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Design of cold storage as a storage space for animal vaccines at PT. XYZ

Sigit Yulianto*, Srihanto, Hariyanto, Bantu Hotsan S, Dwi Yulianto

*Faculty of Industrial Technology, Budi Utomo Institute of Technology, Jakarta, Indonesia

*✉ yuliantosigit@yahoo.com

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Abstract: A refrigeration system is a system used to cool a room or an industrial product in the food, pharmaceutical, beverage, vegetable, fruit, and other industries to maintain product quality. One of its uses is as storage for various kinds of pharmaceutical needs, including vaccines for both animals and humans. The problem with cold storage is that existing vaccine storage has been in operation for a long time so it is necessary to study whether it is still able to maintain the vaccine storage temperature, namely -80C. The aim of designing cold storage is to maintain a stable vaccine storage temperature. Because vaccines consist of various kinds of microorganisms that are easy to activate. To maintain the quality of the vaccine, cold storage is needed. The research methodology for writing this thesis is to collect design data from one of the vaccine storage industry companies, and literature studies, then analysis of cooling load planning studies, vaccine storage capacity in cold storage measuring 10 x 10 x m 3 meters and determine the power of the cooling machine using a system. standard vapor compression cooler. The results of the analysis of the refrigeration system planning study showed that the indoor vaccine capacity was 30,600 bottles or 2056,701 lbs (822,680 kg), storage temperature -80C, cooling load 308,133 Btu/hr, or 90,283 W, this system uses R 134 A refrigeration. Using refrigerant, power compressor 23.32 kW, or 32 HP, COP 3.9.

Keywords: Design; cooling system; vaccine; storage temperature

1. INTRODUCTION

Vaccines are inactivated or weakened antigens (microorganisms) that, when given to healthy people, produce specific antibodies [1]. Vaccines are biological preparations used to produce adaptive immunity against certain infectious diseases [2]. When a vaccine is given to humans, it will have an immune effect against a disease so that it can prevent or reduce the effect of natural or "wild" infection [3].

When vaccines are given to humans, they will have an immune effect. A vaccine is an antigenic material that is used to produce active immunity against a disease so that it can prevent or reduce the effects of natural or "wild" infection [4]. The vaccine can be a strain or one that has been weakened so that it does not cause disease [5]. Vaccines can also be in the form of dead organisms or the products of their purification (etc.). Vaccines will prepare or defend against certain attacks, especially bacteria and viruses. Vaccines can also help the immune system fight degenerative cells.

Like humans, livestock are also susceptible to various types of diseases, both infectious and non-infectious [6]. Vaccination is one way to prevent certain diseases [7]. The aim of vaccination is essentially to provide antibody immunity to livestock so that they can fight antigens or micro-organisms that cause disease [8]. Vaccination is the administration of antigens to stimulate the immune system to produce special antibodies against diseases caused by viruses, bacteria, and protozoa. As is known, diseases in livestock are divided into infectious diseases and non-infectious diseases.

Vaccination aims to provide antibody immunity to livestock so that they can fight antigens or micro-organisms that cause disease [9]. Vaccination provides antigens to stimulate the immune system to produce special antibodies against diseases caused by viruses, bacteria, and protozoa [10]. As is known, diseases in livestock are divided into infectious diseases and non-infectious diseases.

To keep the vaccine active, the temperature of the vaccine needs to be maintained in a cooler with a temperature between 2ºC to 8ºC [11]. Certain types of vaccines must be kept at temperatures below

–15ºC. Vaccine storage is one of the storage systems needed to maintain vaccine quality. The main problem with storing vaccines at room temperature is quality degradation. So it is necessary to store the vaccine according to the character of the vaccine [12].

When storing vaccines, so that their quality is maintained and damage does not occur, storage at a cold temperature is required depending on the specifications of the vaccine [13]. PT. XYZ, which is located in the Cileungsi area of Bogor, is a company that operates in warehousing including storing veterinary medicine vaccines. This company, with a warehouse area of 180 x 170 meters, operates in the warehousing sector, one of which is storing vaccines and veterinary medicines. The vaccine is stored in cold storage with an average size of 10 x 10 x 3 meters. Consists of 14 cold storages. So far, this cold storage was built 15 years ago, so some are still operating and some are no longer operational. This research aims to determine the vaccine storage capacity in cold storage so that the quality of the vaccine remains safe

2. METHOD

Explain the analytical framework for completing this thesis, a flow diagram was created according to

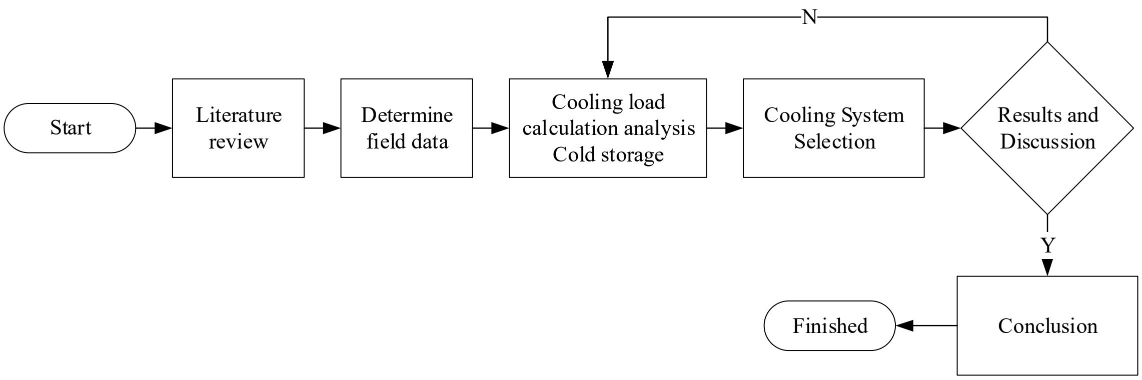

Figure *1*.

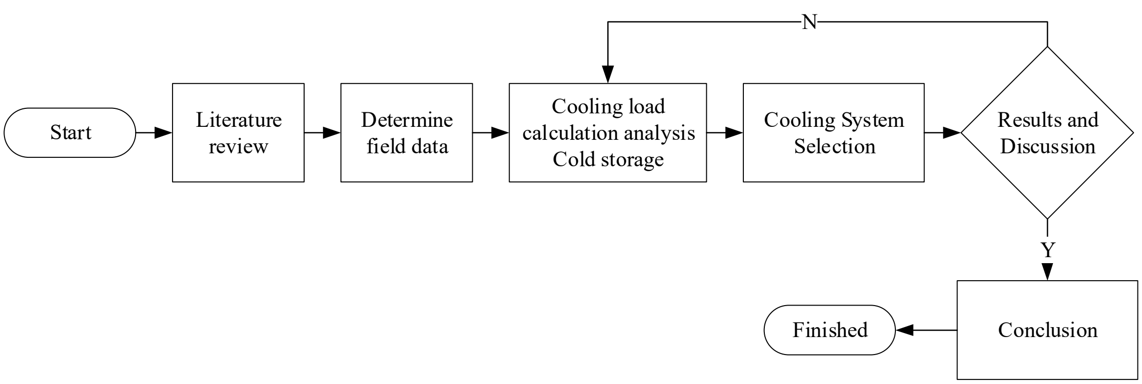

Figure 1. Flow diagram of cold storage design study.

Reference Study: In analyzing the design study of cooling loads and compressor power in cold storage, we use references from various books, scientific journals, websites, and field studies to obtain planning data and analyze cooling loads and compressor power.

Determining field data: From the results of the search for field data, various aspects have been obtained that support the data analysis of the planning study for calculating the vaccine cooling load in cold storage at PT. XYZ.

Cold storage construction data: a) Number of people in the room: 5 people. b) Shelf for storing vaccines: 6 units, c) 36-watt lamp: 3 units, d) 1 Unit door, with dimensions 1 m x 2.5 m = 1 unit. e) Cold storage dimensions: Length = 10 meters, width = 10 meters, height = 3 meters. f) Wall, roof, and floor thickness 154 mm, g) Walls are made of 3 layers, namely: Aluminum sheet, Styrofoam (Polyurethane), and steel plate (Stainless steel).

Temperature data for cold storage planning studies: a) Planned indoor temperature = -8oC, b) Outdoor temperature = minimum 21, maximum 34oC, c) Planned RH = 55%. d) outdoor RH = minimum 60%, maximum 80%.

Analysis of cooling load calculations. Cooling loads are 1. Sensible loads: a) Heat transmission through building materials, through roofs, walls, and glass. b) Partitions, ceilings, and floors. c) Solar radiation. d) Heat from lighting or lamps. e) Radiant heat from the occupants of the room. f) Heat from additional equipment from the room. g) Heat from the electromotor. h) Air change or infiltration ventilation load. 2. Latent heat load: a) Heat from room occupants. b) Heat from ventilation air or room infiltration. 3. Ventilation and infiltration: a) Addition of sensible heat due to differences in internal and external air temperatures (leakage). b) Addition of latent heat due to humidity in the inside and outside air.

In determining the compressor power: Determine the type of refrigerant used (R134a) determine the engine work and at a certain temperature according to the manufacturer then determine the enthalpy price according to the refrigerant table used and analyze to determine the compressor power.

3. RESULTS AND DISCUSSION

Analyze the vaccine cooling load in the cold storage room, data is needed in the design. Data from observations of cold storage construction: a) Number of people in the room = 5 people. b) Racks for placing vaccines = 6 units, c) 36 Watt lamps = 3 units. d) 1 unit door, measuring 1 m x 2.5 m = 1 piece. e) In the middle the polyurethane material is thick = 15 mm. f) Coated with stainless steel plate: 2 mm. g) Dimensions in cold storage = 10 x 10 x 3 meters. h) Thickness of walls, roof, and floor = 154 mm. i) The walls are made of 3 layers, namely = Aluminum sheet, Polyurethane, and Stainless steel. j) Floor Material: Stainless Steel (L3) 2 mm thick. k) In the middle the thick polyurethane material (L4) is 10 mm.

Temperature data for cold storage planning study: 1) Products stored in cold storage are animal vaccines. 2) Planned indoor temperature = -8oC. = -8 x9/5 +32oF= 17.6oF. 3) Outdoor temperature = minimum 21°C, maximum 34°C = 32 x 9/5 +32°F= 93.2°F. 4) Planned RH = 55%. 5) Outdoor RH = minimum 60%, maximum 80%.

Vaccine product data: Vaccines stored in packaging with bottles measuring: 1) Height = 135 mm. 2) Diameter = 60 mm. 3) 1 box = 100 bottles. Cooling load from outside: Apart from the heat load on vaccine products stored in cold storage, the load from outside the cold storage through the walls, roof, and floor is also calculated, this is because the air temperature from outside is very high, so heat propagates through the walls. The amount of heat load flowing through walls, roofs, and doors can be calculated using Equation 1.

$$Q = A \times U \times (D + Sun\ Factor) \times 24 \tag{1}$$

Where:

Q = Amount of heat load flowing (Btu/hr).
A = Surface area (ft^2).
U = Total heat transfer coefficient (Btu/hr.ft^2.°F).
D = The difference in outside and inside temperature (°F).

Determine the area of the wall:
The dimensions in cold storage are: $100 \times 100 \times 3$ m ($32{,}8 \times 32{,}8 \times 9{,}84$ ft).

Door 1 unit size $1 \times 2{,}5$ m ($3{,}28 \times 8{,}2$ ft)

If 1 m = 3.28 ft then:

Floor and roof area (A) = $32{,}8 \times 32{,}8 = 1075{,}84$ ft^2.

Back and side wall area (A) = $32{,}8 \times 9{,}84 = 322{,}75$ ft^2.

Front wall area = wall area – door area = $(32{,}8 \times 9{,}84 \text{ ft}) - (3{,}28 \times 8{,}2 \text{ ft}) = 332{,}75 - 26{,}9 = 305{,}85$ ft^2.

Determine the total heat transfer coefficient of the wall (Btu/hr.ft^2.°F).

The materials used for walls, roofs, floors, and doors in this cold storage analysis are the same, consisting of an aluminum coated outside, then polyurethane inside [14]. The heat transfer coefficient (U) of cold storage walls can be calculated using equation 2.

$$U = \frac{1}{\frac{1}{f_1}+\frac{x}{k_1}+\frac{x}{k_2}+\cdots+\frac{x}{k_n}+\frac{1}{f_o}} \tag{2}$$

Where:

U = Total heat transfer coefficient of the wall (Btu/hr.ft^2.°F).

$\frac{1}{f_1}$ = Convection coefficient of the air film layer on the inner wall of the material.

x = Material thickness (in).

$k_{1,2}$ = Thermal conductivity of the material (Btu/hr.ft^2.°F).

$\frac{1}{f_0}$ = Convection coefficient of the air film layer on the outer wall of the material.

The construction of walls, roofs, floors, and doors in the design of this cooling box car can be seen in Figure 2 and Table 1.

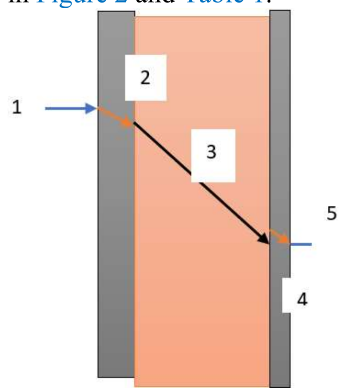

Figure 2. Thick sections of walls, roofs, floors, and cold storage doors (1) Outer layer, (2) Steel plate, (3) Polyurethane, (4) Aluminum, and (5) Inner air layer.

Table 1. Material thermal conductivity value (k).

No.	Material	Thick (x) (inch)	mm	K (Btu inch/hr.ft.°F)
1	Outer air layer	-	-	1,65
2	Steel plate	0,079	2	555,96
3	*Polyurethane*	5,9	150	0,26
4	Aluminum	0,079	2	2,10
5	Inner air layer	-	-	4

Based on the data in Table 1, the heat transfer coefficient (U) values for walls, roofs, floors, and doors can be calculated using Equation 3.

$$U = \frac{1}{\frac{1}{1,65}+\frac{0,079}{555,96}+\frac{5,9}{0,26}+\frac{0,079}{2,100}+\frac{1}{4}} \tag{3}$$

$$U = \frac{1}{23,59}$$

U = 0,042 Btu/hr.ft^2.°F

Determining the price of the solar heat factor (sun factor)

Cold storage is designed to be moveable (can be outside a building or room), so the solar heat factor needs to be taken into account or added. All parts of the cold storage, both walls and roof, are designed using white. Based on Table 2. Allowance for solar radiation, for white roofs and walls.

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Table 2. Allowance for solar radiation.

No.	Type of Surface	East Wall	South Wall	West Wall	Flat Wall
1	Dark-colored surface such as: Slate roofing Tar roofing Black paints	8	5	8	20
2	Medium-colored surfaces such as: Unpainted wood Brick Red tile Dark cement Red, grey, or green paint	6	4	6	15
3	Light colored surfaces such as: White stone **Light colored** Cement White paint	4	2	4	9

According to Table 2 solar factor price.

a. Roof : 9°F
b. Wall : 4°F

The amount of heat load on the wall.

1) The heat load on the west wall is calculated using Equation 4.

$$Q_{west} = A \times U \times (D + \text{Sun Factor}) \times 24 \tag{4}$$
$$= 322{,}75\ \text{ft}^2 \times 0{,}042\ \text{Btu/hr. ft}^2\text{°F} \times [(93{,}2 - 17{,}6\text{°F} + 4)] = 25.896{,}43\ \text{Btu/24 hr.}$$

2) Heat load through the east wall (Equation 5)

$$Q_{east} = A \times U \times (D + \text{Sun Factor}) \times 24 \tag{5}$$
$$= 322{,}75\ \text{ft}^2 \times 0{,}042\ \text{Btu/hr. ft}^2\text{°F} \times [(93{,}2 - 17{,}6) + 4] \times 24 = 25.896{,}43\ \text{Btu/hr}$$

3) Heat load through the front (north) wall with Equation 5:

$$Q_{front} = Q_{north} = A \times U \times (D + \text{Sun Factor}) \times 24$$
$$= 305{,}85\ \text{ft}^2 \times 0{,}042\ \text{Btu/hr. ft}^2\text{°F} \times [(93{,}2 - 17{,}6\text{°F} + 2)] \times 24$$
$$= 23.923{,}83\ \text{Btu/24 hr.}$$

4) Heat load through the back wall (south) with Equation 5:

$$Q_{behind} = Q_{south} = A \times U \times (D + \text{Sun Factor}) \times 24 = 322{,}75\ \text{ft}^2.$$
$$\text{ft}^2 \times 0{,}042\ \text{Btu/hr. ft}^2\text{°F} \times [(93{,}2 - 17{,}6\text{°F}) + 2] \times 24 = 25.245{,}76\ \text{Btu/24hr.}$$

5) The heat load through the roof is calculated using Equation 5:

$$Q_{roof} = A \times u \times (D + \text{Sun Factor}) \times 24 = 1075{,}84\ \text{ft}^2 \times 0{,}042\ \text{Btu/hr. ft}^2.$$
$$\text{°F} \times [(93{,}2\text{°F} - 17{,}6\text{°F}) + 9] \times 24 = 91.744{,}20\ \text{Btu/24 hr}$$

6) Heat load through the floor is calculated using Equation 5.

$$Q_{floor} = A \times U \times (D + Sun\ Factor) \times 24 = 1075{,}84\ ft^2 \times 0{,}042\ Btu/hr.ft^2$$
$$\text{°F} \times [(93{,}2\text{°F} - 17{,}6\text{°F})] \times 24 - 81.984{,}17\ Btu/24\ hr.$$

7) Heat load through the door, analyzed using equation 5: Where door size = 1 x 2.5 m or 3.28 ft x 8.2 ft = 26.9 ft^2. The door faces north with the same material as the wall.

$$Q_{door} = A \times U \times (D + \text{Sun Factor}) \times 24$$
$$= 26{,}9\ \text{ft}^2 \times 0{,}042\ \text{Btu/hr. ft}^2.\text{°F} \times [(93{,}2\text{°F} - 17{,}6\text{°F}) + 2] \times 24$$
$$= 2.003{,}94\ \text{Btu/24 hr}$$

The total heat load through walls, roofs, floors, and doors is ($Q_{outside}$) can be seen at Table 3.

Table 3. The total load from outside through walls, roofs, floors, and doors.

No.	**Partition**	**Heat load (Btu/24 hr)**

1	West wall	25.896,43
2	East wall	25.896,43
3	North Wall (front)	23.923,83
4	South Wall (rear)	25.245,76
5	Roof	91.744,20
6	Floor	81.984,17
7	Door	2.003,94
8	The amount of heat through the barrier (outer Q)	276.694,76

Heat load from inside the room

The heat load in the cold storage room consists of the load of people working in the room, the load of electricity or equipment including lights and others, the load of refrigerated vaccine products, and the load of indoor air changes.

Heat load of people working in cold storage

In the cold storage, the same people work to take, remove, and put the vaccine into the room so that heat is released from the body of the person working. The person working in the room cannot stay for long because, in the cold storage, the temperature is -8 ºC. Calculate the heat load of workers, using Equation 6.

$$\mathrm{Q_{people}} = F \times N \times 24\,hr \tag{6}$$

Where:
Q_{people} = Heat load from people/workers (Btu/h).
Factor = The heat factor of the human body.
Number of People = Number of people/workers.

The human body's heat equivalent factor for cold storage temperature is 17.6°F (-8°C) after interpolation of 1086 Btu/hr. Then the heat load released by workers can be calculated using equation 6.

$$\begin{aligned}\mathrm{Q_{people}} &= 1086 \times 5 \times 4(\mathrm{Btu/24\ hour}) \\ &= 21.720\ \mathrm{Btu/24\ hour}\end{aligned}$$

Heat load of electrical equipment

The load of electrical equipment in cold storage includes lights and evaporator air fans, Equation 7.

1) Fan motor load

$$Q_{fan} = Watt \times 3{,}42 \times 24\ hour \tag{7}$$

Where:
Watt = Electrical equipment power (watts).
= There are 4 units of double motor air fan 36 Watt/unit
= 36 x 4 = 144 Watt
3,42 = Times factor (Btu/watt hr).
hr = How long the equipment has been working.
Q_{fan} = 144 x 3,42 x 24 = 11.819,52 Btu/24hr

2) Heat load from the lamp

It is planned that the cold storage will use 3 LED lights with a power of 36 watts. The amount of cooling load from the lamp can be calculated using Equation 7.

$$\begin{aligned}\mathrm{Q_{lamp}} &= (3 \times 36) \times 3{,}42 \times 24 \\ &= 8.864{,}64\ \mathrm{Btu/24\ hr}\end{aligned}$$

The heat load from air exchange/ventilation

To provide fresh air in the cold storage room, ventilation is needed to exchange air from inside with air from outside, or what is called ventilation. The amount of heat load from air exchange can be calculated using Equation 8.

$$Q_{\text{ventilasi}} = V \times ACL \times ACF \tag{8}$$

ACL = *Air Change Load* (Btu/24hr).
= 3.01 at 10000 Volts ft^3
V = Internal room volume (ft^3).
= $(32{,}8 \times 32{,}8 \times 9{,}84 \text{ ft}) = 10.586{,}27 \text{ ft}^3$
ACF = *Air Change Factor*
= On temperature -8 °F, RH 60% = 3, 07 [19]
$Q_{\text{ventilation}}$ = $10.586{,}27 \text{ ft}^3 \times 3{,}1 \times 3{,}0$
= $98.452{,}31 \text{ Btu/24 hr}$

The heat load of vaccine products

The heat load of the vaccine is calculated based on the storage temperature, namely: 17.60 ft, and vaccines stored in cold storage are calculated using equation 9.

$$Q_{\text{vaccine}} = m \times c \times (t_2 - t_1) \tag{9}$$

Where:
m = Product weight (lb).
c = Specific heat of beef (Btu/lb/°F).
t_2 = Cooling room outdoor temperature (°F).
t_1 = Temperature in the cooling chamber (°F).

1) Product weight analysis (m):
   - Cold storage dimensions = 10 x 10 x 3 meter.
   - In cold storage, 6 shelving units are installed. namely: 3.28 ft wide. 322.8 ft long arranged on a shelf height of 98.4 ft so there are 3 layers of shelves.
   - Number of shelves = 6 x 3 = 18 shelves.
   - The size of the vaccine bottle is stored in a styrofoam box
   - With 1 box 0.6 x 0.6 m = 100 vaccine bottles
   - High vaccine bottle size; 135 mm (0.45 ft), diameter = 60 mm (0.20 ft)
   - Vaccine volume/content = $\frac{1}{4}\pi d^2 \times t = 0{,}785(0{,}06)^2 \times (0{,}135) = 0{,}038151\, m = 38151\, cm^3 (cc)$
   - Where 1 shelf consists of = 17 *boxes*.
   - The cold storage capacity = 18 shelves x 17 boxes = 306 vaccine boxes or = 306 x 100 = 30,600 vaccine bottles.
   - Vaccine volume = $30600 \times 0{,}038151 \text{ m}^3 = 41.183 \text{ ft}^3$(when $1 \text{ m}^3 = 35.29 \text{ ft}^3$
   - The total weight of the vaccine is the specific gravity of the vaccine = $49{,}942\, lb/ft^3$ $m_{vaccine} = 41.183\, ft^3 \times 49{,}94\, lb/ft^3 = 2.056.701\, lb.$
   - Vaccine-specific heat = 0,4 Btu/lb/°F.

Then the heat load of the vaccine:
$Q_{\text{vaksin}} = m \times C \times (t_2 - t_1)$
$= 2.056.701 \text{ lb.} \times 0{,}4 \text{ Btu/lb°F} \times (93{,}2 - 17{,}6)\text{°F} = 6.219.463 \text{ Btu/24 hours}$

Styrofoam box heat load as a place for beef

The vaccine vial is packaged in a styrofoam box where this material needs to be cooled so it needs to be analyzed. The heat load of the packaging can be calculated using Equation 10.

$$Q_{packaging} = W \times C \times (t_2 - t_1) \times 24\, hours \tag{10}$$

Where:

Q = Amount of heat (Btu/h).
W = The weight of the Styrofoam box (lb).
C = Styrofoam box type heat (0,27 Btu/lb°F).
t_2 = Styrofoam box temperature (93,2°F).
t_1 = Refrigeration cold storage temperature (17,6°F).

Number of boxes = 306 vaccine boxes, the weight of one styrofoam box is 0.4 kg (0.88 lb). Table 4 the heat load of the packaging:

$$Q_{kemasan} = (306 \times 0{,}88\, lb) \times 0{,}27\, Btu/lb°\mathrm{F} \times (93{,}2 - 17{,}6°\mathrm{F}) \times 24$$
$$= 97{,}716\, Btu/24\, hr$$

Table 4. Heat load in vaccine cold storage.

No	Source of Heat Load Cooling	Heat load (Btu/24hr)
1	Worker load	21.720,0
2	Electrical equipment load	8.864,64
3	Air exchange load	98.452,31
4	Vaccine product load	6.219.463,8
5	Packaging load	97.716,0
The number of fools in the room (Q_{inside})		**6.446.216,8**

The total load from cold storage is the external heat load plus the internal heat load, as appropriate in Table 5.

Table 5. Total cooling load.

No	Source of cold storage heat load	Heat load (Btu/24 hr)
1	Heat load from outside ($Q_{outside}$)	276.694,76
2	Heat load from within (Q_{inside})	6.446.216,8
3	Total heat load (Qt)	6.722.911,6
4	Number of loads (Btu/hr) = Qt/24	280.121 Btu/hr.

The total heat load of cold storage (Btu/hour):

$$\mathrm{Qhr} = \frac{\mathrm{Qt}}{24} = \frac{6.722.911{,}6}{24} = 280.121\ \mathrm{Btu/day}$$

Maintain fluctuations in heat load, a safety factor of 10% of the load is added to the cold storage load:

$$Q_{cold\ storage} = Qhr + 10\%\, Qhr = 280121 + 18012$$
$$= 308.133\, Btu/hr$$
$$= 308.133 \times 0{,}293 = 90.283\ \mathrm{Watt}$$

The load in tons of refrigerant: $\left(\mathrm{Q_{cold\ storage}}\right)$

$$\mathrm{Q_{cold\ storage}} = \frac{308133}{12000} = 25{,}68\ \mathrm{TR}$$

Analysis of cooling machine energy requirements

One component that requires a lot of energy is the compressor. The function of the compressor in the cold storage refrigeration system is to suck refrigerant from the low-pressure side and press it towards the high-pressure side [15]. The compressor is the heart of the cooling machine.

When choosing a cold storage cooling system, you must pay attention to the temperature required for storage, namely -80C. Cooling heat loads, installation, operations, and economic factors, namely initial costs, operational, costs, and maintenance costs. The operational and maintenance factors include 1) Simple construction and easy to install. 2) Long lasting. 3) Easy to repair when there is damage. 4) Easy to get on the market. 5) Can accommodate changes in operating conditions. 6) High efficiency.

Selection of refrigerant (cooling fluid)

In selecting the refrigerant used in the cold storage machine, the refrigerant temperature in the evaporator is planned to be -8ºC and the temperature in the condenser is 32ºC (ambient temperature). 1) Cooling temperature in the cold storage evaporator -8oC–8ºC = -16ºC. 2). Meanwhile, the coolant temperature in the condenser is 32+8 = 40ºC. 3) Cooling machines usually use heat exchange, namely by sub-cooling, or the temperature in the condenser is reduced by 5ºC and the sub-heating temperature of the refrigerant in the evaporator is added by 5ºC. (9ºF). 4) so that the refrigerant in the condenser is T_cond=40°C-5°C=35°C.(95°F). The temperature in the evaporator is the evaporation temperature of the refrigerant, where in the evaporator heat absorption occurs so that the temperature in the evaporator must be colder than the air in the cold storage, namely -8ºC. Then the evaporator temperature is planned.

$$T_{evap} = -16°\text{C} + 5°\text{C} = -11°\text{C}\ (12°\text{F})$$

Then the planning temperature of the cooling machine:

$$T_{cond} = 35°\text{C}\ (95°\text{F})$$
$$T_{evap} = -11°\text{C}\ (12°\text{F})$$

Figure 3 The type of refrigerant used on the market is a hydrocarbon or R 134 a. We can determine the enthalpy value for temperature using the pressure (P)–enthalpy (h) diagram or the R 134a Refrigerant table and interpolate so that the enthalpy value is known on the R 134a refrigerant diagram. The following is a diagram of refrigerant pressure vs Enthalpy R 134 A:

P-H R 134 A refrigeration diagram.

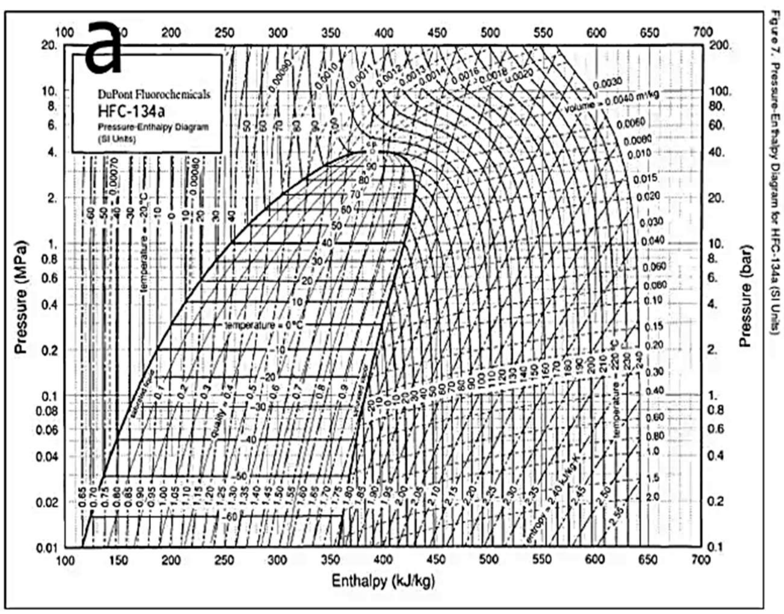

Figure 3. Refrigerant diagram.P-H r 134 A.

Cycle explanation:
1-2 = isentropic compression step from -11ºC to 40ºC. Enthalpy price Hg1 = 400 kJ/kg.
2-3 = condensation step from a temperature of 40ºC to 35ºC, the Enthalpy value of Hg^2 = 440 kJ/kg is obtained.
3-4 = The expansion process is adiabatic, the value of H fg3= Fg4 = 245 kJ/kg.

Energy analysis of refrigeration machines

1) Determine the refrigerant flow (m)

$Q_e = m(hg1 - hf4)$

Where:

M = Refrigerant flow rate (kg/dt).

$Q = Cooling\ Capacity = 308{,}133\ Btu/hr = 90{,}283\ Watt\ 90{,}283\ kW$

$= m\ (400\ kJ/kg - 245\ kJ/kg)$

2) Large compressor power (W).

W $= \mathrm{m\ (h2 - h1)}$
$= 0{,}583\ \mathrm{kg/dt}\ (440 - 400)\ \mathrm{kJ/kg}$
W $= 23{,}32\ \mathrm{kJ/dt} = 23{,}32\ \mathrm{kW}$

Compressor power in HP = 23.32 x 1000/745 = 31.3 HP, compressor power (Wk) = 32 HP.

3) Determine the COP (Coefficient of Performance) Price
Planned AC machine performance:

$$COP = \frac{Refrigeration\ effect}{Compressor\ Work} = \frac{m\ (h1 - h4)}{m\ (h2) - h1)} = \frac{Q}{W}$$

$$COPac = \frac{90{,}238\ kJ/dt}{23{,}32\ kJ/dt} = 3{,}9$$

The actual COP (Coefficient of Performance) price result is 3.9, meaning the energy absorbed by the cooling machine is greater than the energy required by the compressor, meaning the performance of the cooling machine is very good. In general, the refrigeration machine cycle is always greater than 2.0, and R-134a refrigerant is chosen because it is very good and easy to get on the market.

Discussion

The results of the cold storage machine heat load analysis are as follows: 1) The size of the cold storage is 10 x 10 x 3 meters, consisting of 18 shelves and 17 boxes on each shelf, 100 bottles per box. The size of the vaccine stored in cold storage is 30 600 bottles, or stored vaccines; 2056 701 lbs or 822,680 kg. 2) External, internal, and ventilation loads are 308,133 Btu/hr or = 90,283 Watts. (26 TR, (tons of refrigerant). 3). The refrigerant used is R 134 A with a mass flow rate of = 0.583 kg/s. 4). Compressor power obtained (Wk) = 23.32 Watts, or 32 HP. 5) The COP of the cooling machine is = 3.9. Machine performance is very good. 6) The electricity source comes from PLN but the electricity source is prepared from the generator itself so that the machine continues to work 24 hours. Conditions in the cold storage room remain stable at -8°C.

4. CONCLUSION

The size of the cold storage is 10 x 10 x 3 meters, consisting of 18 shelves and 17 boxes on each shelf, 100 bottles per box. The number of vaccines stored in cold storage is 30 600 bottles, or the weight of the vaccines stored; is 2056 701 or 822 680 kg. Cold storage is equipped with a backup power supply so that it remains operational for 24 hours. The heat load of the vaccine cooler is 6,219,463.8 Btu/24 hours or 259,144 Btu/hr (75,929 W). The external, internal, and ventilation load is 308,133 Btu/hr or = 90,283 Watts (26 TR, (tons of refrigerant). The compressor power obtained (Wk) = 23.32 Watts, or 32 HP with a refrigerant mass flow rate of 0.583 kg/sec. The COP of the cooling machine is = 3.9. The engine performance is very good

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