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Utilization of HCR-22 as Substitute for R-22 in Fish Refrigeration Unit

Marcus Samusamu, I Made Aditya Nugraha*
Politeknik Kelautan dan Perikanan Kupang
Corespondance : made.nugraha@kkp.go.id

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ABSTRACT

Since each refrigerant has different vaporization and condensation temperature and pressure, the capacity and working conditions of each system depend on the type of refrigerant used. The criteria for a suitable refrigerant for a refrigeration system are determined by its thermodynamic, chemical, and other factors. This research aims to analyze the capacity and scope of work of refrigerator components that use R-22 refrigerant to be replaced with HCR-22 in a 1.7 TR refrigeration fish refrigerator without having to replace components. This research was carried out from December to March, on a regular fishing vessel, Alalunga Vessel. The research was conducted by reviewing and analyzing the application of refrigerant HCR-22 and R-22 in the refrigerator unit. The results of the analysis of the capacity and scope of work of the components show that HCR-22 refrigerant has a higher advantage than R-22. These high advantages have a positive reaction to the refrigeration effect and refrigerant workload, which include an increase in heat absorption capability, a decrease in compressor and electric motor energy, a decrease in the compression ratio, an increase in the compressor coefficient achievement.

Keywords: fish refrigeration, HCR-22, performance, R-22

INTRODUCTION

There are many ways to maintain the quality or freshness of fish, one of which is through the freezing process (Franceschelli et al., 2021; Wu et al., 2021). The freezing process or known as refrigeration is done by absorbing heat from the cooled product until its temperature reaches the freezing point or below 0°C. The role of refrigeration technology has been proven to be able to preserve fish according to the desired conditions. Through refrigeration technology, the caught fish are cooled and stored at freezing temperatures to avoid the possibility of experiencing changes in physical properties due to changes in temperature and humidity as well as biological properties due to the activity of enzymes and microorganisms as well as if left in environmental conditions (Dawson et al., 2018; Duarte et al., 2020; Nakazawa & Okazaki, 2020; Narang et al., 2017).

The refrigeration system is divided into two major parts, namely the absorption and compression/mechanical systems (Alrwashdeh et al., 2019). Nowadays absorption systems are rarely used, because of the weaknesses that exist in the system, therefore a compression system was developed, one of which was tested in this study (Alrwashdeh & Ammari, 2019; Lima et al., 2021; Pan et al., 2020; Redhwan et al., 2016).

In the compression system, the cold process begins with the compressor working to compress the refrigerant vapor, condensed in the condenser, accommodated in the holding tank, lowered the pressure in the expansion valve, evaporated in the evaporator, and sucked back in by the compressor for the next cycle. This process takes place continuously so that the temperature of the room/product can drop and continue to be maintained as desired.

Since each refrigerant has different vaporization and condensation temperature and pressure, the capacity and working conditions of each system depend on the type of refrigerant used. The criteria for a suitable refrigerant for a refrigeration system are determined by its thermodynamic, chemical, and other factors.

Various types of refrigerants are used for the refrigeration process, but currently the most widely used are refrigerants made from hydrochlorofluorocarbon (HCFC), type of Freon R-22. But on the other hand, there are obstacles to the use of R-22 from this HCFC material, namely its nature which can damage the ozone layer because it contains chlorine (Azmi et al., 2017; Pan et al., 2020; Redhwan et al., 2016; Saab & Ali, 2017; Zanchi et al., 2019).

According to the Copenhagen amendment, 23 – 25 November 1992 (to the Montreal protocol, 1978) a complete cessation of HCFC consumption is scheduled for January 1, 2030, preceded by a gradual reduction in use. Finally, according to the Beijing amendment in December 1999, the complete cessation of HCFC consumption is to be accelerated, where countries included in "article 5" of the Montreal protocol, such as Indonesia are urged to freeze the use of HCFCs starting in 2016 based on average production and ensure the elimination of HCFCs completely. total use of HCFCs as of January 1, 2040.

To overcome the scarcity and danger of using HCFCs, some researchers propose the use of hydrocarbon refrigerants (HC) as a substitute. The use of HC refrigerant is considered to be the best solution at this time because it is environmentally friendly, that is, it does not destroy ozone (ODP=0) and its effect on global warming is negligible (GWP≈0) (Abas et al., 2018; Babarinde et al., 2021). This type of refrigerant is promoted as an energy-efficient refrigerant. In addition, due to the similarity of its thermodynamic properties, to the refrigeration component material and other advantages, this hydrocarbon-based refrigerant can be considered as a drop-in substitute refrigerant or refrigerant substitute that can be used without replacing the refrigeration component with HCFC refrigerant (Babarinde et al., 2021; Moosavi et al., 2014).

In this study, a trial was conducted on the application of refrigerant HCR-22 as a substitute for R-22 in a fish refrigeration unit with a capacity of 1.7 TR on a fishing vessel, owned by the Waiheru State Middle School of Fisheries, Ambon, as one of the initial efforts to respond to the challenges presented in this study. This research is expected to be a consideration for users, especially fishing vessels in Indonesia, in deciding to replace refrigerant type R-22 with HCR-22 which is environmentally friendly in the refrigeration unit.

METHOD

This research took place on the Fishing Training Vessel (KM. Alalunga) belonging to the Waiheru State Fisheries High School, Ambon. This research lasted for 3 months from December to March.

To direct this research, the various rationale is built through the main problems that arise in the minds of researchers as the first step of research. Among them are formulating various changes such as changes in the working quantities of the main components of the refrigeration unit being reviewed.

Based on the problems stated above, this research begins by testing and observation of the refrigeration unit to be tested. The study began by recording all parameters, including recording the capacity of all refrigerator components, calculating the cooling load that must be carried out by the refrigerator. Furthermore, trials were carried out on the two different refrigerants, following the process of filling the refrigerant according to the procedure, starting from calculating the component workload, doing a vacuum, filling in the coolant, and then after the cooling machine was operating perfectly, collecting data on the workload of each component. Furthermore, other parameters are calculated such as the impact of refrigeration, refrigerant flow rate, compression ratio, increase in heat released by the condenser and others, when using one type of refrigerant, then proceed with the same test, on other refrigerants. Furthermore, the test results on the two refrigerants are recorded, compared, and analyzed, for further determination of the results.

Tools and Material

To support this research, various tools and materials were used (Tables 1 and 2). The equipment used in this research is vacuum pump capacity 1 HP, manifold capacity 500 psi, handtools (1 set of ring wrench and spanner, pliers, screwdriver), ammeter capacity 100A capacity, voltmeter capacity 1000V, digital thermometer and mercury, table scale capacity 20 kg, and stopwatch. The materials used in this research are refrigerant R-22 and HCR-22, filter drier, and compressor lubricating oil.

Table 1. Tools Used During The Research

Tool	Function
Cooling Machine 1.7 TR	Refrigerant Test Equipment
Vacuum Pump	To change the pressure in a contained space to create a full or partial vacuum either mechanically or chemically
Manifold (Meter & Hose Fill)	To measure negative pressure as well as positive pressure and is used to repair cooling system in air conditioners and refrgerators
Handtools (Pliers, Screwdrivers, Keys, etc.)	Work aids in the field
Amperemeter	Measuring Electric Current
Voltmeter	Measuring Electric Voltage
Thermometer	Measuring Temperature
Stopwatch/ Timer	Calculating Charging Time

Table 2. Materials used during the research

Material	Function
Refrigerant R-22	Coolant / Experimental Material
Refrigerant HCR-22	Coolant / Experimental Material
Filter Drier / Silica gel	Filter dirt & water vapor
Lubricant	Lubricate the engine or compressor
Diesel fuel	Generator fuel

Determination of Total Cooling Load

Before testing the HCR-22 refrigerant, the cooling load is calculated, which includes product load, transmission load, internal load, and infiltration load. To calculate the total cooling load, refer to Equation (1) – (8) (Stanford et al., 2019). This coolant load value will be used to calculate the working quantities of the cooling engine components.

$$q_{prod1} = mC_1(t_0 - t_1) \quad (1)$$

$$q_{prod2} = mh_f \quad (2)$$

$$q_{prod3} = mC_2(t_1 - t_2) \quad (3)$$

$$q_{prod} = \frac{q1+q2+q3}{n} \quad (4)$$

$$q_{trans} = U.A.\Delta t \quad (5)$$

$$q_{int} = C_p.n.x \quad (6)$$

$$q_{inf} = V.N.q_{cft} \quad (7)$$

$$q_{tot} = (q_{prod} + q_{trans} + q_{int} + q_{inf})\, sf \quad (8)$$

Activity steps

The initial step of the experiment starts with vacuuming the cooling machine until all the air and gas in the system can be removed. Vacuuming is carried out with a vacuum pump with a capacity of 1 HP, for approximately 1 hour, (the pressure on the measuring instrument/ manometer shows -76cm. hg or -30 inch. hg). If it has been vacuumed, the refrigerant is filled (R-22), until the refrigerant indicator shows a normal number/there is enough refrigerant, or the frost line has reached the end of the evaporator pipe; (amount of refrigerant 10.5 kg), with a long charging time of 50-60 minutes. After sufficient coolant, the cooling machine is allowed to operate for 1 hour. After 1 hour, the amount of work of each component is recorded in the journal. Then every 3 hours the results are recorded again. Observations were made for 3 consecutive days.

After being tested for 3 days, the refrigerant is removed and stored in the R-22 tube. After the refrigerant is empty, it is left exposed/in contact with outside air for at least 3 days. Then vacuum again for approximately 1 hour, (the pressure on the measuring instrument/ manometer shows -76cm.hg or -30 inch. hg).

After vacuum, the refrigerant is filled (HCR-22), until the refrigerant indicator shows the normal number/ there is enough refrigerant, or the frost line has reached the end of the evaporator pipe; (amount of refrigerant 4 kg), with a long charging time of 40-50 minutes. After sufficient coolant, the cooling machine is allowed to operate for 1 hour. After 1 hour, the amount of work of each component is recorded in the journal. Then every 3 hours the results are recorded again. Observations were made for 3 consecutive days.

Furthermore, the refrigerant is removed and accommodated in the HCR-22 tube. After the refrigerant is empty, it is left exposed/in contact with outside air for at least 3 days. Then vacuum again for approximately 1 hour (the pressure on the measuring manometer shows -76cm. hg or -30 inch. hg).

Next, steps 2, 3, and 4 were repeated, until the trial of each refrigerant took 3 times. Furthermore, the results of the treatment of the two refrigerants are recorded, compared and analyzed, for further determination of the results.

Calculation of Capacity and Working Amount of Cooling Engine Component

After knowing the total cooling load and getting the test results, the capacity and work size of the cooling engine components are calculated, which include: cooling, cooling action, compression speed, the heat of condensation, compression ratio, coefficient of performance, and rate of refrigeration. To calculate the capacity & work size of the cooling engine components, refer to Equation (9) – (17) (Stanford et al., 2019).

$$Q_c = \frac{24}{RT} \cdot q_{tot} \quad (9)$$

$$Q_t = \frac{Q_c}{3.024} \quad (10)$$

$$(Q_e) = h1 - h4 \quad (11)$$

$$(W_k) = h2 - h1 \quad (12)$$

$$(Q_k) = h2 - h3 \quad (13)$$

$$r = \frac{P2}{P1} \quad (14)$$

$$COP = \frac{Q_e}{W_k} \quad (15)$$

$$(m) = \frac{Q_c}{Q_e} \quad (16)$$

$$(P_k) = m\,(h2 - h1) \quad (17)$$

In supporting these calculations, it is supported by some data. These data include:

1. Cooling chamber volume = 7.41m^3 (L = 2.6m, W=1.9m, H=1.5m)
2. Wall, roof, and floor building materials, as attached.
3. Compressor type: open system, electromotor capacity 4kW, 5.5HP, 3 phase, 380 volts
4. Condenser type: shell and tube, with water cooling
5. Evaporator bar type: without fan
6. Expansion valve type: automatic expansion valve.

RESULT AND DISCUSSION

Several studies have been conducted previously on the replacement of R22 with HCR22. Based on the research, it was found that replacing R22 with HCR22 could save the use of electrical energy. The performance data considered were the evaporator cooling load, the condenser heat rejection, the electrical energy consumption, the refrigeration system temperatures, and the room temperature (Nasution et al., 2013). Another study also stated that The results show that the COP of RSAC increase with the increasing of cooling load (0 W, 1000 W, 2000 W and 3000 W), where the COP with HCR22 increase 16.10%, 12.66%, 16.56% and 19.99 % higher than R22 respectively, and the compressor power consumption were reduced with HCR22 lower than R22 by 18.27%, 20.01%, 16.26% and 22.56% respectively, while the cooling capacity and heat rejection capacity were relatively similar. The experimental results show that HCR22 had better performance compared to R22, and indicating that HCR22 could be used for retrofitting existing RSAC with R22 (Aziz et al., 2018). The replacement from R22 to HCR 22 also shows the use of mass HCR22 (hydrocarbon refrigerant or substitution R22) at hybrid refrigeration machine more economical 57.78% compared to R22 (halocarbon refrigerant) because HCR22 has the higher level of latent heat compared to R22. Cooling rate and heating by HCR22 compared of compressor use of HCR22 is more economical 25.12%compared to hybrid refrigerant can economize of electrical energy consumption and environmental friendly. Based on these studies, it was attempted to replace r22 with HCR22 on the fish refrigeration unit on fishing vessels to get a more effective and efficient refrigeration system.

Cooling Load

Calculation of the cooling load is carried out to determine the amount of cooling load required, which will be used to calculate the amount of component work and the cooling cycle. The results of the analysis can be seen in the calculations below. According to the results of the calculations in Table 3, it can be seen that the heat transmission load (heat through the hatch walls/bulkheads) is too large (53% of the product heat load), this indicates that some of the cooling load occurs due to heat transmission through the hatch walls. This is due to the very poor heat insulation of the hatch walls/ bulkheads, where the walls/ bulkheads of the hatch are only limited by a layer of wood and a layer of fiberglass. The hatch walls should be lined with heat-resistant material, such as glass wool or polystyrene. This is bad for the cooling process.

q_{prod1} = $mC_1(T_0\text{-}T_f)$
= 750kg x 0.76kkal/kg^{o}C x 27.2 ^{o}C
= 15,504 kkal

q_{prod2} = mH_f
= 750 kg x 56.4 kkal/kg
= 42,300 kkal

q_{prod3} = $mC_2\,(T_f - T_2)$
= 750 kg x 0.41 kkal/kg^{o}C x 17.8^{o}C
= 5,473.5 kkal

q_{prod} = 2,636.56 kkal/h or 3,065.77 W

q_{trans1} = $UA\Delta t$
= 1.4481 kkal/hm^{2o}C x 4.94 m^2 x 55
= 393.4488 kkal/h

q_{trans2} = $UA\Delta t$
= 1.0292 kkal/hm^{2o}C x 7.8 m^2 x 55
= 441.5268 kkal/h

q_{trans3} = $UA\Delta t$
= 1.0292 kkal/hm^{2o}C x 5.7 m^2 x 52
= 305.0549 kkal/h

q_{trans4} = $UA\Delta t$
= 1.0292 kkal/hm^{2o}C x 4.94 m^2 x 50
= 254.2124 kkal/h

q_{trans2} = 1,394.24 kkal/h or 1,621.21 W

q_{int} = C_pnx
= 1324 BTU/h x 1 x 0.5 h
= 6.96 kkal/h or 8.093 W

q_{int} = VNq_{cft}
= 261.7 ft^3 x 19.2 x 119.2
= 169.49 kkal/h or 197.08 W

q_{tot} = 4627.98 kkal/h or 5.38 kW

Q_c = 24/RT x q_{tot}
= 24/22 x 4267.98 kkal/h
= 5048.71 kkal/h or 5.87 kW

Q_t = Q_c/3.024
= 5048.71 kkal/h / 3.024
= 1.7 TR

Working of the refrigeration unit with R-22

(Q_e) = h1 –h4
= 397.5 – 244.8
= 152.7 kJ/kg

(W_k) = h2 – h1
= 435.2 – 397.5
= 37.7 kJ/kg

(Q_k) = h2 – h3
= 435.2 – 243.1
= 192.1 kJ/kg

r = P2/P1
= 1354.8 / 244.8
= 5.53

(COP) = Q_e / W_k
= 152.7 / 37.7
= 4.05

(m) = Q_c / Q_e
= 5.87 / 152.7
= 0.0384 kg/s or 38.4 g/s

(P_k) = m (h2 – h1)
= 0.0384 kg/s (435.2 – 397.5)
= 1.45 kW

Working of the refrigeration unit with HCR-22

(Q_e) = h1 –h4
= 419.1 – 232.4
= 186.7 kJ/kg

(W_k) = h2 – h1
= 458.9 – 419.1
= 39.8 kJ/kg

(Q_k) = h2 – h3
= 458.9 – 232.4
= 226.5 kJ/kg

r = P2/P1
= 1290.3 / 238.6
= 5.41

(COP) = Q_e / W_k
= 186.7 /39.8
= 4.69

(m) = Q_c / Q_e
= 5.87 / 186.7
= 0.0314 kg/s or 31.4 g/s

(P_k) = m (h2 – h1)
= 0.0314 kg/s (458.9 – 419.1)
= 1.25 kW

Table 3. Cooling Load

Quantity	Total	Description
Product heat load, q_{prod}	3,065.77 W	
Transmission heat load, q_{trans}	1,621.21 W	
Internal heat load, q_{int}	8.93 W	
Infiltration heat load, q_{inf}	197.08 W	
Total cooling load, q_{tot}	5,38 kW	Safety factor 10%
Cooling Capacity, Q_c	5.87 kW	Running Time 22 hours
Cooling Capacity, Q_t	1.7 TR	

Table 4. Working Performance of Refrigeration Unit

Description	R-22	HCR-22
Cycle performance		
Evaporation temperature	-20°C	-21°C
Evaporation pressure	244.8 kPa	238.6 kPa
Condensation temperature	35°C	34°C
Condensing pressure	1354.8 kPa	1290.3 kPa
Temperature TK. 1	-20°C	-21°C
Temperature TK. 3	35°C	34°C
Enthalpy TK.1	397.5 kJ/kg	419.1 kJ/kg
Enthalpy TK.2	435.2 kJ/kg	458.9 kJ/kg
Enthalpy TK.3 = TK. 4	243.1 kJ/kg	232.4 kJ/kg
Refrigerant Performance on Components		
Cooling working time	22 hours	22 hours
Cooling capacity	5.87 kW	5.87 kW
Cooling effect	152.7 kJ/kg	186.7 kJ/kg
Compression	37.7 kJ/kg	39.8 kJ/kg
Condensation	192.1 kJ/kg	210.6 kJ/kg
Compression ratio	1 : 5.53	1 : 5.41
Performance coefficient	4.05	4.69
Refrigerant flow rate	0.0384 kg/det	0.0305 kg/det
Compressor power	1.45 kW	1.21 kW
Compressor outlet temperature	100°C	97.7°C
Compressor inlet pressure	248.2 kPa	239.6 kPa
Compressor outlet pressure	1,357.3 kPa	1292.4 kPa
Crankcase pressure/lubricant	362.7 kPa	352.9 kPa

Description	R-22	HCR-22
Average temperature of the condenser	35°C	34°C
Cooling water temperature (in)	28°C	28°C
Cooling water temperature (out)	33°C	32°C
Expansion valve pressure (in)	1,354.8 kPa	1,290.3 kPa
Expansion valve pressure (out)	244.8 kPa	244.8 kPa
Average temperature of evaporator	-20°C	-21°C
Average pressure of evaporator	244.8 kPa	238.6 kPa
Voltage	380 Volt	380 V
Electric current	8.7 Amp	7.3 Amp
Electric Power	3.31 kW	2.77 kW
Use of Cooling Material	10.5 kg	4.0 kg

The internal heat load is very small because the cooling room is small, so it is not equipped with lights, and the number of workers who enter the cold room to work, is generally 1 person with a relatively short working time (< 1 hour), so that the internal heat load is small, this is good for the cooling process.

The overall cooling load (before adding the safety factor) is 4.89 kW, which is the sum of all cooling loads. However, in practice, this total cooling load must be added to the safety factor, which is assumed to be 10%. After adding the safety factor (safety factor 10%), the total cooling load becomes 5.38 kW.

During the cooling process, the refrigeration unit does not work for a full day (24 hours). This is because during the refrigeration time, there is a defrosting time or delay time, so the running time for the cooling process is generally calculated between 16 to 22 hours. In this calculation, considering the small size of the cooling room, the defrosting and delay times are assumed to be 2 hours per day, so the operating hours per day are assumed to be 22 hours. Thus obtained a cooling capacity of 5.87 kW or in units of tons of Refrigeration of 1.7 TR. The amount of this cooling load will not change for the two refrigerant treatments and will be used to carry out tests and calculate the performance of each refrigerant.

Performance of Cooling Unit Component for Applications R-22 and HCR-22

The magnitude of the component work on the refrigeration unit for the application of R-22 and HCR-22 can be seen in Table 4. This result was obtained from measurements three times a day, at 10 am, 1 pm and 4 pm. From the table, it can be explained that there are positive advantages in the application of HCR-22. The evaporation temperature is reduced by 5%, which will make the product temperature lower. The evaporation pressure also decreases by 2.5%, this will make the refrigerant boil at a lower temperature, so the evaporation process takes place faster. The condensation temperature drops by 2.9%, this will support the process of changing the form of the vapor refrigerant to liquid refrigerant. The condensation pressure drops by 10%, which has a positive impact, which will facilitate the change of refrigerant into liquid refrigerant. The temperature at condition 1, the same as the temperature in the evaporator, decreased, as well as the temperature at condition 3, in the condenser, also decreased, which had a good impact on component work and the cooling process. The enthalpy in conditions 1 and 2, increased by 5.4%, this indicates the nature of the refrigerant itself, where HCR-22 has a higher heat absorption than R-22, so the ability to absorb heat HCR-22 when compressed is higher. of R-22, this has a good impact on the cooling/heat absorption process. The enthalpy at conditions 3 and 4, decreased by 4.4%, this condition is related to the nature of the refrigerant itself, where the ability to release heat that occurs in the condenser is smaller, so that the pressure and temperature in the condenser also decrease, this is also has a good impact on the condensation process. In terms of the amount of refrigerant working on the components, the cooling and cooling times are the same, because the tests were carried out on the same cooling machine and the same running time. The cooling effect increased by 22.3%. This shows that the cooling effect produced by HCR-22 is greater than that of R-22. This has a good impact on the cooling process. The compression ratio has decreased by 2.1%, which has a positive impact, which will work with lighter loads, thus extending the life of the compressor. In compressor work, compressor power also decreased by 16.6%, which is the impact of a decrease in compression ratio, this has a good impact, because the compressor will work with lower power requirements, so it is more energy-efficient. This is a positive thing, where with an increase in compressor performance, the heat absorption process from the cooling cycle will be higher, so the cooling process will take place better. The mass flow rate of HCR-22 refrigerant is smaller than that of R-22, or a decrease of 20.1%, this is because the amount of HCR-22 refrigerant flowing in the system, during the cooling process, is less than that of R-22 or only about 38.1% of R-22. The use of power and electric current in the driving motor (electromotor) has also decreased. This has a good impact, where with a decrease in electric current, the electromotor will work lighter. Meanwhile, with lower power usage, the electromotor will be more energy efficient in the use of electrical power, which also has an impact on cost savings. Thus, when compared to R-22, HCR-22 has advantages and a better demonstration of work than R-22.

Refrigeration Cycle of R-22

The refrigeration cycle using refrigerant R-22 is depicted on a Mollier diagram or pressure-enthalpy diagram (pH diagram), which can be seen in Figure 1 and Table 5. The dotted line shown by the AB curve is the R-22 pH curve, where A-TK is the refrigerant condition. in liquid form, and the B-TK limit is the condition of the refrigerant in the form of vapor, while the TK point is the critical point, where there is a change from vapor to liquid. The line at points 1-4, describes the cooling process that occurs in the refrigeration machine, the results of test cycle 1 (point 1), the compressor sucks in the low-pressure refrigerant that evaporates from the evaporator, this low-pressure vapor is compressed in the compressor. When there is a compression process on the compressor; the pressure, temperature, and enthalpy of the refrigerant (R-22) will increase, until the pressure, enthalpy, and temperature reach point 2. After the addition of point 2, the temperature of the refrigerant will decrease and its enthalpy will also decrease, as the temperature increases. heat in the condenser. The refrigerant will release heat to the air conditioner in the condenser, according to the coolant temperature after leaving the condenser will increase, otherwise, the enthalpy and coolant temperature will decrease. After the refrigerant enthalpy drops, R-22 will change state, from high-pressure vapor to high-pressure liquid. In the next stage, the refrigerant enters stage 3, where the refrigerant pressure will be lowered, through the expansion valve, while the enthalpy remains the same. The purpose of pressure drop is to lower the boiling point, so the refrigerant will boil faster at lower temperatures, and will absorb heat faster. Entering the fourth cycle, the refrigerant will boil or evaporate, because the pressure has dropped when it enters the evaporator. For this process, the refrigerant will absorb as much as possible, to be able to boil/evaporate, so that the temperature of the object or environment around the evaporator will decrease, because heat is absorbed by the refrigerant in the evaporator.

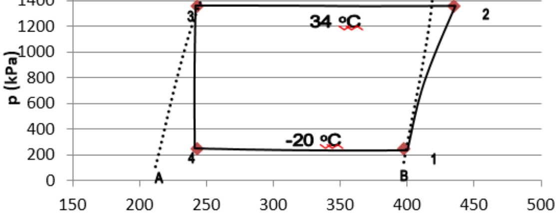

Figure 1. Vapor compression cycle of R-22

Table 5. Description of Compression Cycle in Applications R-22

TK	P (kPa)	h (kJ/kg)	s (kJ/kg°K)
1	244.8	397.5	1.78415
2	1,354.8	435.2	1.70576
3	1,354.8	243.1	-
4	244.8	243.1	-

Refrigeration Cycle of HCR-22

The refrigeration cycle using HCR-22 refrigerant which is depicted in the Mollier diagram or pressure-enthalpy diagram (pH diagram), can be seen in Figure 2 and Table 6. AB curve is the HCR-22 pH curve, where the A-TK curve is the condition of the refrigerant in liquid form, and the B-TK curve is the condition of the refrigerant in the form of vapor, while the TK point is the critical point, where there is a change from vapor to liquid. The line at points 1-4, describes the cooling process that occurs in the refrigeration machine, according to the test results, where in cycle 1 (point 1), the compressor sucks in low-pressure refrigerant vapor that evaporates from the evaporator. Pressurized steam is compressed in a compressor. When the compression process occurs in the compressor, the pressure, temperature, and enthalpy of the refrigerant (HCR-22) will increase, until the pressure, enthalpy, and temperature reach point 2. After leaving point 2, the refrigerant temperature will decrease and the enthalpy will decrease as well. with heat dissipation in the condenser. The refrigerant will release heat to the cooling water in the condenser, as a result the temperature of the cooling water after leaving the condenser will increase, otherwise, the enthalpy and temperature of the refrigerant will decrease. After the refrigerant enthalpy drops, HCR-22 will change state, from high-pressure vapor to high pressure liquid. In the next stage the refrigerant enters stage 3, where the refrigerant pressure will be lowered, through the expansion valve, while the enthalpy remains the same. The purpose of pressure drop is to lower the boiling point, so the refrigerant will boil faster at lower temperatures, and will absorb heat faster. Entering the fourth cycle, the refrigerant will boil or evaporate, because the pressure has dropped when it enters the evaporator. For this process, the refrigerant will absorb as much heat as possible, to be able to boil/evaporate, so that the temperature of the object or environment around the evaporator will decrease because heat is absorbed by the refrigerant in the evaporator.

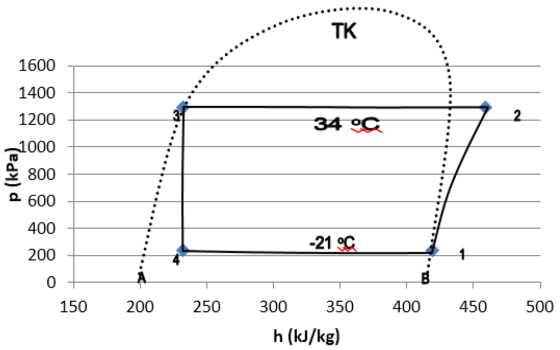

Figure 2. Vapor compression cycle of HCR-22

Table 6. Description of Compression Cycle in Applications HCR-22

TK	P (kPa)	h (kJ/kg)	s (kJ/kg°K)
1	238.6	419.1	1.88124
2	1,290.3	458.9	1.80822
3	1,290.3	232.4	-
4	238.6	232.4	-

CONCLUSION

Based on the results of the trials that have been carried out, it can be concluded that the working performance of refrigerant HCR-22 in refrigeration machines is better than refrigerant R-22, and refrigerant HCR-22 can be used as a substitute for refrigerant R-22 in refrigeration machines without changing components. The result of analyzing the capacity and the component scope of work show that refrigerant HCR-22 has a high superiority compared with R-22. Those high-superiority has a positive reaction for the refrigeration effect and refrigerant workload, which include the increase of heat absorption ability, the descent of compressor and electromotor energy, the descent of ratio compression, the increase of compressor's coefficient achievement, etc. Concluded that the performance of refrigerant HCR-22 at the refrigerator is better than R-22. It can be concluded that HCR-22 could be used as alternative R-22 at the refrigeration unit, without replacing the component.

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