Technology Application of Environmental Friendly Refrigeration (Green Refrigeration) on Cold Storage for Fishery Industry

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Abstract. The application of refrigeration technology to postharvest fishery products is an very important. Moreover, Indonesia is a tropical region with relatively high temperatures. Fish storage age can be prolonged with a decrease in temperature. Frozen fish can even be stored for several months. Fish freezing means preparing fish for storage in low-temperature cold storage. The working fluid used in cold storage to cool low-temperature chambers and throw heat into high-temperature environments is refrigerant. So far refrigerant used in cold storage is Hydrochlorofluorocarbons (HCFC) that is R-22. Chlor is a gas that causes ODP (Ozone Depleting Potential), while Flour is a gas that causes GWP (Global Warming Potential). Government policy began in 2015 to implement Hydrochlorofluorocarbons Phase-Out Management Plan. Hydrocarbon (HC) is an alternative substitute for R-22. HC-22 (propane ≥ 99.5%) has several advantages, among others: environmentally friendly, indicated by a zero ODP value, and GWP = 3 (negligible), thermophysical property and good heat transfer characteristics, vapor phase density Which is low, and good solubility with mineral lubricants. The use of HC-22 in cold storage is less than R-22. From the analysis results obtained, cold storage system using HC-22 has better performance and energy consumption is more efficient than the R-22.

1. Introduction

Refrigeration technology plays a very important role in life, both in industrial and household use. One application of refrigeration technology is in the field of fishery industry to extend product shelf life and to maintain product quality. Related to the national fishery industry still faces various problems in terms of economic and governance, such as the production level is not maximal, availability of inadequate infrastructure, exports are still dominated by raw materials, and governance that has not terintegrasi. Presidential Instruction No.7 of 2016 focuses on reviewing interagency policies, strengthening cold chain systems, reforming business-friendly services and encouraging sustainable investment. Provision of sufficient electricity demand for cold chain system fulfillment (such as cold storage, water blast freezer, contact plate, ice flake machine etc.), as a means to maintain the quality of fish that require relatively high electrical power can not be fully guaranteed by government.

The concept of green refrigeration will reduce energy consumption significantly through several passive design and active design methods. Using the concept of green refrigeration does not need to sacrifice comfort and productivity due to energy savings. Green refrigeration not only saves energy but also conserves natural resources, and improves air quality. Green refrigeration is a refrigeration technology concept based on natural balance.
Refrigeration is a process of absorption of heat from a room or product and throw out of the
room. Then maintain in such a way under certain temperature conditions so that the room temperature
is lower than the ambient temperature. Substances that play a role to absorb heat from a product /room and throw out into the environment is a refrigerant. Refrigerant is a working fluid that circulates
in the refrigeration cycle. ASHRAE defines refrigerant as working fluid in refrigeration machine [1].
Refrigerant plays an important role in the refrigeration system because the refrigerant can cause
cooling and heating effects on the refrigeration machine.

Refrigerant commonly used in refrigeration system is halocarbon class, HCFC (R-22). R-22 can
cause damage to the ozone layer and potentially lead to global warming [2]. Therefore, the R-22 needs
to be replaced with environmentally friendly refrigerant. The alternative refrigerant offered is
hydrocarbons because they have eco-friendly properties indicated by the value of Ozon Depleting
Potential (ODP) zero, and Global Warming Potential (GWP) that can be ignored. Consideration of the
choice of hydrocarbons as refrigerants because of their natural, non-toxic, compatible with lubricant
oil, and drop in substitutes without replacing.

One of the hydrocarbon refrigerants used is Musicool (MC) produced by Pertamina. However, the
weakness of hydrocarbon refrigerant is that it has flammable properties. This combustible nature
causes the major disadvantages of using hydrocarbons. This can be addressed and safe if safety
measures are taken to prevent leakage of refrigerant from refrigeration system, keeping hydrocarbon
concentration below LFL (Low Flammable Limit) limits with open air circulation system and tightly
sealed (closed) electrical conditions [3].

Several studies have used hydrocarbon in place of CFC and HCFC. Wongwises tested a mixture of
propane hydrocarbons (R290), butane (R600), and isobutane (R600a) to replace R134a in automotive
[4]. Wongwises and Chimres used a mixture of propane, butane and iso-butane to replace HFC134a in
the refrigerator [5]. Granryd stated that hydrocarbons can be used on air conditioning and heat pumps
with efficient energy use [6]. Han testing the R32/R125/R161 mixture yields better COP than R407c
[7]. Mani and Selladurai examined the R290 / R600a mixture in lieu of R12, R134a [8]. Park tested
propylene, propane, HFC-152a and dimethylether mixtures resulting in better COP compared to R22 in
split AC and heat pumps [9].

In relation to the above problem, the effort made to overcome the problem by replacing halocarbon
refrigerant, HCFC (R-22) with hydrocarbon, HC-22. Technological advances in the field of
refrigeration for the future will be able to provide an environmentally-based and sustainable effect.
Therefore the application of the concept of Green refrigeration is a demand that must be done by the
perpetrators of refrigeration technology.

2. Experimental Setup and Test Procedure
This research was conducted experimentally using cold storage with 3.73 kW compressor capacity. The system uses two stage compressor with R-22 refrigerant. The purpose of this study was to compare the performance of the system with HC-22 refrigerant. The content of MC-22 is 99.7% propane and 0.03% is butane. The schematic of the test equipment is shown as in Figure 1 [10]. The main components of the steam compression vapor refrigeration system consist of compressor, condenser, expansion valves and evaporator. The process of taking pressure data (P, psig), temperature (T, °C), voltage (V, volt), and current (I, Ampere), is done by direct measurement of the optimum refrigerant mass. Data is recorded ± 30 minutes after the machine is in steady condition. Secondary data were obtained with the help of p-h diagrams. The amount of mass refrigerant MC-22 is equal to 46.6% by weight of R-22. The value of 46.6% is obtained from the results of mass of type MC-22 with R-22 at 100% times. At the time of steam conditions, the density of R-22 = 44.232 kg/m³ and MC-22 20,646 kg/m³.

Pressure on the high side pressure and low side pressure is measured by bourdon pressure gauge type with an accuracy of ± 5 psi and ± 1 psi respectively. The refrigerant temperature at each test location is measured using a T-type thermocouple with an accuracy of ± 0.1 °C and is connected to a TC-08 data logger system type Picolog Recorder. Whereas, the current and voltage of the compressor are measured with amperemeter (accuracy ± 2.0%) and voltmeter (accuracy ± 1.0%).

To analyze the observed data, we use the following equations: COP is an efficiency refrigeration cycle expressed by comparison between refrigerating effect (ER) with compressor work (Wcom).

\[
\text{COP} = \frac{\text{ER}}{\text{Wcom}} = \frac{(h_1-h_4)}{(h_2-h_1)}.
\]

where \(h_1, h_2\): enthalpy on the inlet and outlet of the compressor (kJ/kg), \(h_4\): enthalpy on the inlet evaporator (kJ/kg).

Electric power 3 phase = \(\sqrt{3} \cdot V \cdot I \cdot \cos \phi\) (Watt). Energy consumption is the product of motor power with time (t). While the energy savings obtained based on the comparison of energy consumption between systems using R-22 with MC-22.

### 3. Results and Discussion

Table 1. Physical properties and thermodynamic refrigerant [11].

| Parameter                                      | R-22     | HC-22    |
|------------------------------------------------|----------|----------|
| Normal boiling point, °C                       | -40.80   | -42.05   |
| Critical temperature, °C                       | 96.00    | 96.77    |
| Critical Pressure, psia                        | 723.7    | 616.0    |
| Heat type of saturated liquid at 37.8 °C, kJ/kgK | 1,325    | 2,909    |
| Heat type of steam saturated at 37.8 °C, kJ/kgK | 0,9736   | 2,238    |
| Pressure of saturated fluid at 37.8 °C, psia   | 210.7    | 188.3    |
| The density of saturated fluid at 37.8 °C, (kg/m³) | 1138     | 471.3    |
| Solid steam density at37.8 °C, (kg/m³)         | 62.64    | 28.53    |
| Solid steam density at NBP, kg/m³              | 4,705    | 2,412    |
| Thermal conductivity of saturated liquids at 7.8 °C,K/mK | 0.0778   | 0.0868   |
| Conductivity Thermal steam saturated at 37.8 °C,K/mK | 0.0128   | 0.0211   |
| The viscosity of the saturated fluid at 37.8 °C, uPa-s | 143.1    | 84.58    |
| Viscosity of saturated vapor at 37.8 °C, uPa-s | 13.39    | 9.263    |
The specific energy consumption shown in Figure 5 was calculated by taking into account the production of hot water generated in the heat recovery system.

Figure 2. Comparison of COP to evaporation temperature.

Figure 3. Comparison of energy consumption to evaporation temperature.

The physical and thermodynamic properties of refrigerant HC-22 are shown in Table 1. Refrigerant HC-22 can replace R-22 directly without replacement of refrigeration system components because it has almost the same characteristics.

Figure 2 shows that COP refrigeration system using HC-22 refrigerant is higher than using R-22 refrigerant. This is due to the compressor power consumed by systems that use the smaller HC-22 refrigerant (Figure 3). As a result of optimum mass filling systems using less HC-22 refrigerant than R-22. As well, HC-22 has a latent evaporation heat twice as large as R-22 (Table 1).

Low condensing temperatures can reduce compression work and increase COP values. The value of COP decreases with decreasing condensation temperature. Condensation is the process of releasing heat to the environment so that the refrigerant phase changes from steam to saturated liquid but the pressure and temperature remain high. In the cooling process the low condensation temperature we want because it will reduce the compression work so as to increase COP. While the decrease in evaporation temperature will reduce the cooling effect resulting in the decrease of COP value of refrigerant in use. The energy consumption of the compressor will decrease in refrigeration capacity or refrigeration effect and increase COP [12].
In the test results of various evaporative temperatures for the same refrigerant as shown in Figure 2, the lower the evaporation temperature the COP value decreases. This is due to lower condensation temperatures and lower evaporation temperatures. The lower the evaporation temperature the longer the time it takes to reach the evaporation temperature so that the required energy consumption increases and causes COP to decrease.

Results obtained by HC-22 refrigerant showed higher COP values than R-22, and HC-22 energy consumption was smaller than R-22. Viewed from the standpoint of energy efficiency it can be stated that the system using refrigerant hydrocarbon (HC-22) is more efficient than using halocarbon refrigerant (R-22).

4. Conclusions
Based on the calculation and analysis done on the optimum mass testing of refrigerant R-22 and HC-22 is hydrocarbon refrigerant can be used as an alternative refrigerant in cold storage. COP systems with HC-22 refrigerants are slightly larger than systems with R-22. The system using HC-22 refrigerant is more energy efficient than the system using R-22.

5. Acknowledgments
The authors acknowledge the financial support received from the Higher Education Directorate General of the Ministry of Research, Technology and Higher Education of the Republic of Indonesia.

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