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"SOLID STATE WATER COOLER/HEATER FOR ARMOURED VEHICLES"

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ABSTRACT

During the journey to war field; it is an acute problem for the soldier for getting comfortable cold drinking water, especially during summer. Generally after three hours; soldiers used to take warm water for drinking purpose and due to this physiological parameters of human body goes from bad to worse. Similarly for cooking their food, they were unable to get warm or hot water during their war field. Such warm or hot water they may like to use for preparing their Meals ready to eat. Hence; they need such a system which may be able to resolve both the above requirements during their war field. It could be possible by Solid State Cooling/Heating concept where the system has to be much simpler, requires small size and weight, ensures safe and maintenance free operation, and is extremely reliable compared with any other competing cooling/heating concepts.

Keeping this in mind; the objective of this work is to design the typical system of Solid State Water Cooler/Heater for Army personnel by considering all the boundary condition given for respective Armoured Vehicles.

KEYWORDS: Armoured Vehicles, Peltier Effect, Solid State/Thermoelectrics Cooling & Heating

INTRODUCTION

The **Solid State Cooling & Heating** is based on **Peltier Effect**. This effect is observed where direct current is allowed to flow across the junction of two dissimilar materials. The junction region is found to either absorb or release heat depending on the direction of the current. In other words, what was the hot face will become the cold face and vice-versa.

The above technique is going to use to cool or heat the water of **Armoured Vehicles**, which can be operated by DC Power Supply (mainly by their back-up battery system), Voltage ranging from 20 V DC to 28 V DC during their war field. The power consumption from DC Power supply depends on the parameters like ambient temperature, supplied voltage & amount of heat to be extracted or to be thrown.

Depending on above parameters the water temperature will also vary. Design of the system presents no hazards, such as burns or sharp edges, to the users. All the electrical components are comply with Military Standard. The switches are designed to start a cooling or heating processes and installed to prevent inadvertent operation or damage. There are protective circuit to terminate or prevent the device, if the supply voltage goes beyond the limit. To the best of our knowledge, such type of system is not available to our Defence personnel. In this regard some US patents [1, 2 & 3], Defence technical reports [4, 5, 6 & 7] and one thesis for the partial fulfillment of the requirements for Bachelor of Science Degree in Mechanical Engineering, in School of Engineering, Santa Clara University, California, USA [8] are available. From the above literatures it can be concluded that mostly they had done the theoretical work on cooling system. Mathiprakasam [6] technical report on "Development of Thermoelectric water Heating / Cooling Devices" for United States Army Natick, Research, Development and Engineering Centre, Massachusetts, USA tells about water

Cooling / Heating system for US Army. But from this report [6], it is not very clear that US Army has/had implemented such system at their Armoured Vehicles. If at all; US Army implemented such system for their Armoured Vehicles, it may not suit our Indian environmental conditions. By considering all our Indian environmental conditions as well as boundary conditions of our indigenous Armoured vehicles, it needs to develop our own technical approach to built up such typical and unique system where other conventional systems are either impractical or undesirable.

TECHNICAL APPROACH

The water tank for the armoured vehicle has two compartments. The bigger compartment is of 35 liters from where the water pore to smaller compartment to be of capacity of 10 liters. For cooling mode, this needs to cool from 55^{o}C to 25^{o}C or for heating mode it needs to heat up to 75^{o}C. When the bigger tank is totally empty, in that situation the whole system will be "OFF". For cooling mode when the temperature of smaller tank reaches to 25^{o}C, then the cooling system will step down the power consumption to 1/4 of its full power. When again the temperature goes beyond 35^{o}C, the cooling unit will be "ON". In any Solid State Cooling/Heating system, the provision of total cut-off the power is not desirable. Otherwise, there will be a back flow of heat. To prevent back flow of heat, a very small amount of current (i.e. low watt power) has to be given to stop the back heat flow. This amount of power consumption is negligible compared to the power required for cooling or heating the water from ambient to desire temperature. The position of water tank at typical battle tank is shown in Figure 1.

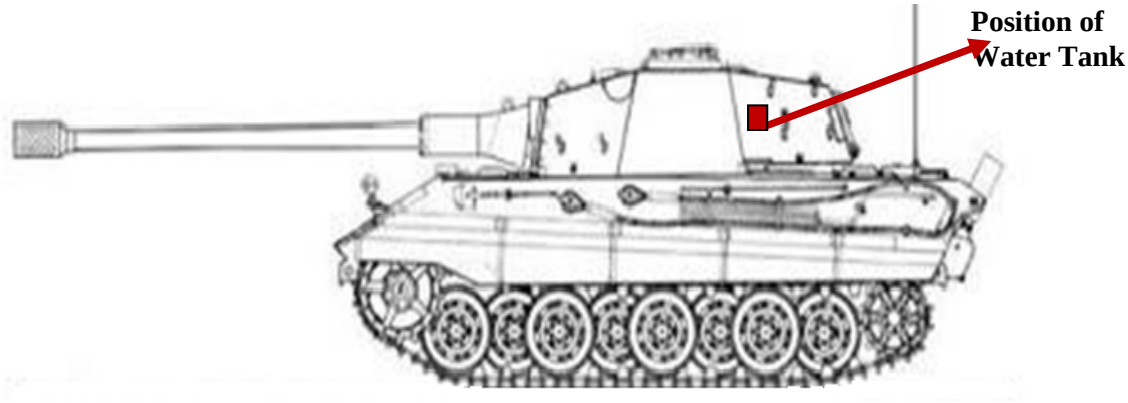

Figure 1: Position of the Water Tank at Battle Tank

If the water consumption is continuous from the small tank (~10 Lts.), in that case, valve will be open till water comes to the required level as marked as "max-level" and Cooling system will be "ON", power consumption will be continuous till achieve the temperature 25^{o}C. After attaining the "max-level" of water at smaller tank (10 Lts.), the valve will be closed (stop water) but cooling system will be "ON" till achieving the required temperature i.e. 25^{o}C. There is one back-up sensors/alternative By-pass system to protect from any failure. Typical conceptual design of the Water tank are is shown in Figure 2 & Figure 3.

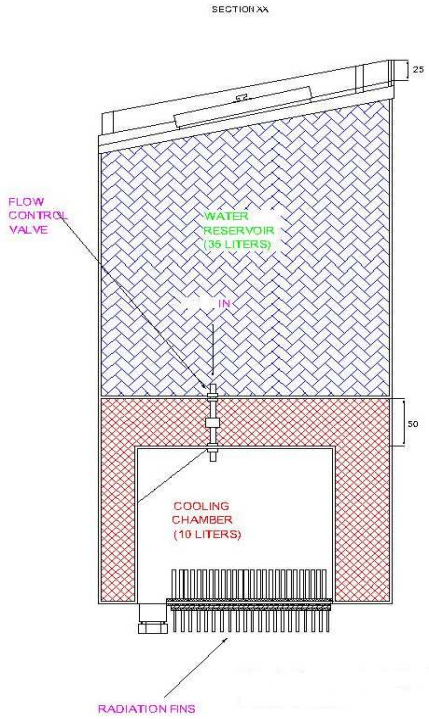

Figure 2: Conceptual Design of Drinking Water Cooling/Heating Tank for Armoured Vechicles

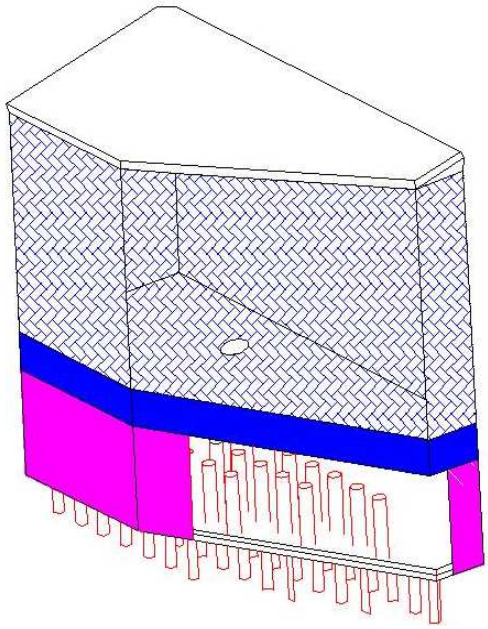

Figure 3: 3D View of Drinking Water Cooling/Heating Tank by Considering All the Boundary Condition of Armoured Vehicle

For heating mode, it needs to reverse the direction of current. In this situation, water start heating from ambient temperature and goes upto 75^{o}C. When temperature reaches 75^{o}C, the heating mode will step down the power consumption to ¼ of its full power. *When the temperature comes down to 60^{o}C, the unit will be "ON" till it reaches upto 75^{o}C.* Similar "ON" / "OFF" cycle will continue till the water tank is totally empty. When the water tank is empty; the whole system will be "OFF".

Brief Outline of the Electrical System for Drinking Water Cooling/Heating Tank

Various components of the temperature control system, will be as under

- Temperature sensor, Level sensor, Valve unit, Control cabinet

Temperature Sensor

It will be a RTD element, suitably encased in an stainless steel thermo-well. This should be fixed in the lower tank, below the low water level sensor.

Level Sensors

These will be non-corrosive probes, which should be suitably fixed to the tanks. They will be of very low potential and high impedance, so as not to cause any galvanic activity.

Valve Unit

This will comprise of a SS ball valve, coupled to a SS normally closed, AVCON make solenoid valve below it. Both of them will have a 3/8″ BSP fitting and shall be suitable for water application.

Control Cabinet

This will be a fully wired **RITTAL** make modular, wall mounting, IP55 cabinet with plastic coated finish. Front hinged door will have all the indicators and actuators mounted on it. These are

- ON/OFF isolator.
- Start / stop actuator
- 'Cooling On' Indicator
- 'Valve Open' Indicator
- Top Tank Level Low indicator
- Lower Tank Level Low indicator
- Lower Tank Level maximum indicator
- Temperature Indicator

Rest of the control units, those shall be mounted inside the cabinet are as under

- A GE Fanuc MicroPLC
- Temperature indicating controller
- Relays for temperature and valve control

All external connections (mentioned below) will be introduced inside the enclosure through easily disconnectable military duty plug and sockets

- Main power input

- Sensors
- Solenoid valve
- Peltier modules

Standard 5 meter field cabling will be provided with each MIL plug on the control cabinet. The typical block diagram of electrical circuitry is shown in Figure - 4

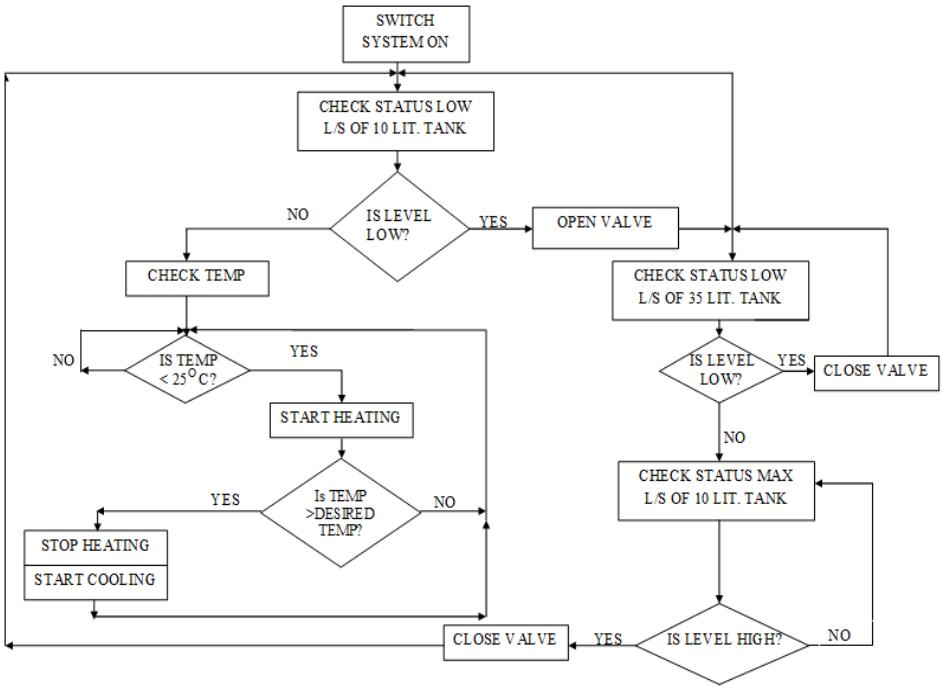

Figure 4: Typical Block Diagram of Control Circuit for Drinking Water Cooling/Heating Tank

RESULTS & DISCUSSIONS

For such heating & cooling system, 12 numbers of thermoelectric modules were used in cascading manner with electrical combination of 3S X 2P i.e. three modules in series and two in parallel. Each thermoelectric module having 127 number of n^- & p^- type of couples with geometric factor 0.170 cm and size 40 X 40 X 3.48 mm. All n- & p- type couples are sandwiched between two Alumina Ceramic Plates.

For Cooling Mode

Some typical observations/results are highlighted herewith. When the voltage is fixed i.e. 24 V DC and ambient changes, in this situation cold water temperature reaches to at 8^oC as ambient comes from 58^oC to 38^oC. The amount of heat to be extracted from water is almost constant i.e. around 210 Watts. Input power from Armoured Vehicles is varying from 374 Watts to 415 Watts, in other words when ambient decreases, input power increases to achieve more cooling effect. Typical graphical interpretations are shown in Figure 5(a) & (b).

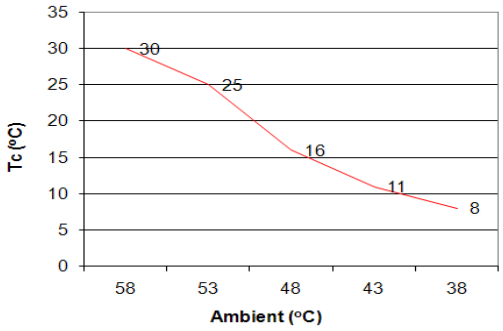

Figure 5(a): Ambient Decreases, Cold Water Temperature Decreases

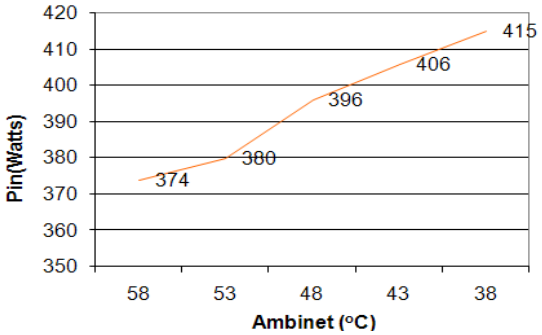

Figure 5(b): Ambient Decreases, Input Power Increases

When ambient temperature is constant that is around 53^{o}C and the supplied voltage changes from 20V DC to 28 V DC, cold water temperature changes from 32^{o}C to 19^{o}C, where amount of heat to be extracted from water is almost constant i.e. 210 watts. In this situation input power from Armoured Vehicle varies from 266 Watts to 522 Watts, which indicates that if voltage increases, cold water temperature decreases and input power increases. Typical graphical interpretations are show in Figure 6(a) & (b).

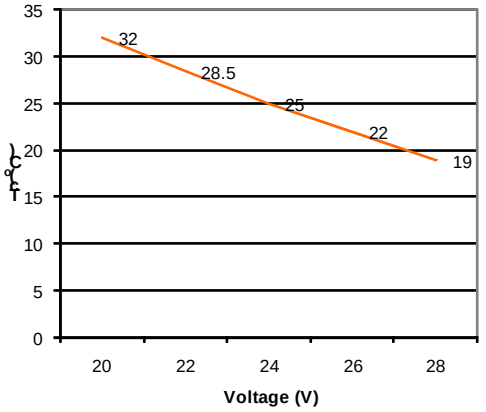

Figure 6(a): Voltage Increases, Cold Water Temperature Decreases

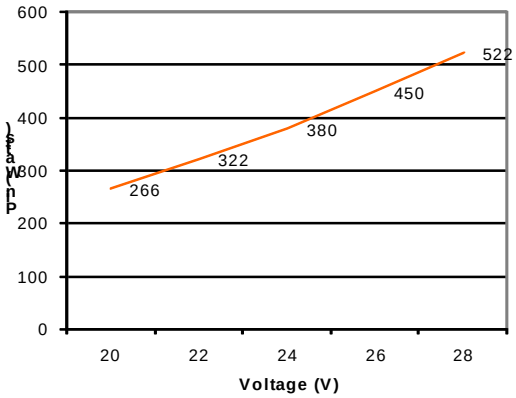

Figure (b): Voltage Increases, Input Power Increases

If ambient temperature constant i.e. 53^{o}C, cold water temperature constant i.e. 25^{o}C but supplied voltage increases from 24V DC to 28V DC, in this situation heat extraction and input power both increases, but amount of heat extracted is not much compared to the input power.

Typical graphical interpretations are shown in Figure 7(a) & (b).

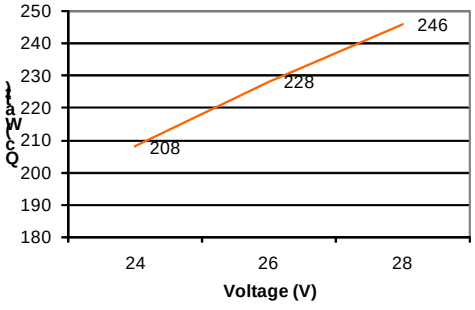

Figure 7(a)

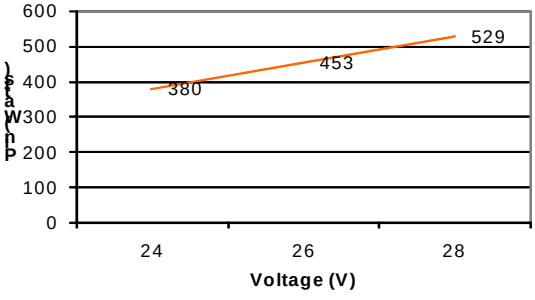

Figure 7(b)

For Heating Mode

For heating mode; One stage thermoelectric modules array were used with electrical combination 3Sx2P (three modules in parallels and two modules in series). If the voltage is constant i.e. 24V DC and ambient changes from 40^{o}C to 60^{o}C; in this situation the hot water temperature raises upto 70^{o}C and the power consumption from back-up battery varies from 193 watts to 177 watts.

If the ambient temperature is constant i.e. 55^{o}C and input voltage varies from 20 V DC to 28 V DC, the hot water temperature raises upto 75^{o}C. The power consumption from the back-up battery increased from 125 watts to 250 watts.

CONCLUSIONS

The development of basic design and simulation of Solid State Water Cooler and Heater for Army personnel is the foundation for proceeding towards prototype as well as for final manufacturing of such typical cooling / heating system for any armoured vehicles and may be also applicable for our Indian battle tank.

By simply changing the polarity of DC power supply of the system the cold water become warm/hot, which could be used for preparing their meals for eat. This system may be ideal for the place like Siachan, Ladakh, Leh and Kargil.

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