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A study on the design of vaccine cooling boxes for remote and border areas

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Abstract. Immunization is an effort to actively generate/increase a person's immunity to a disease, so that if one day they are exposed to the disease, they will not get sick or only experience mild illness. This is done by administering a vaccine into a person's body. Vaccines used to form antibodies have some susceptibility or weakness to damage. Vaccines have the potential to be damaged when exposed to heat and freezing temperatures. Vaccines should be stored at a temperature between 2 oC - 8 oC continuously. Vaccine storage should not reach the freezing temperature of the vaccine so as not to damage the function of the vaccine itself. Often the temperature of the vaccine increases over long journeys, thereby increasing the exposure of the vaccine to heat. This happens a lot when administering vaccines to remote border areas and islands, especially in border areas. The quiet design of vaccine cooler boxes is important by taking into account the ability to maintain room temperature. Factors that must be considered in designing this include insulating materials, electrical equipment and technology indicators, energy storage media discussed here. Parameters that affect tool performance are also discussed. So with this paper we can learn how to design a vaccine box comprehensively to produce a device that meets health standards.

1. Introduction

Immunization is an action to provide immunity to a disease by giving a vaccine to the body. The immunity in question is the ability to prevent disease or minimize the effects caused by the disease to a person (Kemenkes 2014). This is done by administering a vaccine into a person's body. Vaccines used to form antibodies have some susceptibility or weakness to damage. Vaccines have the potential to be damaged when exposed to heat and freezing temperatures. Vaccines should be stored at a temperature between 2 ^{o}C - 8 ^{o}C Vaccine storage should not reach the freezing temperature of the vaccine so as not to damage the function of the vaccine itself. Often the temperature of the vaccine increases over long journeys, thereby increasing the exposure of the vaccine to heat. This happens a lot when administering vaccines to remote border areas and islands, especially in border areas. The quiet design of vaccine cooler boxes is important by taking into account the ability to maintain room temperature. Factors that must be considered in designing this include insulating materials, electrical equipment and technology indicators, solar energy or energy storage media discussed here. Parameters that affect tool performance are also discussed. So with this paper we can learn how to design vaccine boxes comprehensively including the concept of heat transfer, insulation materials, phase change materials, Thermo Electric Cooling (TEC) and optimization of tool performance to produce equipment that meets health standards.

2. Heat Transfer and Insulation

3. Heat transfer is the transfer of energy that occurs due to a temperature difference between objects or materials. The energy that is transferred is called heat or heat. In a thermoelectric cooling system, heat transfer occurs by conduction and convection. Conduction heat transfer occurs in the heat sink on the hot side of the peltier and on the heat sink on the cold side of the peltier. Meanwhile convection heat transfer occurs in the air that passes through the heat sink, and the air in the room or test equipment.

Conduction heat transfer occurs when there is a temperature difference between two surfaces separated by a solid or fluid. Another requirement of this heat transfer model is that there is no bulk movement of the media, whether it is caused by heat transfer or external equipment. Conduction occurs because of the contact of molecules/particles, and energy moves from molecules/particles that have more energy to particles with lower energy. The average amount of energy that moves per unit time in the conduction process is known as the heat transfer rate q'_{cd} (W/m2) we can calculate using an equation known as Fourier's law.

$$q'_{cd} = -k.A.\frac{dT}{dx} \qquad (1)$$

Where A is the area in the direction of displacement (m^2) and is directly proportional to the temperature gradient dT/dx in the same direction of displacement, where k is the thermal conductivity (W/m.^{o}C). When expressed in heat energy (joules), the equation becomes:

$$Q_{CD} = k.(T_h - T_c) = k.\Delta T \qquad (2)$$

The second heat transfer mode is convection, this heat transfer model takes place between the surface and the medium / fluid that passes through the surface. The movement is not only microscopic as in the conduction heat transfer model, but there is also a macroscopic bulk movement. So that energy transfer takes place through bulk movement of the fluid (advection) and molecular interactions in a natural way or using external equipment such as pumps, blowers, compressors and so on. To calculate the quantity of heat transfer by convection we use an equation known as Newton's law of cooling.

$$q'_{cv} = h.(T_s - T_\infty) \qquad (3)$$

Where:

T_s= Surface Temperature (^{o}C)
T_∞= Fluid Temperature (^{o}C)
h = Convection heat transfer coefficient (W/m^2 ^{o}C)

The third is heat transfer mode is radiation. Thermal radiation is energy emitted by a surface at a finite temperature. In the following discussion, the radiation that occurs is focused on solid materials, although emissions may occur in fluids or gases. Radiant energy is carried through electromagnetic waves in contrast to conduction or convection heat transfer which requires a medium, radiation does not. In fact, the radiation energy transfer process is most effective under vacuum conditions.

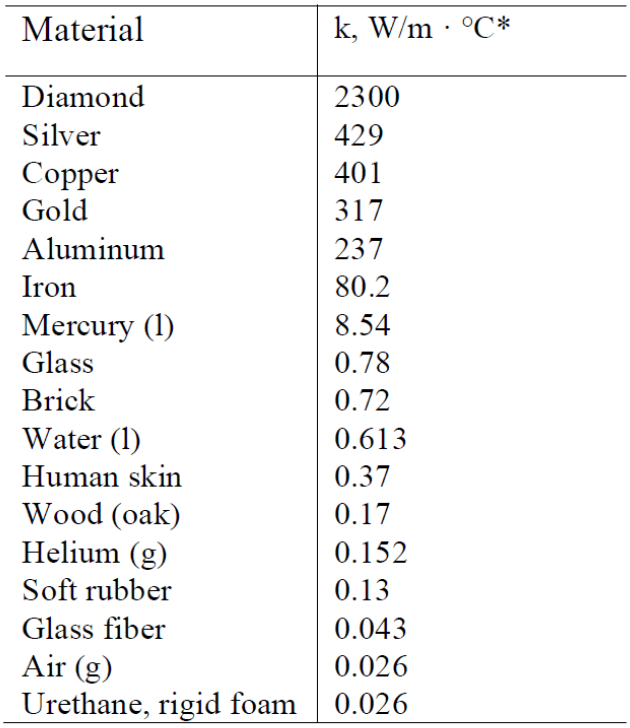
Radiation always travels at the speed of light, 3 x 10^{10} cm/s. Thermal radiation propagation takes place in the form of quantum and each quantum contains energy of :

$$E = h.\nu \;, \qquad h = \text{konstanta Planck, } 6{,}625 \times 10^{-34} \text{ J.s} \qquad (4)$$

In the design of the vaccine box, the material selection is divided into 2. Namely, thermal insulation materials and materials for storing heat in the media so that the cooling effect can be longer or better known as Phase Change Material (PCM).

Understanding thermal insulation in general is a method or a series of processes used to reduce or reduce the rate of heat energy transfer. The energy as described above can be attenuated in several ways, namely conduction, convection and radiation. The amount of heat energy flowing in a material varies, depending on the nature of the thermal conductivity of the material used.

Table 1. Materials thermal conductivity value



Material	k, W/m · °C*
Diamond	2300
Silver	429
Copper	401
Gold	317
Aluminum	237
Iron	80.2
Mercury (l)	8.54
Glass	0.78
Brick	0.72
Water (l)	0.613
Human skin	0.37
Wood (oak)	0.17
Helium (g)	0.152
Soft rubber	0.13
Glass fiber	0.043
Air (g)	0.026
Urethane, rigid foam	0.026

Materials used to reduce the rate of heat transfer are called insulators or insulators (Bergman, Lavine, Incropera 2011). In the process or method, the first step is very important to know the type of insulation so that there are no mistakes in the selection. The ability of a particular solid to conduct heat is called its thermal conductivity or is known as the k factor. To choose a material that has good insulation, the smallest value of k is chosen. The following are several types of insulation materials based on their thermal conductivity values.

3. PCM Material

Phase Change Material (PCM) is generally widely used in cooling systems. This material has a high melting heat, melts and freezes at a certain temperature and has the ability to emit or generate high enough energy. The melting point of PCM ranges from -33 °C to 101 °C with the use of TEA-16, ethylene glycol, n-Dodecane, and water to protect the freshness of products such as fruit, fish, meat or vaccines with melting points ranging from -16 °C , -11.5 °C, -9.6 °C, and 0 °C (Zalba et al. 2003; Sharma et al. 2009; Meng 2008; Agyenim et al 2010).

Materials consist of 3 states, namely solid, liquid and gas, which requires latent heat to change its state. Phase change material is one type of thermal energy storage that is able to maintain temperature for a certain period of time. The external heat is used to break the internal lattice bonds of the PCM material, thus it absorbs a large amount of latent heat at the phase temperature. When the PCM temperature drops below the phase change temperature (sub cooling or under-cooling), this state can be used as a nuclear shield for phase change. Phase reversal begins at the phase change temperature by releasing latent heat back into the environment when conditions are under sub-cooling. For this reason the requirement of sub-cooling conditions for phase change is an important property of PCM (Kuznik, Virgone, and Noel 2008). Figure 1 presents a working phase change scheme of matter in a solid-liquid PCM example.

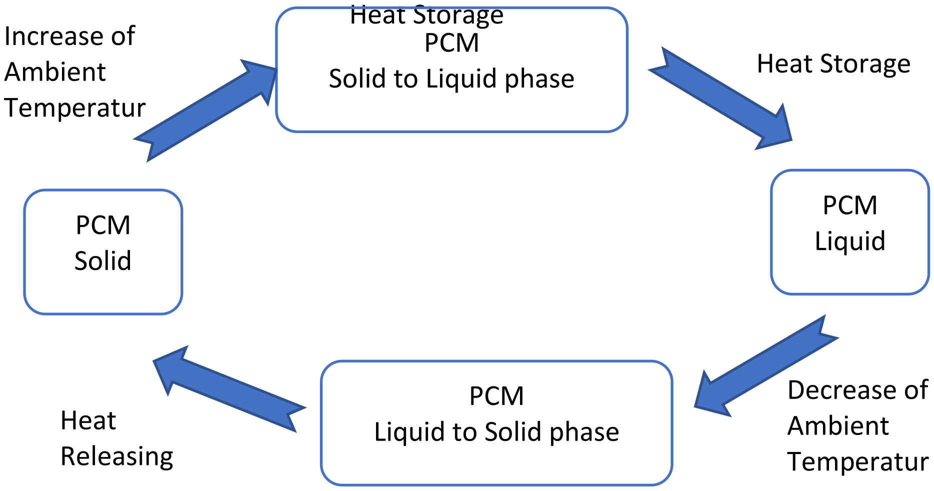


Figure 1. Phase change material working scheme (Kuta, Matuszewska, and Wójcik 2017)

The latent heat of PCM has a high specific heat, therefore PCM can share 2-3 times as much heat or cold per volume or per mass which can be stored as sensible heat in water in a temperature interval of 20 °C.

These types of materials are often classified as inorganic, organic, and eutectic phase change materials, which have been discussed in several papers (Abhat 1983) (Farid et al. 2004), (A. Sharma et al. 2009), (Zhou, Zhao, and Tian 2012), (Kenisarin and Kenisarina 2012), (Li et al. 2013) (Fallahi et al. 2017). A large number of phase change materials can be classified as shown in Fig. 2 below.

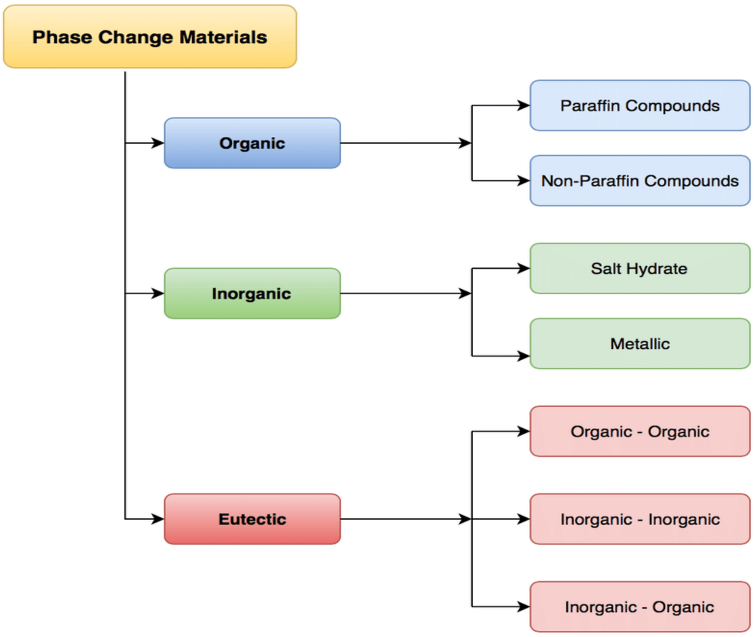


Figure 2. Phase change Material Classification

Solid-liquid material PCM is best suited for thermal energy storage. Solid-liquid PCM consists of organic PCM. A comparison of these different types of PCM is listed in Table 2.

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Table 2. Comparison of various types of PCM (Zhou, Zhao, and Tian 2012)

Classification	Advantages	Disadvantages
Organic PCMs	1. Availability in a large temperature range 2. High heat of fusion 3. No supercooling 4. Chemically stable and recyclable 5. Good compatibility with other materials Inorganic PCMs	1. Low thermal conductivity (around 0.2 W/m K) 2. Relative large volume change 3. Flammability
In Organic PCMs	1. High heat of fusion 2. High thermal conductivity (around 0.5 W/m K) 3. Low volume change 4. Availability in low cost Eutectics	1. Supercooling 2. Corrosion
Eutectics	1. Sharp melting temperature 2. High volumetric thermal storage density	Lack of currently available test data of thermo-physical properties

3.1. PCM thermal stability

PCM requires good stability in latent heat storage. Changes in the thermal properties of the PCM should not be too large after the thermal cycle occurs. Many studies have been carried out on the stability of PCM for salt hydrates, organic mixtures, inorganic mixtures (S. D. Sharma, Buddhi, and Sawhney 1999), (A. Sharma, Sharma, and Buddhi 2002), (Kimura and Kai 1988).

From several researchers, it was found that potential PCM data were identified as having good stability and thermo-physical properties. As, Shukla et al (Shukla, Buddhi, and Sawhney 2008) who tested the thermal cycle on several organic and inorganic PCMs where this test was based on physics, chemistry, thermal and kinetic as shown in Table 3. From several existing research results it can be shown that organic PCM has better thermal stability than inorganic PCM. Tests on the thermal cycle have been carried out by Tyagi and Buddi (Tyagi and Buddhi 2008) for calcium chloride hexahydrate, the results shown are small changes in melting temperature and heat of fusion, only about 1-1.5 C and an average variation of 4% respectively. for 1000 thermal cycles. Calcium chloride hexahydrate is recommended to be a promising PCM for future applications.

Tabel 3. Comparison between the different methods of heat storage (Hasnain 1998)

Property	Rock	Water	Organic PCM	Inorganic PCM
Density, kg/m3	2240	1000	800	1600
Specific heat, kJ/kg	1.0	4.2	2.0	2.0
Latent heat, kJ/kg	–	–	190	230
Latent heat, kJ/m3	–	–	152	368
Storage mass for 106 J, kg	67,000	16,000	5300	4350
Storage volume for 106 J, m3	30	16	6.6	2.7
Relative storage mass	15	4	1.25	1.0
Relative storage volume	11	6	2.5	1.0

3.2. Aplications of commercial PCM

Depending on the application, PCM must first be selected based on its melting temperature. Materials that melt below 15°C are used to keep cool in air conditioning applications, while those that melt above 90°C are used for absorption refrigeration. All other materials that melt between these two temperatures can be applied in solar heating and for heat load leveling applications (Farid et al. 2004). Inexpensive commercial paraffin wax with a medium thermal storage density (200 kJ/kg or 150 MJ/m3) and a wide melting temperature range (Fig. 3a). They undergo negligible subcooling and are chemically inert and stable without phase separation. However, they have a low thermal conductivity (0.2 W/m C), which limits their application. Metal fillers, metal matrix structures, finned tubes and aluminum shavings are used to increase the thermal conductivity (Hasnain 1998).

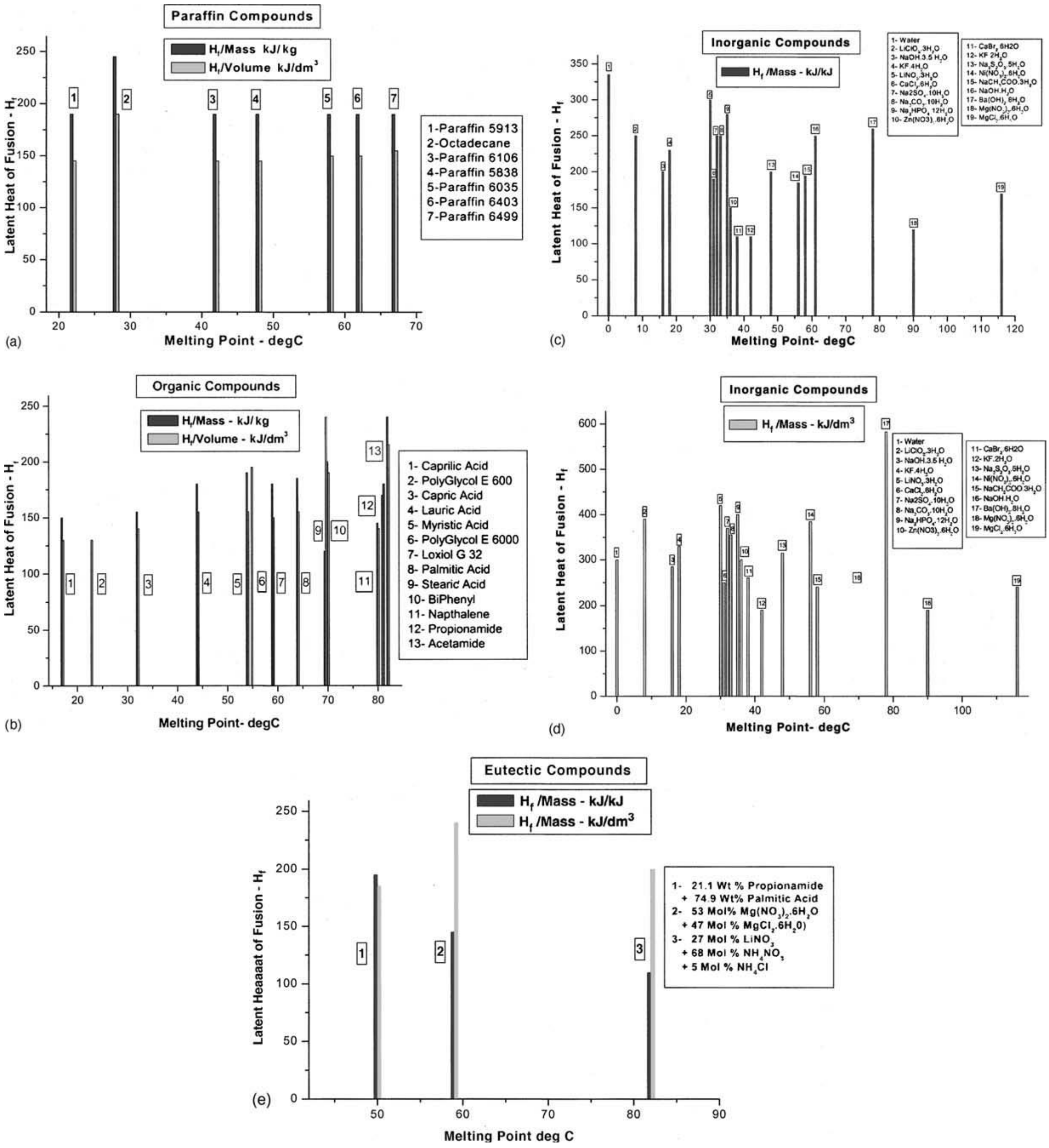


Figure 3. (a) Latent heat of melting of paraffin compounds (Abhat 1983). (b) Latent heat of melting of non-paraffin organic compounds (Abhat 1983). (c) Latent heat of melting/mass of inorganic compounds (Abhat 1983). (d) Latent heat of melting/volume of inorganic compounds (Abhat 1983) . (e) Latent heat of melting of eutectic compounds (Abhat 1983).

4. Termo Electric Cooling (TEC)

The field of thermoelectrics developed rapidly in the 1950s when the basic science of thermoelectric materials became well established, the important role of heavy doped semiconductors as good thermoelectric materials became accepted, and the Bi2Te3 thermoelectric material was developed for commercialization, thus launching the thermoelectric industry. (Dresselhaus et al. 2007).

Thermoelectric modules are integrated circuits in solid form that use three thermodynamic principles known as the Seebeck, Peltier and Thompson effects.

Thermoelectric devices can also convert thermal energy from a temperature gradient into electrical energy—this phenomenon was discovered in 1821 and is called the "Seebeck effect". As mentioned above, when a temperature difference is created between the hot and cold ends of the semiconductor material, a voltage is generated, i.e. the Seebeck voltage. Actually the Seebeck effect is the opposite of the Peltier effect. Based on this Seebeck effect, thermoelectric devices can also act as power generators. (Riffat and Ma 2003)

The thermoelectric construction consists of a pair of p-type and n-type semiconductor materials that form a thermocouple. This module can be used to generate heat and cold on each side if an electric current is used normally applied as a cooling system (Riffat and Ma 2003), (Riffat, Omer, and Ma 2001), for example vaccine cooler boxes (Chatterjee and Pandey 2003), (Putra et al. 2009), (Pourhedayat 2018),(Cuce, Guclu, and Cuce 2020) or to generate electricity when hot and cold are used as the temperature difference (Riffat and Ma 2003), (Pourkiaei et al. 2019).

1.1. Performance modul termoelectrik

To find the performance of the thermoelectric module, it is presented with the equation can be written as below.

$$Q_{sb} = \alpha.I.T_c \tag{5}$$

The symbol alpha α is the average Seebeck coefficient of the thermoelectric material. From this equation we can see the relationship between the rate of heat transfer that is dissipated when flowing with the current. Thermal energy in Joules: The flow of current I produces resistive heating or Joules (Q_J) in a thermoelectric material. This energy is then divided into two, namely Joule heat towards the cold end of 50% and another 50% towards the hot end. Joule heating is given by equation (6) below :

$$Q_J = I^2.R \tag{6}$$

Combining Equations (2), (5), and (6) into an energy balance at the end of the thermoelectric couple gives the following (7) equatioan:

$$Q_c = Q_{sb} - 0.5.Q_J - Q_{CDJ} = [\alpha.I.T_c] - 0.5[I^2.R] - \left[k.A.\frac{\Delta T}{dx}\right] \tag{7}$$

Hence to calculate the energy consumption in this thermocouple pair, the equation is :

$$Q_E = I^2.R + \alpha.I.\Delta T \tag{8}$$

Equation (8) is the standard equation of thermal module performance. This equation shows that a thermoelectric module no longer operates (Qc=0) when the sum of one half the Joule heat (0.5QJ) and the conducted heat (Qcd) equals the Peltier heat (Qsb). The COP of the thermoelectric module for cooling is:

$$\varepsilon = Q_c / Q_E = \frac{Q_{sb} - 0.5.Q_J - Q_{CDJ} = [\alpha.I.T_c] - 0.5[I^2.R] - \left[k.A.\frac{\Delta T}{dx}\right]}{I^2.R + \alpha.I.\Delta T} \tag{9}$$

The magnitude of the optimum (maximum) current at the COP can be written as follows:

$$I_{opt} = \frac{\alpha.\Delta T/R}{\sqrt{1 + Z.Tm} - 1} \tag{10}$$

If the magnitude of the current I is replaced with the optimum current I_{opt} then the magnitude of the optimum COP can be written

$$\varepsilon_{opt} = \frac{T_c}{T_h - T_c} \frac{\sqrt{1 + Z.Tm} - \frac{T_h}{T_c}}{\sqrt{1 + Z.Tm} + 1} \qquad (11)$$

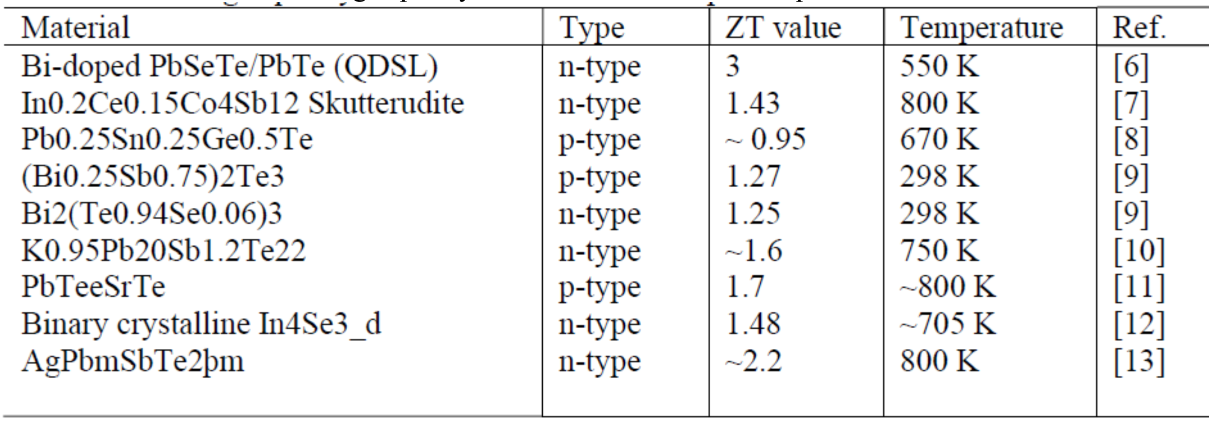
Z is the Seebeck coefficient, R is the electrical resistivity and k is the thermal conductivity. This parameter can be expressed as a dimensionless value by multiplying it by T (T is the average temperature of the hot and cold sides of the thermoelectric module, K).

$$ZT = \frac{\alpha^2.T}{k.R}$$

1.1. Development of thermoelectric materials

With regard to materials containing nanoscale, researchers have found that a good thermoelectric material is the so-called phonon-glass electron-crystal (PGEC) (G. Snyder and Toberer 2008)(Nolas, Poon, and Kanatzidis 2006), in which electrons of high mobility are free to transport charges. and heat but the phonons are disturbed at the atomic scale from heat transport. Some of the main bulk thermoelectric materials are skutterudites, clathrates and Heusler half alloys, which are principally produced by the doping method. Low-dimensional materials, including 2D quantum wells, 1D quantum wires and 0D quantum dots, process the quantum confinement effect of electron charge carriers that can increase the Seebeck coefficient and thus the power factor. Furthermore, the number of interfaces introduced will scatter phonons more effectively than electrons so that the thermal conductivity will decrease more than the electrical conductivity (Dresselhaus et al. 2007). The best commercial thermoelectric materials currently have a ZT value of about 1.0. The highest ZT value in the study was around 3, reported by Harman in 2005 (Harman et al. 2005). Another best reported thermoelectric material has a figure-of-merit value of 1.2e2.2 in the temperature range of 600 - 800 K, as shown in Table 4. It is estimated that a thermoelectric cooler with a ZT value of 1.0 operates at only 10% Carnot efficiency. Approximately 30% Carnot efficiency (comparable to home cooling) can be achieved by devices rated ZT 4. However, increasing ZT to 4 remains a formidable challenge (Disalvo 1999).

Table 4. The high-quality thermoelectric materials reported in this decade



Material	Type	ZT value	Temperature	Ref.
Bi-doped PbSeTe/PbTe (QDSL)	n-type	3	550 K	[6]
In0.2Ce0.15Co4Sb12 Skutterudite	n-type	1.43	800 K	[7]
Pb0.25Sn0.25Ge0.5Te	p-type	~ 0.95	670 K	[8]
(Bi0.25Sb0.75)2Te3	p-type	1.27	298 K	[9]
Bi2(Te0.94Se0.06)3	n-type	1.25	298 K	[9]
K0.95Pb20Sb1.2Te22	n-type	~1.6	750 K	[10]
PbTeeSrTe	p-type	1.7	~800 K	[11]
Binary crystalline In4Se3_d	n-type	1.48	~705 K	[12]
AgPbmSbTe2þm	n-type	~2.2	800 K	[13]

5. Improve cooling system performance and discussion

- In the design of the thermoelectric cooling system, we must take into account the power output of the cooling system and the cooling COP taking into account the performance of the thermoelectric module and the design of the heat sink. Therefore, in fact, the design of the thermoelectric cooling system is a compromise between cooling capacity and COP. There are three methods that lead to the improvement of the performance of the thermoelectric cooling system. The first is through the design and optimization of thermoelectric modules, such as the length of the thermoelements, the number of thermocouples, the ratio of length to cross-sectional area, the slenderness ratio (X(Ap/lp)/(An/ln)) and thermoelements with non-constant cross-sectional area. The second approach deals with the design and thermal optimization of the cooling system, which includes the investigation of the geometry of the heat sink, the allocation of the heat transfer area and the heat transfer coefficient of the hot and cold side heat sinks, the thermal and electrical contact resistance and the analysis of the interface layer, further the effective heat sink (ie heat sink integrated with thermosiphon and phase change material) . The third approach relates to the working conditions of the thermoelectric cooling system (i.e. input amperage, cooling heat sink, and mass flow rate of the coolant. Various system optimization methods have been adopted.. (Y. H. Cheng and Lin 2005) [35] uses genetic algorithms to optimize the physical thermoelement dimensions (length, cross-sectional area and number of thermo elements). (Lineykin and Ben-Yaakov 2007) provides a user-friendly and intuitive graphical approach to thermoelectric refrigeration system design. (Lee 2013b) presents temperature entropy analysis to demonstrate the cooling cycle of thermoelements.General direct approach, instead of the commonly used iterative procedure, to optimize thermoelectric refrigeration Dimensionless analytical method, with the advantage of reducing optimal design parameters, has been carried out in the open literature by several authors Entropy generation number based on thermal conductance to evaluate external irreversibility in thermoelectric cooling systems, taking into account the first law of thermodynamics a and second. A new dimensional group to represent important parameters of thermoelectric devices such as thermal conduction ratio, conduction convection ratio, and load resistance ratio is developed by Lee, 2013 (Lee 2013b). The use of Heat sinks to help increase the heat dissipation on the cold side which causes an increase in the efficiency of the module. The difference in size, temperature and construction causes the power generation potential of a single thermoelectric module to be different depending on the size, will be different. If the temperature difference is getting bigger on the hot side and the cold side, the module will produce a larger voltage and current. Thermoelectric modules can also be connected together either in series or in parallel like batteries to produce voltage or electric current. Each module is capable of producing an average voltage of 1-2V DC and even up to 5V DC depending on the temperature delta variation, in general for one thermoelectric module it produces 1.5-2V DC (Zhao and Tan 2014) .
- Recently, heat sinks with nanofluid have shown potential to achieve lower thermal resistance (Nnanna et al. 2009)(Putra, Yanuar, and Iskandar 2011). In addition, cooling technologies based on heat removal from the heat sinks using synthetic jet or microchannel, either single-phase or two-phase flow, are noticeable.

- The performance of the heat sink on the hot side has a more dominant role than the heat sink on the cold side. This is due to the higher heat flux density on the hot side. The heat transfer area or heat transfer coefficient between the hot and cold sides has an important role. In a thermoelectric module with a certain cooling capacity, the optimal allocation ratio is to achieve maximum COP. Typical allocation ratios generally range from 0.36 - 0.47.
- Model keseimbangan energi yang disederhanakan untuk pendingin termoelektrik dapat memenuhi banyak aplikasi pendinginan termoelektrik seperti pendinginan perangkat elektronik dan AC
- Although p-type and n-type thermoelements have different values of Seebeck coefficient, electrical conductivity, and thermal conductivity in one thermoelectric module, to some extent, these differences are negligible in numerical studies. Therefore, only a set of Seebeck coefficients, electrical and thermal conductivity will be used in the simulation. _ Modeling temperature changes across all thermo elements to capture module performance is complex and time consuming. Energy balance models or compact models can be applied to simplify the numerical study process, especially for modeling systems including heat sinks on the hot and cold sides.
- The Thomson effect affects the Seebeck coefficient with the temperature variable affecting it. The value of the Thomson coefficient can improve the thermoelectric cooling performance by about 5-7% (Chen, Liao, and Hung 2012), If the Thomson coefficient is negative, the cooling performance will decrease (Lee 2013b). In commercial thermoelectric coolers on the market the Thomson effect is small and can be neglected. (G. J. Snyder et al. 2012) . In the development of the Thomson cooler concept and the equivalent ZT approximation a higher hot/cold side temperature difference can be achieved in traditional Peltier coolers.
- The coefficient of performance and cooling capacity depend on the length of the thermoelement. This dependence is seen in the decrease in the length of the thermoelement. If other parameters (such as cross-sectional area) of the thermoelement are constant, then in general, a longer thermoelement length helps to achieve a larger Coefficient Of Performance, and a shorter thermoelement length results in a greater cooling capacity. Most commercially available thermoelectric modules have a thermoelement length range from. 1,0 . 10^3 m to 2,5 .10^3 m. There is an increase in cooling power density when the ratio of the length of the thermoelement to the cross-sectional area decreases.
- The thermal contact resistance at the interface layer of the thermoelement affects the thermoelectric cooling capacity and its COP. An increase in the ZT of a thermoelectric material does not usually result in an increase in the ZT of a thermoelement during the presence of an interface layer (Yamashita 2011).
- For a given hot and cold side fluid temperature, there is an optimal cooling capacity leading to the maximum COP (Lee 2013a). Analisis tanpa dimensi adalah alat yang ampuh untuk mengevaluasi kinerja sistem pendingin termoelektrik. Dimensionless analysis is a powerful tool for evaluating the performance of thermoelectric cooling systems. New dimensionless parameters, such as dimensionless entropy generation number (Zhu and Yu 2017).
- The process and proper installation method play a very important role in providing high-quality thermoelectric modules, and selecting the appropriate module parameters. Current applications of thermoelectric cooling can be categorized into five application areas. First, in the civil market, thermoelectric refrigeration devices are used to cool

household appliances such as domestic and portable refrigerators, portable ice boxes, beverage can coolers and picnic baskets. Second, this technology is also applied to medical, laboratory and scientific applications. cooling equipment for laser diodes or integrated circuit chips. Third, thermoelectric refrigeration devices have attracted great attention for heat dissipation in industrial refrigeration and temperature control electronic devices. All four applications can be found in the automotive industry, such as car mini refrigerators, thermoelectric coolers/heaters in car seats. The last is the use of this technology for domestic thermoelectric air conditioning systems (Putra et al. 2009), (Shen et al. 2013), (Gillott, Jiang, and Riffat 2010), (T. C. Cheng et al. 2011) .

6. Conclusion

This paper presents the design optimization of cooling box devices using Thermoelectric Cooling which is well known today. The heatsink is a new dimension parameter introduced in this thermoelectric technology. Design optimizations include power output for cooling and Coefficient Of Performance which is simultaneously related to the external load resistance and geometry of the thermoelectric element. The optimal design will provide optimal dimensional parameters (thermal conduction ratio, convection convection ratio, and load resistance ratio as well as cooling power, efficiency and temperature at the high and low side joints).

Information about the optimal thermal conductance is very important in the design of microstructured or thin film thermoelectric devices.

This paper also discusses the development of thermoelectric cooling in the material aspect, its modeling and application. Advances in thermoelectric materials through nanotechnology allow for a significant increase in the ZT factor.

This paper also discusses the potential of PCM, where it also offers opportunities for the development of innovative materials by combining energy storage with other functional attributes.

There are three ways to improve performance in the selection of the thermoelectric model, namely first through good design and optimization of the thermoelectric module, Second, namely the design and optimization of the cooling system, third, improving the working conditions of the thermoelectric cooling system.

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