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An IoT enabled Convenient Vaccine Cold box for Biomedical Use

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Abstract :

Vaccines are very crucial for treating preventable diseases, but its need a constant environment like maintenance of temperature. Currently it is a barrier in healthcare scenario. In this paper, work is focused on the designing of the cold box which is capable to maintain a temperature range from 2^0-8^0 C constantly using Peltier-based thermoelectric chip, specific structural design obtain through calculation and IoT based solutions. Another crucial characteristic of this instrument is that it delivers an optimal power usage forecast to keep the ideal vaccine storage in precise temperature range in

presence of limited power supply from environment. Due to a collective action of the phase change material and thermoelectric device, the temperature inside the box is will be maintained. The details of the location and the temperature settings will be accessible and visible on the Blink Application. This box is an efficient carrier as it will aid in tracing, automated settings, consistent temperature, carrying and packaging which will be an alternative to the currently available techniques in practice.

KEYWORDS: Cold Chain system, thermoelectric cooler, Cold Box, IoT, sensors, cold life, container, portable box, vaccine, PCM, ice packs.

I. Introduction

Whenever humans undergo a pandemic or any infectious disease vaccine plays a major economic cost [1]. In 2020 world is undergoing a worst pandemic situation. Every researcher is trying to search vaccine against COVID19. Current challenge is definitely investigation of preventive measures against COVID and complete world is spending billions on the vaccine research and on making. The secondary challenge will be vaccination coverage. One of the reasons many countries lack enough vaccination coverage is due to insufficient cold storage in the vaccine supply chain. Despite the efficiency and benefits of the vaccines, factors such as lack of power supply, geographical ruggedness, and insufficient efficiency have prevented the spread of vaccine coverage in developing countries. In these harsh conditions, the vaccination method is more effective than other medical methods. Vaccines should be stored under specific temperature range which is 2˚ to 8˚ C; otherwise the potency of the vaccine is lost. If the vaccine is kept at a temperature above or below on the label, it could adversely affect the vaccine. This work mainly deals with the development of a thermally insulated cold box which can store 12-15 vials and can be tracked using sensors and can provide sensor's information to a cloud server of a mobile app [2].

In several proposed designs [1,3,4,5], proposed a vaccine cooler with long span cooling effect. This design will mainly target on long span cooling time as well as continuous monitoring and automatic retention of temperature. This paper is divided into four sections. Section I introduces about the need of design. Section II provides information about the methodology used for box design with mathematical analysis. Section III gives in-depth analysis of material IoT based implementation. Section IV ends with discussion on result and conclusion.

II. Design Methodology of Cold box

This paper focuses on conceptual development of a device to store the vaccine for specific temperature range, maintaining the temperature and track its live location with the help IoT. In analyzing the root of the problem, there are two ways to approach this problem; One of the most dominant causes in technical point of view is the poor performance of power supply i.e. difficulty in providing constant DC power supply. The appropriate temperature for the vaccine to be fully effective is between 2℃ and 8℃. In order to avoid unfavorable environment which can destroy the vaccines and establish an appropriate cold storage transportation network and cold chain, stable supply of electric power becomes very important. Second, the live position or tracking of the box is also a major problem. Once they are sent from storage room to vaccination site they are not monitored or tracked by any person, the doctor or management. [4]

The vaccine cold box was designed to proceed with this study. The factors that should be considered in the design process are summarized as follows.

1) Seeking of a stable power supply to use in developing countries
2) Design and search for a structure and method that is easy to transport.
3) Build a low-cost design.
4) Build a portable box.
5) Build a viable monitoring system.

A. Box Design constraints

With consideration of these objectives, four prototypes were made using various different insulating materials and observations for individual prototype were taken. Volumes of the box, battery consumption, and thickness of insulating layers were the major aspects in designing the box. The limitations of previous prototype were corrected in next prototype. A vaccine cooling instrument was fabricated using a Peltier-based thermoelectric chip (TEC). The heat was transported away from the hot side of the peltier to a remote heat exchanger i.e heat sink with 5V DC fan. The dimensions of the box (17*17*16) cm with inner dimensions for the cavity (9*9*8)cm. A duct is created on one side of the box for the peltier chip and heat sink. The box has the capacity to store 12-15 vials of 10ml, 20ml. [3]

B. Material Selection

1. Medium Density Fiberboard (MDF): Fig 1 shows MDF sheets, a wood product comprising of wood fibers that are combined with resin and wax and pressed into flat panels at high temperature and pressure. The major use is in making plywood as a building material in housing and commercial construction. MDF board is a good insulator with thermal conductivity of 0.035 W/mk.

Fig 1 Medium-density fiberboard (MDF) Sheet [6]

2. Puff Foam (Polyurethane): Polyurethane foam is generally defined in the methodical literature having the lowermost thermal conductance among the series of common thermal insulation material. Expanded polystyrene and low density rigid polyurethane foam system significantly have gained the highest market acceptance for applications where low thermal/heat transmission is required. Foam is the mostly used flexible foam plastic. It is used to harvest a wide spectrum of items including thermal insulation. [6]

c. Mathematical Analysis

The calculations related to the determination of heat loss and thickness of the material is as follows:

Dimensions: (9X9X8) cm

Ambient Temperature: 40˚C (T2)

Inside Temperature: 6˚C (T1)

Capacity: 12-15 vials

Data: K(mdf) = 0.05 W/mK

K(foam) = 0.035 W/mK

K(clp) = 0.067 W/mK

Formula: $Q = \frac{A*k*\Delta T}{l}$

Heat loss from side walls (without convection)

$$Q = 9*8*34*10^{-4}*(\frac{0.035}{2.4*10^{-2}}+\frac{0.14}{0.6*10^{-2}}+\frac{0.14}{0.6*10^{-2}})$$

$$\boldsymbol{Q = 12.414\,W}$$

For, four such walls,

Q = 12.414*4

Q = 49.896 W …..(1)

Heat loss from top walls (without convection)

$$Q = 9 * 9 * 34 * 10^{-4} * (\frac{0.035}{2.4 * 10^{-2}} + \frac{0.14}{0.6 * 10^{-2}} + \frac{0.14}{0.6 * 10^{-2}})$$

Q= 13.23 W

For, two such walls

Q=13.23

Q=26.46 W …..(2)

Q for all the 6 walls of enclosure

Qwall +Q(top+bottom) = 49.89+26.46

Qtotal = 76.35 W

Therefore, the total heat loss from the container is **76.35 W**. We need to select a peltier module which would overcome this heat loss and maintain the temperature.[7]. Fig 2 and Fig 3 shows Top view, side view and exploded view of proposed model using above calculations defined in this section.

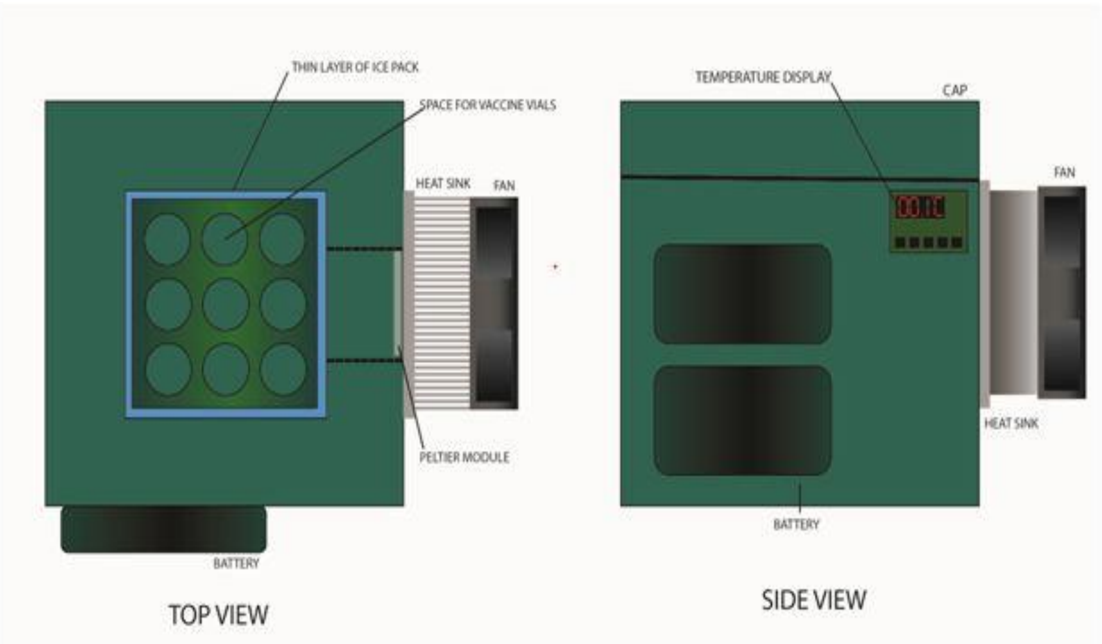

Fig 2 Top and Side view of proposed Model

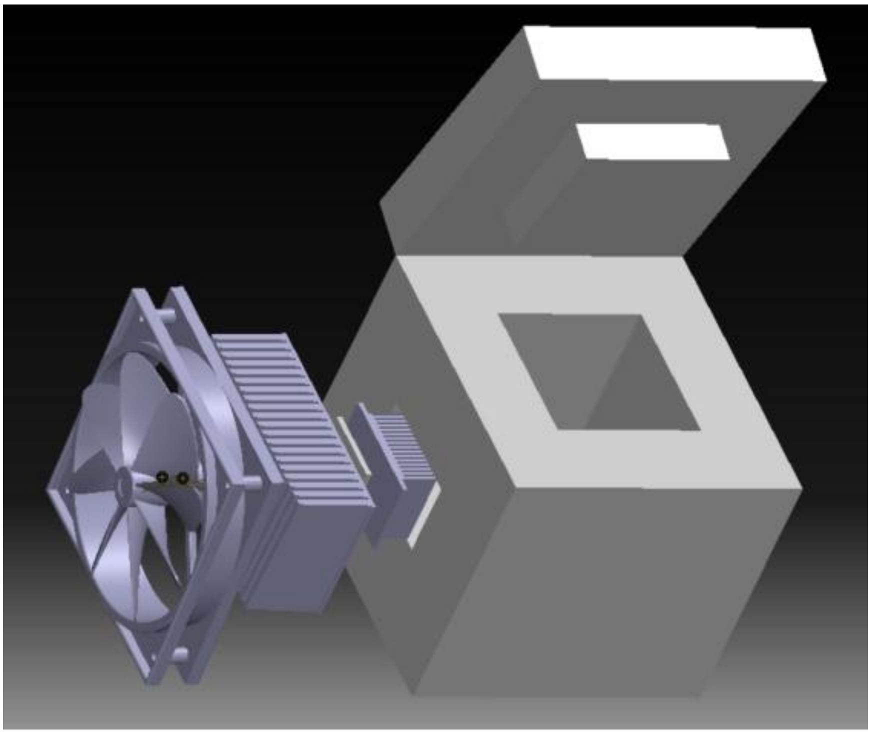

Fig 3 Exploded view of cold box

III. Electronic Assembly and Algorithm

IoT is the next measure modification introduce to design smart box[7]. Here the temperature tracking is done with the help of sensors, NodeMCU, and Ardiuno board. The values of all the sensors are collected by NodeMCU as it has inbuilt Wi-Fi module and all the data is transferred to the application through Wi-Fi, analysis is done in Blynk app and notifications are sent according to the conditions.

The components which are required for monitoring the temperature and location are

1. DHT11- Temperature sensor
2. NodeMCU-ESP8266
3. GPS module
4. Blynk Application.

Fig 4 shows the flowchart of temperature tracking and maintenance. Process start with hardware connection establishment. Node MCU checks for Wifi availability; if it is available then it displays information through Blynk application as shown in Fig 5. Temperature sensor checks for temperature range $2^{0-}8^{0}$, if any variation found control system applies feedback action for auto controlling temperature in prescribed range. Fig 6 and Fig 7 shows the proposed setups side and top view.

Fig 4 Process Flow of temperature monitoring and automatic cooling

Fig 5 Location of display on Blynk.

Fig 6 Side view of cold box

Fig 7 Top view of cold box

IV. Discussion and Conclusion

The testing of the prototype was done and observations were made. The minimum temperature reached was 7˚C. All the values of the sensors are collected by Node MCU and are sent to Blynk application. The location and temperature reading were observed on the screen of the Blynk Application. The work is very beneficial for proper cold chain storage. The portability of the box will ease the use of vaccines at vaccination sites. Use of thermoelectric module will increase the efficiency of cooling. External power supply can be provided if required at the vaccination sites. However, Storing capacity can be further increased. The Power supply given to the box can be provided with solar power control which will increase the efficiency of cooling. To increase the rate of cooling due to peltier module, water cooling can be applied to dissipate the heat at higher rate. The interfacing of NodeMCU done with blynk application can be replaced with a cloud connection. The cloud connection will keep the data at a specific location and maintaining would be easier. The needs for such technological innovation is evident from the reports of Global Burden of Disease studies[8-12]. Few of the related articles were reported[13-20].

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