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Heat Pipes: Design, Development, Manufacturing- A case study of Oil cooler model

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Abstract— Heat pipe is a device which transfers heat from a source to sink by alternate evaporation and condensation of fluid inside a sealed system with temperature drop of 5°C per meter length of pipe. Heat pipe is a stationary device and also it does not have any moving parts. It has three basic components the container, working fluid and the capillary structure. A heat pipe allows to transfer thermal energy (heat) over a distance very efficiently. The transfer occurs quickly and with very little temperature loss across the distance. Over a six inch length, the thermal conductivity of the heat pipe can be 100 times greater than a comparable copper rod. A heat pipe is a hollow aluminium or copper tube, sealed at both ends, and filled with a capillary wicking material that is saturated with a liquid. When heat is applied to one end, the liquid at that end absorbs the heat and evaporates. The vapour travels to the other end where it is cooled and condenses back to liquid form, releasing the heat it had absorbed. Because the heat pipe is sealed, the liquid wicks back toward the hot end, starting the process all over again.

Keywords— Heat pipe, condensation, evaporation, capillary wicking, thermal conductivity etc

I. INTRODUCTION

Heat pipes offer high effective thermal conductivities (5,000 W/mK to 200,000 W/mK), energy-efficiency, light weight, low cost and the flexibility of many different size and shape options. As passive heat transfer systems, heat pipes offer simple and reliable operation, with high effective thermal conductivity, no moving parts, ability to transport heat over long distances and quiet vibration-free operation. Heat pipes transfer heat more efficiently and evenly than solid conductors such as aluminum or copper because of their lower total thermal resistance.[1] The heat pipe is filled with a small quantity of working fluid (water, acetone, nitrogen, methanol, ammonia or sodium). Heat is absorbed by vaporizing the working fluid. The vapour transports heat to the condenser region where the condensed vapour releases heat to a cooling medium. The condensed working fluid is returned to the evaporator by gravity, or by the heat pipe's wick structure, creating capillary action[2]. Both cylindrical and planer heat pipe variants have an inner surface lined with a capillary wicking material.

II. CURRENT SITUATION IN INDUSTRIES:

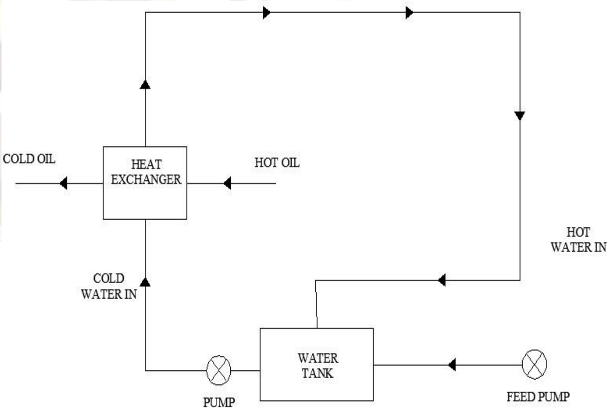

Fig 1. Schematic view of Present Situation in Industries

III. DRAWBACKS OF USING ABOVE PROCESSES IN INDUSTRIES:

- Large utilization of electricity,
- Large Usage of water,
- It takes more space,
- It requires more maintenance,
- Running cost is high.

IV. TO OVERCOME THESE DIFFICULTIES AN EFFECTIVE & EFFICIENT METHOD OF COOLING IS DEMANDED:

To develop an Oil Cooler on the concept of Heat-Pipe, which can cool the high temperature Servo System 57 (Oil) from 200°C to working temperature 100°C at 5 lpm flow rate.

V. THE COOLER REQUIREMENTS:

- It should utilize less quantity of Water.
- It should utilize less Power.
- It should reduce temperature of oil with the help of Natural Circulation.
- It should occupy less space.
- It should have less running cost.
- It should have less maintenance.
- It should avoid problems like corrosion, scaling, etc.
- Environmental friendly[6].

VI. BASIC CONCEPT OF HEAT PIPE:

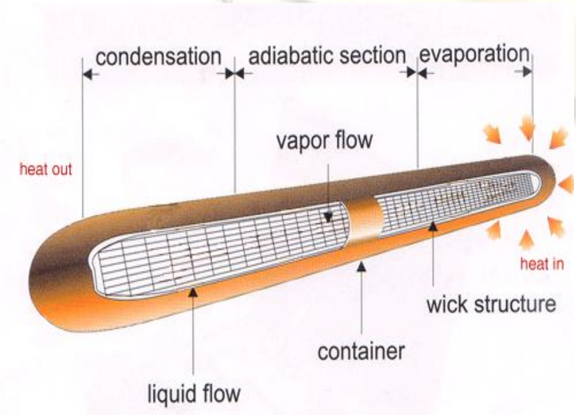

Fig 2. Schematic representation of Heat Pipe

VII. THE BASIC COMPONENTS OF A HEAT PIPE ARE:

A. The container,
B. The working fluid,
C. The wick or capillary structure.

A. The container :

Container of heat pipe should have following properties –

- Compatibility (both with working fluid and external environment)
- Strength to weight ratio
- Thermal conductivity
- Ease of fabrication, including welding, machineability and ductility
- Porosity
- Wettability.

B. Working fluid:

The prime requirements are –

- compatibility with wick and wall materials,
- good thermal stability,
- high latent heat,
- high thermal conductivity,
- low liquid and vapour viscosities,
- high surface tension.

MEDIUM	MELTING PT (° C	BOILING PT AT ATM PRESSURE (° C)	USEFUL RANGE (° C)
Helium	- 271	- 261	- 271 to -269
Nitrogen	- 210	- 196	- 203 to - 160
Ammonia	-78	- 33	- 60 to 100
Acetone	- 95	57	0 to 120
Methanol	-98	64	10 to 130
Flutec PP2	-50	76	10 to 160
Ethanol	-112	78	0 to 130
Water	0	100	30 to 200
Toluene	-95	110	50 to 200

MEDIUM	MELTING PT (°C	BOILING PT AT ATM PRESSURE (°C)	USEFUL RANGE (°C)
Mercury	-39	361	250 to 650
Sodium	98	892	600 to 1200
Lithium	179	1340	1000 to 1800
Silver	960	2212	1800 to 2300

VIII. WICK OR CAPILLARY STRUCTURE:

Two main types of wicks: homogeneous and composite.

A. Homogeneous - made from one type of material or machining technique. Tend to have either high capillary pressure and low permeability or the other way around. Simple to design, manufacture, and install.

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B. Composite - made of a combination of several types or porosities of materials and/or configurations. Capillary pumping and axial fluid transport are handled independently. Tend to have a higher capillary limit than homogeneous wicks but cost more.

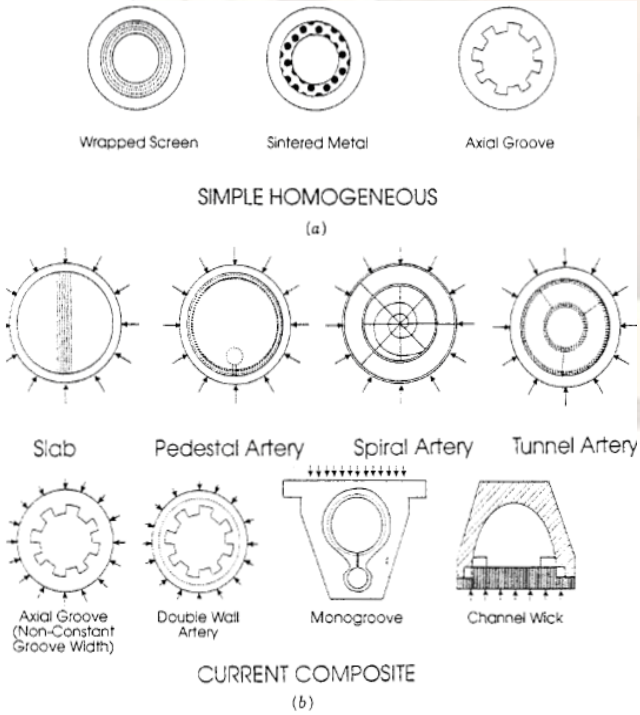


Fig 3. Figure representing various wicking structures[6].

IX. HEAT PIPE PRINCIPLE:

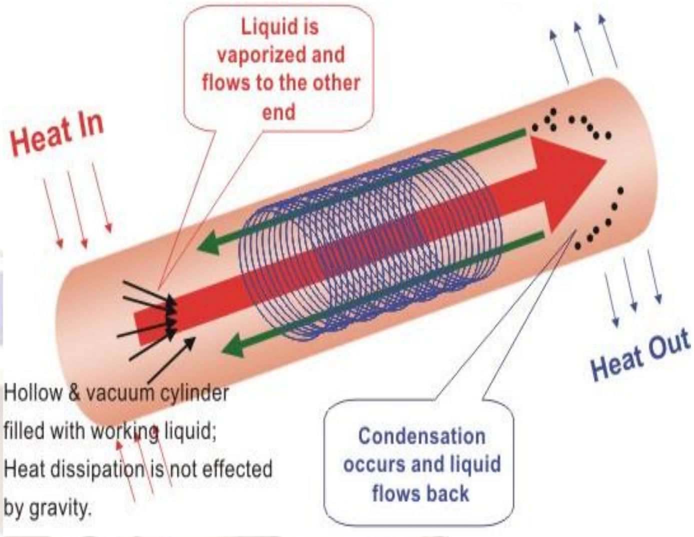


Fig 4. Figure showing Heat Pipe Principle[8].

X. APPLICATIONS:

- Space Technology
- Heat pipes for Dehumidification and Air conditioning
- Notebook And Mobile Pcs Thermal Control
- Laptop Heat Pipe Solution
- Electronic Equipment cooling
- Used in between in Solar Panels and Solar Plates.

XI. WORKING MODEL OF OIL COOLER:

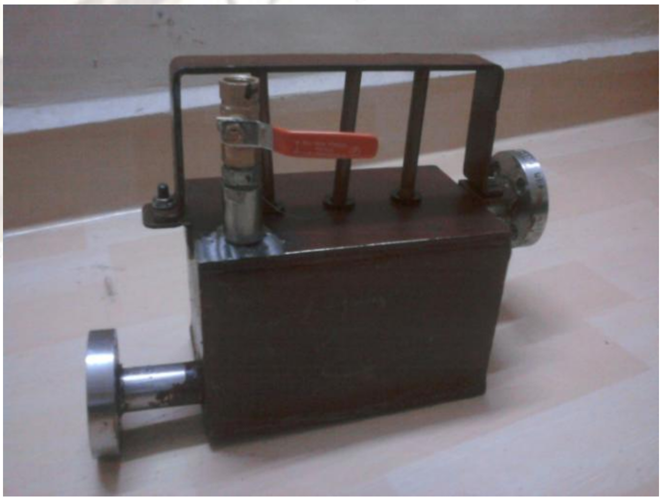
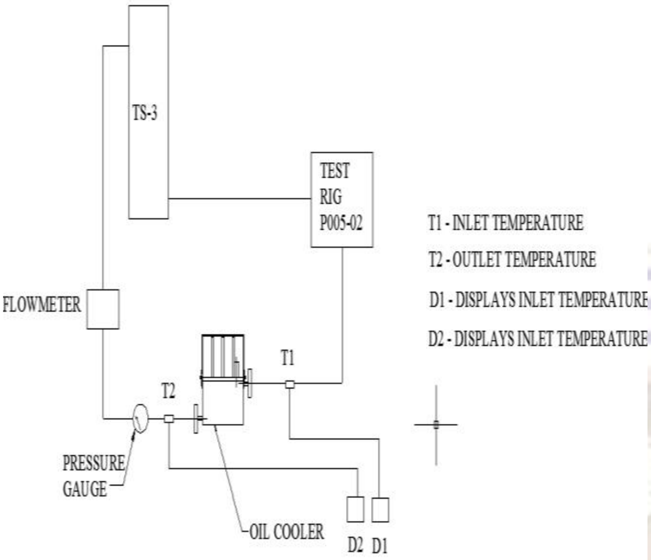


Fig 5. Working model of oil cooler.[7]

XII. PERFORMANCE TESTING:

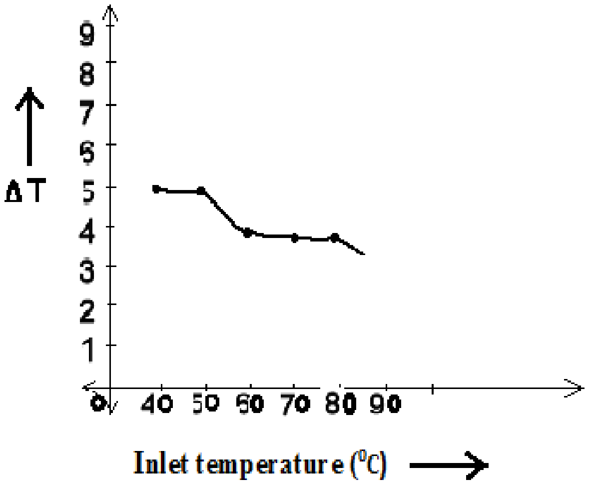


XIII. FOR 5 LPM FLOW RATE:

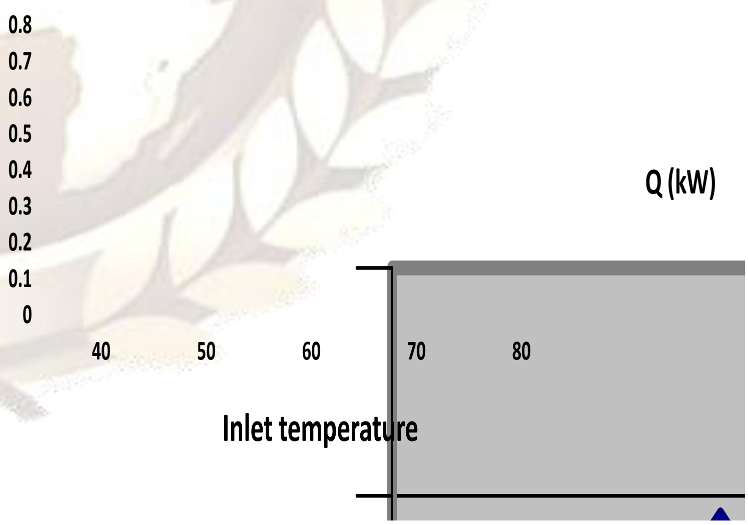
Flow rate (lpm)	Inlet Temperature (T1) ^{0}C	Outlet Temperature (T2) ^{0}C	Change in Temperature (δT) =(T1-T2) ^{0}C	Heat rejected (Q) kW
5	40	35	5	0.675
5	50	45	5	0.675
5	60	56	4	0.54
5	70	66	4	0.54
5	80	76	4	0.54

XIV. TEMPERATURE DROP (ΔT ° C) VS INLET TEMPERATURE (° C):

A. AT 5 LPM:



B. HEAT REJECTED (Q) VS INLET TEMPERATURE (℃):



XV. CONCLUSION:

- As the oil flow rate rises, the total heat rejected increases.
- As the inlet oil temperature rises for same flow rate, the temperature drop across the cooler decreases thus reducing heat transfer capacity.
- This unit is more efficient at lower temperatures.
- Heat pipes needed to fulfil company's requirement, for 5 lpm flow rate are 75 numbers.
- The experimental result matches with rated capacity of standard heat pipes we used.

XVI. FUTURE TRENDS:

- We can change the heat pipe material as per application.
- We can increase the no. of heat pipes for efficient cooling.
- We can provide fins, to increase the heat transfer rate.
- Forced convection can improve its heat removal rate.
- We can increase the dimensions of heat pipe for better heat removal capacity.

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