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Temperature control system in the vaccine box uses the PID method with blynk application monitoring

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Abstract

This journal discusses the manufacture of boxed vaccines using thermoelectric with temperature control using PID (Proportional Integral Derivative) modeling with the Ziegler-Nichols method and the temperature can be monitored using the Blynk application. In 2018, 64,3% of community health centers in the Palembang area did not have external freeztag vaccine monitoring tools for temperatures below 2 degrees Celsius, so that 50,6% of vaccines were damaged. The vaccine refrigerator temperature must be more than 8 degrees Celsius. Based on the Vaccine Vial Monitor (VVM) it is 50,5%, the vaccine is damaged and the vaccine is frozen by 9,3%. With this data, it can be said that there are still many vaccines that are damaged due to incorrect procedures for using the vaccine box. One use of vaccine boxes for vaccine distribution is using ice gel (thermal freeze) or ice cubes. Poor vaccine management occurs when the vaccine storage temperature reaches more than 8 degrees Celsius, resulting in damage to the vaccine. This happens when using a boxed vaccine. Vaccine boxes that are only equipped with ice gel that melts easily cannot maintain the temperature, causing the vaccine to be damaged. In the research, it was found that thermoelectric voltage parameter control can ensure that the temperature of the vaccine box is maintained at less than 6 degrees Celsius using the PID method and the use of a flashing application to monitor the temperature. This system was created to reduce dependence on the use of ice cubes or ice gel which melts easily when distributing vaccines.

Keywords

Temperature control system, Vaccine box, PID method

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Introduction

In 2018, 64.3% of community health centers in the Palembang area did not have external freeztag vaccine monitoring tools for temperatures below 2°C, the percentage of poor quality vaccine management was 50.6%, storage temperature in refrigerators > 8°C was 43.3% [1] the vaccine is damaged based on the Vaccine Vial Monitor (VVM) at 50.5% and frozen vaccine at 9.3% [1][2]. With this data, it can be said that there are still many vaccines that are damaged due to user ignorance, one of which is the use of vaccine boxes, in distributing vaccines using vaccine boxes using ice gel (thermal freeze) or ice cubes. to refrigerate the vaccine, which poses a huge risk to quality. vaccines, for example ice gel or ice cubes melt or can freeze vaccines at temperatures of more than 2°C [2][3] and when using a vaccine box, the user does not know the exact temperature inside the vaccine box. Poor vaccine management occurs when the vaccine storage temperature reaches >8°C, resulting in damage to the vaccine. This happens when using a boxed vaccine. Vaccine boxes that are only equipped with ice gel that melts easily cannot maintain the temperature, causing the vaccine to be damaged. The factor that determines the success of an immunization program is the cold chain where vaccine storage is very susceptible to damage so special handling is required to maintain vaccine quality. Vaccine quality is not only determined through potency tests (laboratory tests) but depends on its management [4][5]. Vaccines which are included in the freeze sensitive vaccine and heat sensitive vaccine if not stored at the right temperature can cause the vaccine to lose its potency. Potential vaccine damage can be prevented through proper transportation, storage and handling of vaccines from the time the vaccine is produced until it is used in health services. The vaccine production process in the factory has special procedures in accordance with Good Manufacturing Practices (GMP) under the supervision of the National Regulatory Authority (NRA) [6][7][8] so that monitoring the quality of vaccine management is aimed at managing vaccines in storage warehouses at the primary level up to health service units.

Until now, the cold chain is still a problem for immunization program activities in developing countries, including Indonesia, especially in areas that are difficult to reach [9]. Based on vaccine and immunization news data from WHO (1996) of around 3.5 billion vaccine doses used in immunization programs in the world [11][12], at a cost of 150 million US dollars it is estimated that 1 billion doses are wasted [13][14]. Sending vaccines to remote areas or areas that are difficult to reach means that the vaccine will be late in arriving at the location, which can result in the vaccine being damaged before it is used [15]. Vaccine damage could occur due to late monitoring of the vaccine temperature which could result in the vaccine being no longer usable. The temperature of the vaccine must be kept stable between 2°C - 8°C [16][17] so that the vaccine remains in good condition. Inappropriate temperatures can certainly damage the condition of the vaccine and the vaccine cannot be used again. Currently, the government is trying to facilitate cold chains for hospitals and health centers. There are 2 types of cold chains, namely active and passive units. Active unit for storing vaccines in large quantities and uses an electric power supply. Meanwhile, a passive unit is a tool used to carry vaccines mobility without using a power supply or is called a vaccine carrier or vaccine box. The passive cold chain used for vaccine distribution from health facilities to hospitals and community health centers still uses a cool box (vaccine carrier) which is refrigerated using an ice box which needs to be cooled before use [18] and there is no temperature monitoring and the temperature is not maintained according to the requirements. It is recommended that this has the potential to cause damage to the vaccine, apart from the temperature factor which affects the quality of the vaccine, other parameters are humidity and sunlight which should not be exposed directly to the vaccine [19].

In this research, thermoelectric control was carried out on the voltage parameters in the vaccine box to ensure that the temperature of the vaccine box was maintained at <6°C using the PID method and using a flashing application to monitor the temperature. This system was created to reduce dependence on the use of ice cubes or ice gel which melts easily when distributing vaccines. Reducing dependence on the use of ice cubes or ice gel (thermafreeze) which melts easily during vaccine distribution which results in damage to the vaccine and presenting new technology in the field of medical supporting equipment.

A vaccine is a biological product made from bacteria or viruses, germ components, or germ toxins that have weakened or killed or imitated germs and is useful for stimulating the formation of a person's immune system actively and specifically against diseases caused by these germs. According to Gubernatorial Regulation No. 14 of 2008 concerning Immunization Vaccine services, to maintain the high quality of vaccines from the time they are received until they are distributed to the next level (or used), vaccines must always be stored at a predetermined temperature, which can be seen in the following explanation and Table 1 [20]. As can be seen in Table 1, which is a list of vaccine shelf life with storage temperature requirements.

1. Polio Vaccine Drops are stored at -15°C to -25°C in room or freezer.
2. Other vaccines are stored at temperature 2°C to 8°C in cold room or Vaccine refrigerator storage for no more than 3 months.
3. Storage period not more than 2 months.

Table 1. List of vaccine shelf life and storage temperatures [20]

Vaccine	province	Regency/City	PKM/PUSTU	Bides/UPR
	Vaccine Shelf Life			
	2 Month + 1 Month	1 Month + 1 Month	1 Month + 1 Week	1 Month + 1 Week
Polio	-15°C to -25 °C			
DPT-HB-Hib	2°C to -8 °C			
DT				
BCG				
CAMPAK				
Td				
IPV				
Hepatitis B				Room Temperature

In the previous study [12], we have conducted a simulation of the possibility to replace gasoline with LPG for conventional fleets in Magelang in order to increase the income of the crews and improve passenger services. As a result, it was both economically feasible and technically challenging since the conventional fleets in Magelang City are dominated by old vehicles (made before 2005). In the present time, although the Government through Pertamina (a state-owned corporation) has provided LPG dispensers in Magelang, it still requires significant pre-conversion costs so that the risk of failure can be minimized. In addition, there must be a conversion funding plan that involves cost-sharing between fleet owners, the government, and even CSR from state-owned corporations.

Method

PID for Temperature Control Vaccine Box

The Proportional Integral Derivative controller is a controller to determine the precision of an instrumentation system based on the characteristics of feedback on the system. PID components consist of 3 types, namely Proportional, Integral and Derivative [21]. The three can be used together or individually, depending on the response we want from a plant as seen in Figure 1.

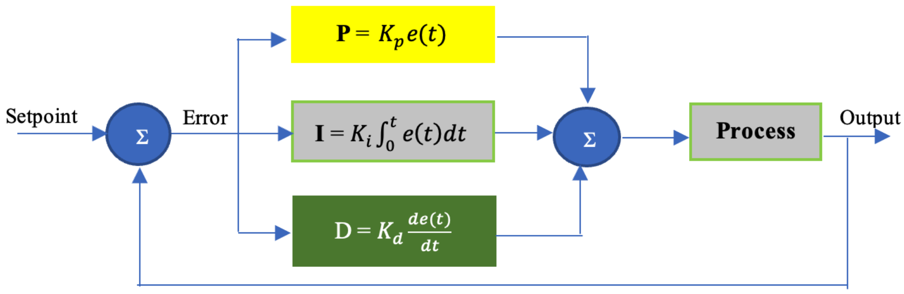

Figure 1. PID Controller [21]

Component of Control Vaccine Box

A thermoelectric cooler is a cooling device that uses a peltier element in its system as a heat pump. The heat pump is produced by the peltier effect which arises from two different metals being connected and the two ends of the metal being kept at different temperatures, apart from that there will be other phenomena that will occur in the two metals, namely the joule effect, fourer effect, peltier effect and thomson effect. When two wires of different materials are connected and one side is heated, a continuous current will flow. The temperature difference that occurs between two conductors of different materials will produce a voltage difference between the two substances. The following is a picture of a peltier element with type tc – 12710 as seen in Figure 2.

Figure 2. Thermoelectric peltier [22]

DS1820 is the latest digital temperature sensor series from Maxim IC, this sensor is capable of reading temperature with an accuracy of 9 -12 bits, range -550C -1250C with an accuracy of (+/- 0.50C) each sensor produced has a unique 64 bit code embedded in the each chip, making it possible to use a large number of sensors using just one cable (single wire data bus). This is an extraordinary component and is the benchmark for temperature-based data logging and control projects out there. Based on the specifications of the DS18B20 sensor, it is a digital sensor that has high accuracy because it can detect changes as small as 0.0012 volts as seen in Figure 3.

Figure 3. Temperature Sensor [23]

In this research, the NodeMCU ESP8266 V3 was used, which is a microcontroller with the addition of a WiFi module. Apart from having memory for storing programs, there is also a digital Input - Output port, an analog input port and ports with special functions such as serial UART, SPI, I2°C. The blynk application is a platform for Mobile OS applications (iOS and Android) which aims to control Arduino, Raspberry Pi, ESP8266, WEMOS D1, and similar modules via the internet.

Results and Discussion

The Box vaccine currently used has a temperature resistance of 2°C - 8°C and only lasts for 1-2 hours. After that, the temperature in the vaccine box only lasts up to 20 °C depending on the strength of the ice gel and the quality of the ice gel. Meanwhile, if you use a thermoelectric temperature control method with the PID method on the vaccine box and monitoring based on the blynk application, you can maintain the highest temperature in the vaccine box at 4°C - 8°C and this system can monitor the temperature via smartphone or on the display on the tool box. With this method, there is no need for ice cubes or ice gel (thermalfreeze) which are often used to cool vaccine boxes which are replaced by thermoelectric. This component is called a peltier on the market. When we start using the vaccine box, the temperature set point can be determined manually or automatically via the set button. the temperature will be processed through the microphone controller. to give orders to the peltier controller so that the peltier can maintain the vaccine box room temperature set at the beginning of determining the setpoint temperature. In this method, a peltier heatsink, exhaust fan and water block are used. The purpose of adding an exhaust fan and water block is to ensure that the hot side of the peltier is not too hot because if the hot side of the peltier is too hot it will affect the temperature produced on the cold side of the vaccine box. Then the temperature will be read by a temperature sensor which will be displayed on the screen, and will be displayed on the smartphone and the blynk application which can help users monitor the temperature in real time without needing to closely monitor the vaccine box. The vaccine box currently used cannot control the desired temperature. This is because in this system the Ziegler-Nichols based PID method is used, here is the room temperature monitored from the vaccine box. The initial room temperature of the vaccine box is 28 °C, and at the 600th second, using this method the vaccine box can stay at 5.81 °C. By maintaining the temperature at 5.81 °C, it is hoped that the vaccine will not be damaged. Temperature testing on the vaccine box can be seen in Table 2.

Table 2. Test results for the temperature output produced by the vaccine box with controller

Time (per 40 sec)	Temperature (°C)	Time (per 40 sec)	Temperature (°C)
0	28,38	320	9,25
40	27,38	360	8,25
80	24,75	400	7,56
120	21,00	440	7,00
160	17,44	480	6,44
200	14,38	520	6,13
240	12,13	560	5,88
280	10,50	600	5,81

PID Parameter analysis

The system response from temperature measurements in the vaccine box, as shown in Figure 4, is used to determine the proportional, integral and derivative values of the PID controller using the Ziegler Nichols method.

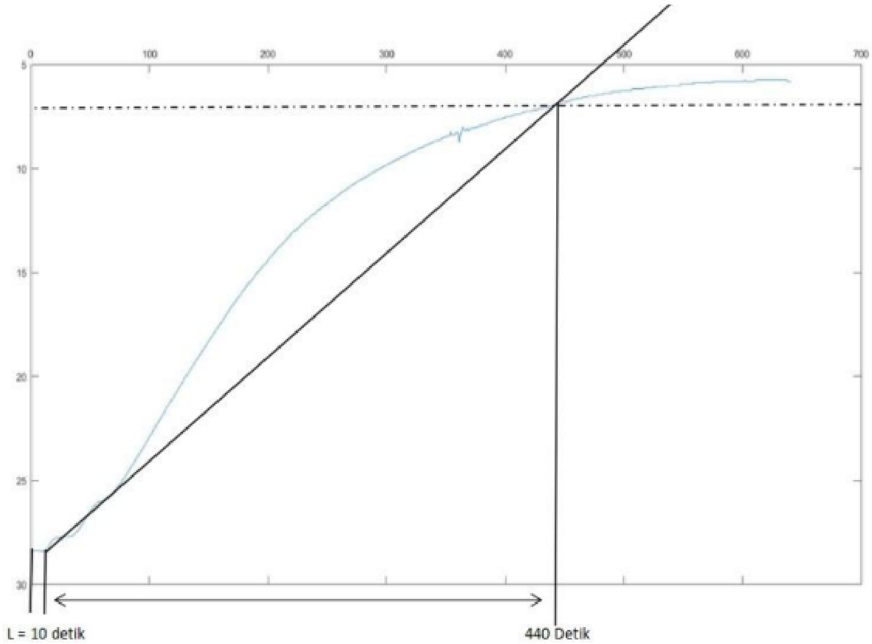

Figure 4. Temperature Graph Response Vaccine Box

The S curve in the system shows the values L = 10 seconds and T = 440 - 10 = 430, so based on the temperature response the parameters Kp, Ti, and Td are obtained as follows:

Kp = 21,5 So the Ki formula is; Ki = Kp/Ti = 21.5/ 20 = 1.08 And the Kd formula is; Kd = Kp/Td = 21.5 / 5 = 4.3

So that after the system is controlled using the PID method, the system response is obtained as shown in Figure 5, which shows that the system can adapt to changing external temperature conditions while using the PID method to maintain the room temperature required for vaccine storage.

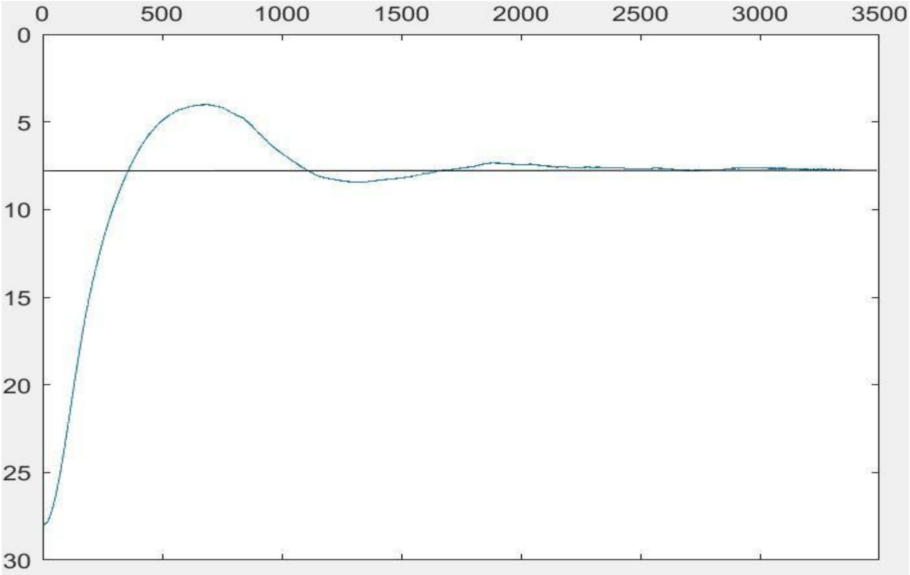

Figure 5. Temperature Graph Response Vaccine Box with PID Method

In the picture above you can see the temperature response using the Ziegler Nichols method at a set point of 6°C which runs for 3385 seconds where the reading at 663 seconds touches the lowest temperature, namely 4°C and slowly rises to 5.68°C approaching the set point temperature. This shows that controlling the thermostat with Pertier components using the PID method works as expected. So, if this method is applied to the vaccine box, it will be able to maintain the room temperature conditions of the vaccine box according to the temperature setpoint which is set according to the temperature standard for the type of vaccine that will be stored in this vaccine box.

Conclusion

Thermoelectric temperature control using the PID method for vaccine storage shows quite good performance, where from the data taken when the simulation was carried out without applying a load, the simulation was carried out for 3385 seconds and the temperature remained at 5.84°C even though there was an overshoot of up to 4°C. in 654 seconds but was able to restore a stable temperature in the required time of 2430 seconds, and had a deviation value of 0.74°C from the setpoint value. To simulate the application of loads or disturbances, 5 vials of dummy vaccine were used at a temperature of 30°C. The simulation lasted for 2350 seconds. The imitation vaccine was administered at the 783rd second. and it takes 1182 seconds to reduce the temperature to 9.44°C, then the vaccine is removed from the box again so that the temperature drops again to 8.75°C until the simulation process is complete. This simulation took 2350 seconds and the deviation value obtained was 1.01°C from the set point. From experiments with loads, the load in question is putting the vaccines in a box. By maintaining the lowest temperature of 5.84°C without the help of ice gel, the vaccine in the box can be maintained until it reaches the destination location. Research to maintain the room temperature in the vaccine box was achieved at 5.84°C using PID control on the peltier, this is in accordance with the main requirement for cooling the vaccine room between 2°C - 8°C.

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