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An Application of Heat Pump for Infant Incubator

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Abstract

The purpose of this study is to develop an infant incubator that is efficient, simple to implement, and can be utilized especially in the rural area of Thailand. Instead of the current one which employed electrical heater, an electrical operated heat pump infant incubator is designed. The requirement of the air conditioning system to provided the room temperature lower than the desired temperature in the incubator (30 - 38 °C) is no longer needed. An electrical operated heat pump infant incubator using a simple four ways control valve will switch the incubator side to become evaporator when the ambient temperature is higher than the desired temperature and, in contrary, condenser when the ambient temperature is lower. A large mass heat exchanger attached to the indoor coils is desired to store energy sufficient that air temperature in the incubator would not drop lower than 0.5 °C from the set point between the compressor cut-out and cut-in. This application of heat pump could provide the opportunity for over six thousand small hospitals in the rural area of Thailand to employ the infant incubator.

Key words : Infant incubator, heat pumps

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Introduction

The heat pumps were employed by number of investigators for various applications. Zyalla *et al.*[1] employed heat pump in drying and dehumidification systems and found that a heat pump assist dryer had advantages over the conventional system. An application of closed loop water source heat pump was shown to be economic for space conditioning by Reiley[2]. Najjar and Radhwan[3] showed the heat pump system gave better performance than a diesel engine system using similar operating conditions. These concepts gave a general idea to apply heat pump system for infant incubator.

The concept of incubator using heat energy was first introduced in China to hatch the chicks, 120 years BC. This concept was conceived and developed to produce infant incubator by American inventors since early eighteen century. Rotch[4] used heat energy from fuel and a water heat exchanger for infant incubators.

In Thailand, Katsing[5] constructed an infant incubator using three 40 watts electric bulbs as a heat source. Most of the infant incubator in Thailand had electrical heater as a heat source. Since the basic concept of this method is to supply heat energy. The necessity of lower environmental temperature than the desired temperature in the incubator chamber is essential condition.

Objective

The major concern of this work is to provide a mobile, electrical operated and easy to maintain infant incubator for the public welfare in the rural area of Thailand. The infant incubator is required to work without controlled surrounding.

Design Consideration

An advantage of heat pump that the evaporator and the condenser could easily exchanged by controlling the flow direction of the refrigerant is considered. Incubator desired for working in tropical climate is particularly important since the specific incubator temperature is higher than the average ambient temperature in summer and, in contrast, lower in winter. Table 1 gives the typical incubator temperature for infants based on weight and age[6].

Table 1. Specific infant physiology data at 50-70% relative humidity

Weight (grams)	Age of Infant (days)			
less than 1000	<10	>10	>21	>35
1000-1500	-	<10	>10	>28
1500-2000	-	<2	>2	>21
2000-2500	-		<2	<14
2500-3500	-			<2
Incubator temperature (°C)	35	34	33	32

Moreover, the economic operating cost is convinced by the high coefficient of performance (COP) of the heat pump.

Apparatus

A full scale prototype was designed, constructed and tested to ensure the suitability for this certain purposed. The infant incubator consists of a clear acrylic incubator chamber of

0.16 m^3 and a heat pump system placed on the mobile frame beneath the chamber. Fresh air and oxygen required (0.57 m^3/min) for infant were supplied through the air inlet holes located at the left hand side of the model. The return air was mixed with fresh air and directed through the stack of leak proof indoor coils. This supplied air with desired temperature is then passed into the chamber.

The designed heat pump system applied the principle of vapor cycle to control the temperature inside the chamber. A 670 Btu/hr reciprocating compressor was used to circulate R-12 refrigerant in the system. An electrical four ways control valve is utilized to regulate the flow direction of refrigerant. The direction is depend on the relative temperature between ambient and desired chamber temperature. Two sets of flow regulated device are provided to make it possible for the system to work as heat pump or refrigerator. Heat is removed or supplied to the system at the indoor and outdoor coils. The required fresh air and the returned air flow through the indoor coils and supplied to the chamber by a cross flow blower. A fan is also provided at the outdoor coils to increase heat conducted.

To reduce temperature fluctuation while the compressor is not working, a large mass heat exchanger, made from aluminum, is attached to the indoor coils. The propose of these aluminum fins is to keep consistent temperature in the incubator with in the limit of ± 0.5 °C from the set point between the compressor cut-out and cut-in.

Function

Figure 1 shows the schematic diagrams of cooling and heating process of a heat pump infant incubator, respectively. The cooling process is activated when the ambient temperature is higher than the desired temperature. Since the lowered temperature is needed, heat is taken from supplied air at the indoor coils (evaporator) to vaporize the refrigerant. The vapor is directed from port 2 to port 4 at the control valve and return to the accumulator. The refrigerant in vapor state is discharged from the compressor and directed from port 1 to port 3 at the control valve. Heat is removed from the system at the outdoor coils (condenser). The refrigerant condensed to liquid state and flow through the flow regulated device (B) to reduce the pressure. Then liquid refrigerant is supplied to the indoor coils to complete the working cycle.

If the ambient temperature is lower than the desired temperature the heating process is applied. The control valve connects the vapor line between port 1 and port 2, and the return liquid refrigerant between port 3 and port 4. This made the outdoor coils become evaporator and the indoor coils become condenser. The reduction of liquid pressure in the liquid line is done by the flow regulated device (A). Heat is supplied to the indoor coils to increase chamber temperature.

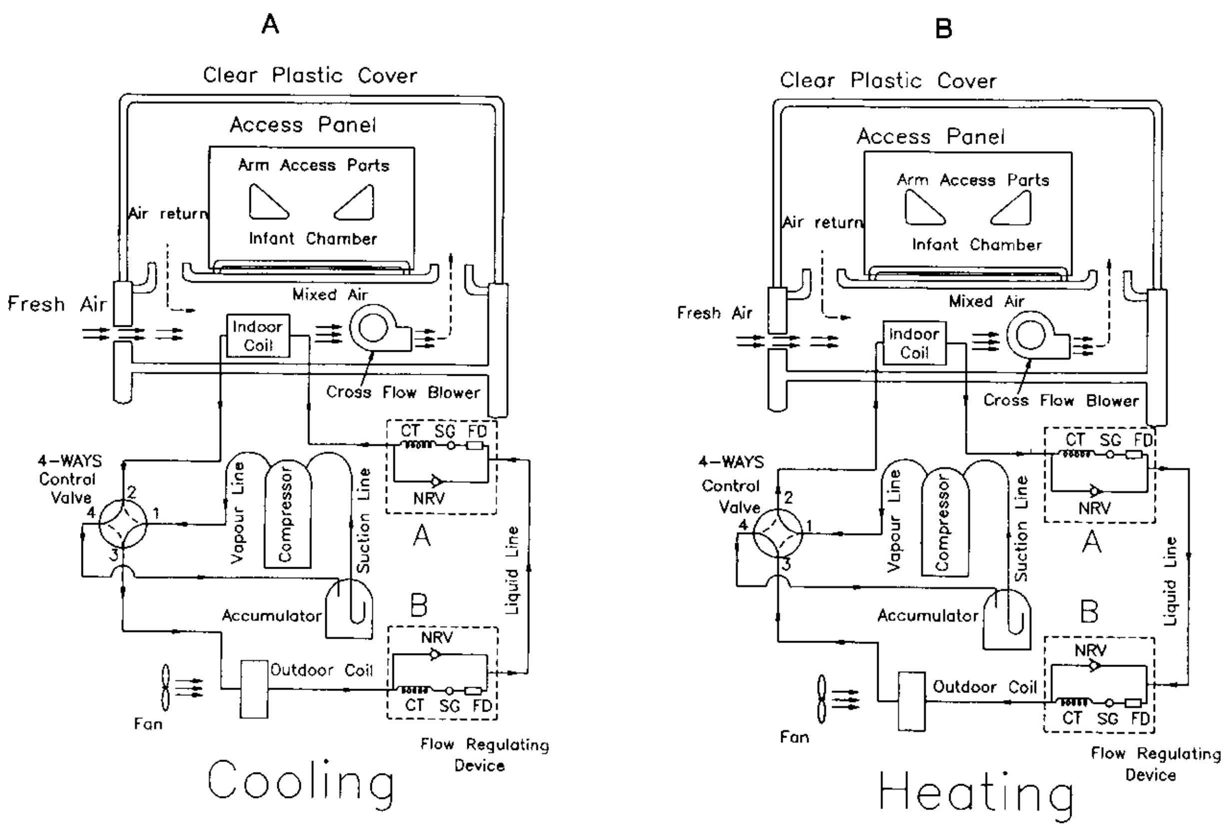

Figure 1. Schematic diagrams of infant incubator for cooling (A) and heating (B) process

Experimental Procedure

The temperature distribution in the incubator chamber is determined using thermisters. Twenty two calibrated thermisters having the resistant of 30 KΩ at 25 °C are located at 25 mm above the base plate of the chamber. The location of the thermisters and the measuring point are shown in Figure 2.

Two sets of examination were conducted for the cooling process at the ambient temperature of 36 °C with the set point at 31 °C and 33 °C. The time respond of the system, the time required from start-up until the temperature in the incubator reach the desired temperature, were determined. The achieved set point temperature was justified from the temperature of return air at measuring point.

For the heating process the ambient temperature is provided at 29 °C. The time respond for three desired set points at 31, 33 and 35 °C were investigated.

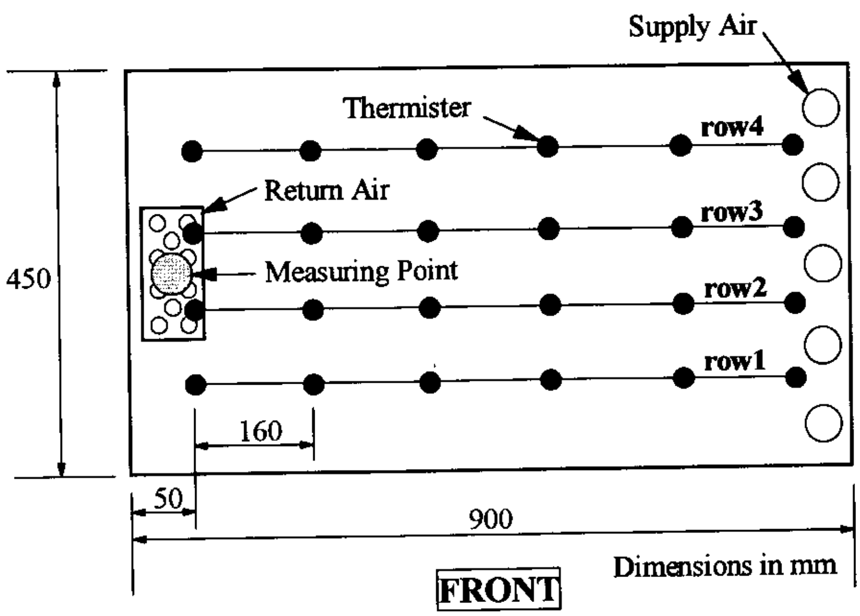

Figure 2. Top view of infant incubator chamber show location of thermisters and measuring point

Results

Figure 3 shows the temperature distribution on the base plate of the incubator chamber. The fluctuation of temperature distribution on row 1, 2 and 3 are observed while on row 4 the temperature is more consistent. These are probably due to the configuration of the chamber used. However, the fluctuation of temperature distribution in the chamber are acceptable since the allowable limit of ± 0.5 °C from the set point were not exceeded.

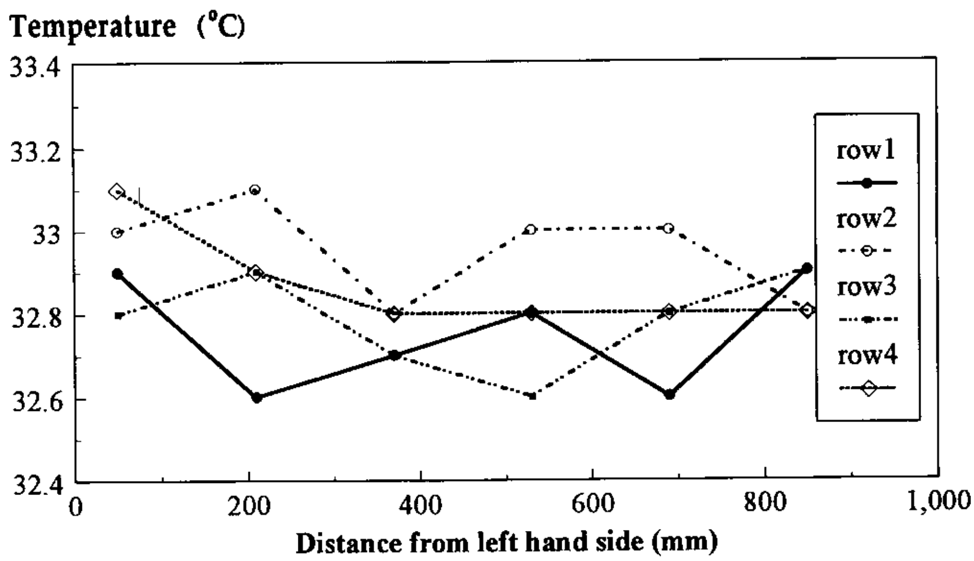

Figure 3. Typical temperature distribution in the chamber at set point 33 °C and ambient temperature at 30 °C

Figure 4. shows temperature in the chamber versus time from the start-up for cooling process having ambient temperature at 36 °C. The respond time were 30 and 50 minutes for the set point temperature at 33 and 31 °C, respectively.

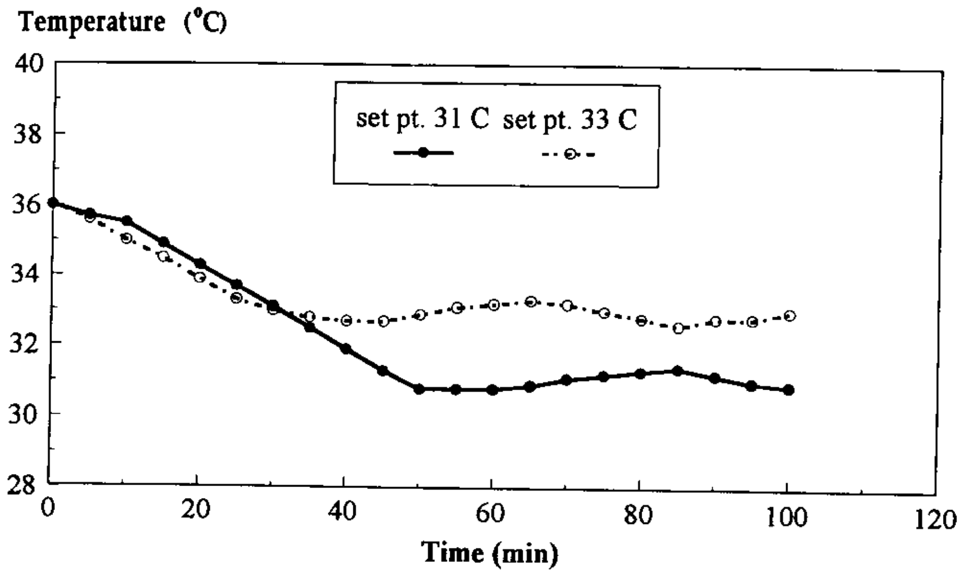

Figure 4. Temperature in the chamber versus time in cooling process at 36 °C ambient temperature

The set point times for heating process are determined from Figure 5. The set point temperature at 31, 33 and 35 °C with the ambient temperature at 29 °C were 15, 35 and 65 minutes, respectively. The set point times for cooling and heating process demonstrated the same tendency that the closer the set point to the ambient temperature the shorter the respond time. However, these respond times were not linearly dependent on the difference between the ambient temperature and the set point.

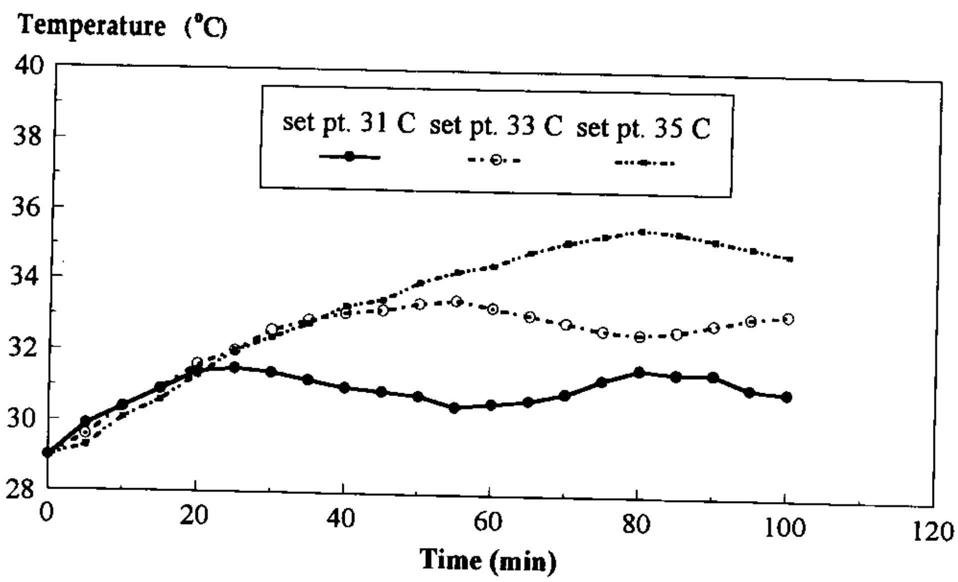

Figure 5. Temperature in the chamber versus time in heating process at 29 °C ambient temperature

Though not mention in the procedure above, the relative humidities in the chamber were also measured for both cooling and heating processes. It was found that, for all the measurement undertaken, the relative humidities were in the range of 50-70%.

Conclusion

This work confirmed the potential of applying heat pump for infant incubator. The functions of the designed infant incubator were satisfied. Some modification are also needed prior to the production. For example, the noise and vibration from the compressor should be lowered and the refrigerant used should be changed to make it more environmental friendly.

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