heat Pipe & Without Fan



Without Heat Pipe & With Fan:




With Heat Pipe & With Fan:




## VIII. CONCLUSION:

Heat pipe is the advanced technology for heat dissipation inside the control panel. The setup of heat pipes used for cooling of the control panel is not only cost effective but also efficient. The setup helps in achieving the stable temperatures inside the control panel and also helps in enhancement of the life of the components inside the control panel which in turn enables the control panel to have a longer active life. After completing the experimentation work by using heat pipe in the setup we have achieved greater temperature reduction and cooling. The temperatures without heat pipes were high and not favourable for the working conditions of the control panel. We managed to decrease the temperature of the setup by 80oC using heat pipes which was not possible by only using a conventional electric fan. Thus heat pipes played an effective role for the cooling of control panel as it helped in increasing the heat transfer rate. The effective thermal conductivity of heat pipe is very high and it helps in the transportation of heat from the aluminium block to the air carried by the fan thus hereby increasing heat dissipation. From this experiment it has been concluded that heat pipe can transfer heat without any moving parts which also makes it noise-free, maintenance-free and highly dependable. Due to its small size and weight it can be used in cooling electronic devices. Widening the scope of using heat pipes not only in electronics field but also in other mediums where efficient cooling is required at a marginal cost.

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