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Experimental Study of Retrofit AC Inverter Performance Based on R32 and R410a to R1270

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***Abstract* - In this study, an overview of energy performance was obtained from the comparison of refrigerants (R32 to R1270 and R410a to R1270) in split inverter AC equipment. R32 testing was carried out with temperature settings of 16ºC and 27ºC while R410a was carried out with temperature settings of 18ºC and 27ºC. At each temperature setting, the cooling load is carried out under conditions using a heater and without loading. In this analysis, a comparison of energy performance and energy efficiency is carried out using the VDMA 24247-2 standard. The results of this study showed that the refrigeration effect value of R1270 was greater than R32 and R410a in all conditions. For compressor work, R1270 has a lower value than R32 and R410a because the value of ∆P (P_2-P_1) on R1270 is smaller so that the compressor work in the compression process is lower. In terms of system, the efficiency for R1270 in various conditions for replacing R32 is almost the same while for R1270 for replacing R410a, the highest efficiency is at a temperature setting of 16ºC, namely at 100% mass condition. Based on the VDMA 24247-2 standard, the highest total energy efficiency value in R32 is 17.17% while in R1270 with a mass of 90%, 100% and 110% is 18.15%, 21.09% and 21.86%. The highest total energy efficiency value in R410a is 5.44% while in R1270 with a mass of 90%, 100% and 110% is 6.25%, 6.22%, 7.42%.**

Keywords: R32, R410a, R1270, AC inverter, efficiency, VDMA 24247-2 standard, subcooling, superheat.

I. INTRODUCTION

In various refrigeration or cooling systems, the goal to be achieved in this system is to maintain the temperature so that a room remains cold by expelling energy as heat irrationally from the space. Most of these systems involve a working fluid which is circulated through the system in a recycling or cycle which is commonly referred to as a refrigerant. Refrigerant is a substance used as a working fluid in a cooling system engine that works in the heat absorption process. There are several types of refrigerants that have been developed, starting from those that are not flammable but have high GWP (Global Warming Potential) and ODP (Ozone Depleting Potential) values and vice versa, there are those that are flammable but have low GWP and ODP values. This refrigerant is a fluid that functions to absorb heat in the conditioned environment by the evaporation process and releases heat to the outside environment by the condensation process.

In line with the implementation of the ban on the use of R22 since 2015 related to its damaging impact on the ozone layer, split type air conditioners that use R410a refrigerant have been circulating on the market, followed by the presence of air conditioners that use R32. In its application, this type of standard split AC with R410a is considered too large in consuming electrical energy. So in order to get around this, experts and consumers choose to retrofit using carbon refrigerants with reference to the successful experience of using MC22 which has been proven and tested and can be used to substitute refrigerant in R22 type split air conditioners and provide good cooling performance and saving electricity. Another thing that many technicians and practitioners encounter is still not aware that there is a significant difference in technical characteristics between R22 and R410a, so that if the R1270 (Breezon MC32) retrofit treatment on the R410a split AC is treated the same as the Musicool MC22 retrofit on the R22 AC, then it is certain lacking or even unsuccessful.

The analysis that will be carried out in this study is to compare the energy performance of refrigeration machines, as well as the consumption of electrical energy consumed by split AC types using energy analysis and energy efficiency using the VDMA 24247-2 standard on inverter split AC system equipment. The AC system equipment to be studied has the following cooling capacities:

- For R32 refrigerant has a cooling capacity of 2638 Watt (1 pk) using R32 refrigerant with an inverter AC system that is set to a temperature of 16ºC and 27ºC under load and no-load conditions.
- For refrigerant R410a has a cooling capacity of 3516 Watt (1.5 pk) using refrigerant R410a with an inverter

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AC system which is set to a temperature of 18°C and 27°C under load and no load conditions.

II. METHODOLOGY

To analyze the air conditioning (AC) system based on energy analysis and the VDMA 24247-2 standard, several mathematical relationships are needed. By going through this mathematical relationship it will be known the value of energy performance in various components and can also be compared with different refrigerants based on energy parameters.

Energy analysis in this study was carried out in several stages, namely entering the required data including: thermodynamic properties of the refrigerant used for research, refrigerant temperature and pressure (evaporator, compressor, condenser, and expansion), temperature and humidity cooling fluid (outputair evaporator), temperature and humidity room passed, ambient air temperature and humidity, compressor electrical loading (voltage, current, power factor, and load), refrigeration capacity and compressor efficiency. The refrigerants used in this analysis are refrigerants R32, R410a, and R1270.

2.1 The Scope of Research

At this testing stage, testing the performance of the installed AC system was carried out with temperature settings of 16°C/18°C and 27°C in room conditions with coolant loading using a 2000 Watt heater and without cooling. This test was carried out within 24 hours with different refrigerants (R32, R410a, and R1270).

This test method is carried out using 2 (two) inverter AC units with a cooling capacity of 2.64 kWth or around 9000 BTU/h (for R32) and 3.52 kWth or around 12,000 BTU/h (for R410a). The two AC units will be retrofitted using R1270 refrigerant or commonly called Breezon MC32 to test their performance. The performance in question is the room air temperature starting from the pull down load condition to steady state, COP, cooling capacity and energy required.

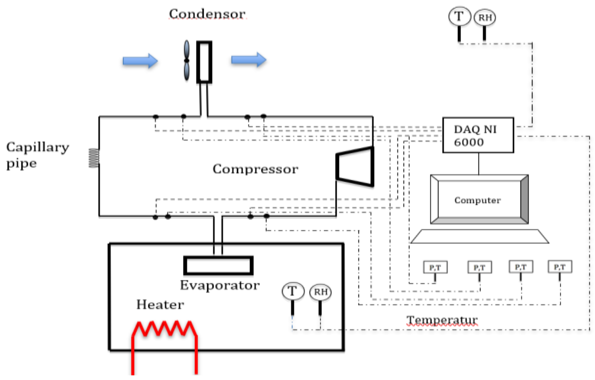

Figure 1: Setup of test equipment

For test equipment, the device setting stage consists of the evaporator unit being placed in a test room and the condenser placed outside the room while the room temperature conditions are maintained at 16°C for R32 and 18°C for R410a (according to the minimum temperature setting for the AC unit), and 27°C for both units AC with condenser inlet air condition according to ambient air temperature.

Temperature and pressure gauges are installed before and after the compressor and before and after the capillary tube. In addition, a thermometer and RH meter are also installed on the air side, where they are set at the point where the air enters and leaves the evaporator and also outside the room a measuring instrument is set to measure the temperature and humidity of the ambient air. All of these measuring instruments are linked to a data acquisition.

This AC unit test was carried out using and without a cooling load. The cooling load in question is a heater with a power of 2 kW and a space cooling load that is estimated to be a maximum of 2.8 kW. So the maximum cooling load is 4.8 kW. The test was carried out in an almost steady state. This state is achieved when the measurement of the outside air is relatively constant. In the test, what is meant by testing with a cooling load is the cooling load originating from the heater and the room, while testing without a cooling load is testing with a cooling load originating only from the cooling load of the room.

Based on the provisions for refrigerant mass replacement, it is necessary to have a density value of the existing refrigerant and refrigerant replacement at a temperature of 50-55°C.

To vary the test in order to obtain optimal values, the mass of the replacement refrigerant (R1270) is varied with volume conditions of 90%, 100%, 110% which will be tested for conditions close to steady state. From the condition of varying the volume of the replacement refrigerant, the mass of R1270 refrigerant to be used is obtained, namely:

a) Mass of refrigerant R1270 instead of R32: 211 grams; 235 grams; and 258 grams or equivalent to 50%; 55%; and 60%
b) Mass of refrigerant R1270 instead of R410a: 252 grams; 280 grams; and 308 grams or equivalent to 45%; 50%; and 55%

2.2 Data Source

In this study, the data used to evaluate and analyze comes from:

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a) The amount of primary data, namely the data obtained from the test results for a period of 24 hours with variable temperature settings of 16ºC/18ºC and 27ºC under no-load and with cooling loads. These primary data include:

- Refrigerant pressure (evaporator, compressor, condenser, and expansion valve)
- Refrigerant temperature (evaporator, compressor, condenser, and expansion valve)
- Ambient air temperature and humidity
- Temperature and humidity of cooling air (evaporator output)
- Conditioned room temperature and humidity
- Electrical loading (voltage, current, power factor, and load)

b) Secondary data sources are data supporting analysis that can provide data but do not come from test results. These data are obtained from references or scientific journals as well as handbooks related to cooling systems.

2.3 Data Collection

Data collection is a very important step in research, because the data collected is used to test the hypotheses that have been formulated. In general, the data collection method in this study is primary data obtained from:

a) Test the performance of the inverter AC system with R32 refrigerant without load at a temperature setting of 16ºC
b) Testing the performance of the inverter AC system with refrigerant R32 without and with a load at a temperature setting of 27ºC
c) Testing the performance of the inverter AC system with refrigerant R1270 instead of R32 without and with a load at a temperature setting of 16ºC
d) Testing the performance of the inverter AC system with refrigerant R1270 instead of R32 without and with a load at a temperature setting of 27ºC
e) Testing the performance of the inverter AC system with refrigerant R410a without load at a temperature setting of 18ºC
f) Testing the performance of the inverter AC system with refrigerant R410a without and with a load at a temperature setting of 27ºC
g) Testing the performance of the inverter AC system with refrigerant R1270 instead of R410a without and with a load at a temperature setting of 18ºC
h) Testing the performance of the inverter AC system with refrigerant MC-R1270 instead of R410a without and with a load at a temperature setting of 27ºC

In general, testing is used to measure or assess the performance of an AC system, especially with regard to temperature conditions and cooling loads.

In this study, the researchers used the test results to measure the performance of the inverter AC system after treating the cooling load and different types of refrigerant. In addition, this research also assesses the magnitude of the energy performance values that occur under test conditions so as to obtain an overview of the parameters that can lead to increased energy efficiency in inverter AC systems.

III. RESULTS AND DISCUSSIONS

The purpose of the first law thermodynamic analysis is to determine the variation of the coefficient of performance (COP) with evaporator temperature, condenser temperature, compressor isentropic efficiency and superheating temperature. For this reason, the first law analysis is applied to each component of the system.

The energetic performance of the entire system is determined by evaluating its COP, calculated as the ratio between the cooling capacity and the electrical power supplied to the compressor.

Energy analysis of the vapor refrigeration compression cycle requires application of the first law of thermodynamics. The general equation according to this principle is as follows.

Table 1: Mass and energy balance in vapor compression refrigeration systems

Component	Mass Balance	Energy Balance
Evaporator	$\dot{m}_4 = \dot{m}_1$	$\dot{m}_4 h_4 + \dot{Q}_{evap.} = \dot{m}_1 h_1$
Compressor	$\dot{m}_1 = \dot{m}_2$	$\dot{m}_1 h_1 + \dot{W}_{comp} = \dot{m}_2 h_2$
Condenser	$\dot{m}_2 = \dot{m}_3$	$\dot{m}_2 h_2 = \dot{m}_3 h_3 + \dot{Q}_{cond.}$
Expansion Valve	$\dot{m}_3 = \dot{m}_4$	$\dot{m}_3 h_3 = \dot{m}_4 h_4$

Refrigerant properties to calculate the experimental output parameters, namely refrigerant mass flow rate, compressor real work, compressor isentropic work, compressor isentropic cooling, cooling capacity, condenser capacity and Coefficient of Performance (COP). Refrigerant property values were determined using REFPROP 9.0 software with refrigerant references R32, R410a, R1270 and ASHRAE standards. To determine the refrigerant properties

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using software, the pressure value measured with a pressure gauge in Psig units is increased to Psia units [1 Psig = (Psig + 14.67) Psia].

1) Refrigerant Mass Flow Rate

With the problem of steady flow so that the mass flow rate of the refrigerant is assumed to be constant.

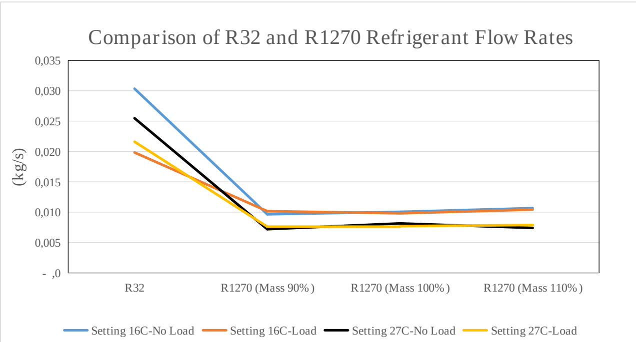

Figure 2: Comparison of refrigerant flow rates R32 and R1270

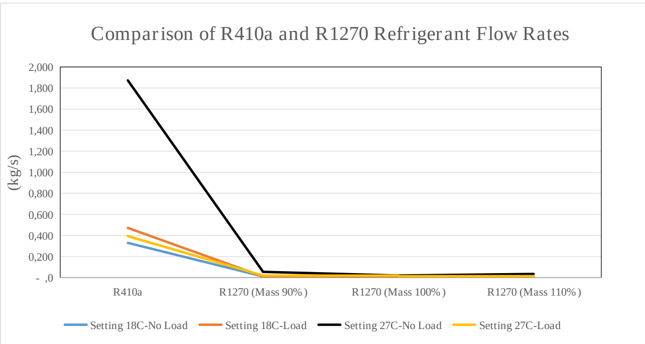

Figure 3: Comparison of refrigerant flow rates R410a and R1270

From the description of the refrigerant flow rate, it can be seen that the refrigerant flow value of R1270 is smaller than that of R32 and R410a. This condition illustrates that in terms of thermodynamic properties, the cooling index value of R1270 is greater than that of R32 and R410a.

2) Cooling Capacity

Inside the system, the evaporator vaporizes the refrigerant that enters the vapor-liquid phase to turn into a saturated vapor phase. In the evaporation process there is a separation of heat from the environment into the system. The amount of cooling capacity can be calculated as follows.

$$\dot{Q}_e = \dot{m}_r \left(h_1 - h_4\right)$$

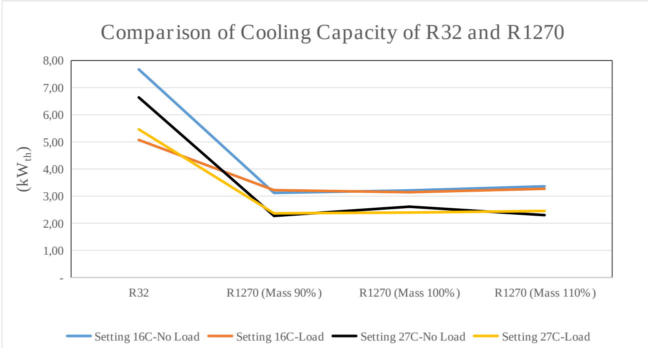

Figure 4: Comparison of cooling capacity of R32 and R1270

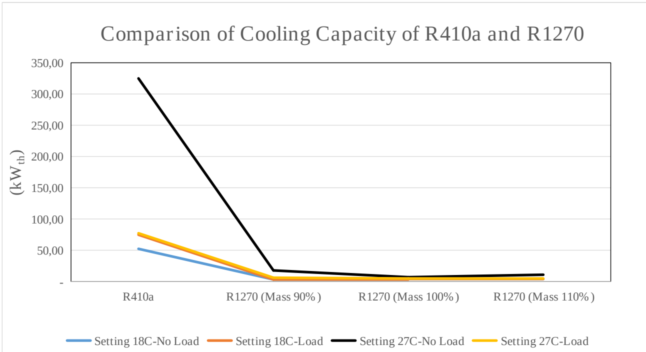

Figure 5: Comparison of cooling capacity of R410a and R1270

From the description of the refrigeration capacity values, it can be seen that the refrigeration capacity of R1270 is smaller than that of R32 and R410a. This condition illustrates that in terms of thermodynamic properties, the density value of R1270 is smaller than that of R32 and R410a.

The refrigerant flow rate can affect the evaporator capacity, the greater the refrigerant flow rate, the greater the evaporator capacity. This is caused by the difference in the density of R32 and R410a with R1270. Large evaporator capacity can increase compressor work.

3) Refrigeration Effect (RE)

Refrigeration Effect (ER) is the heat received by the system from the environment through the evaporator per unit mass rate of refrigerant. The cooling effect is an important parameter, because it is a useful and desirable effect of an engine cooling system. The value of the refrigeration effect can be calculated as follows.

$$RE = h_1 - h_4$$

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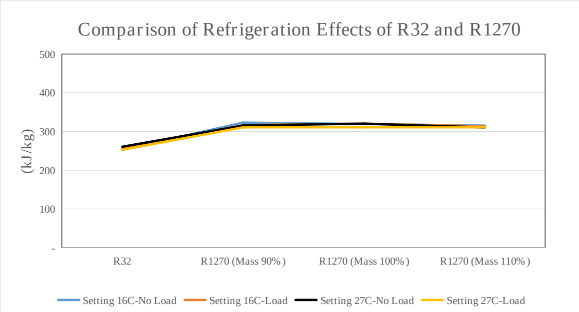

Figure 6: Comparison of Refrigeration Effects of R32 and R1270

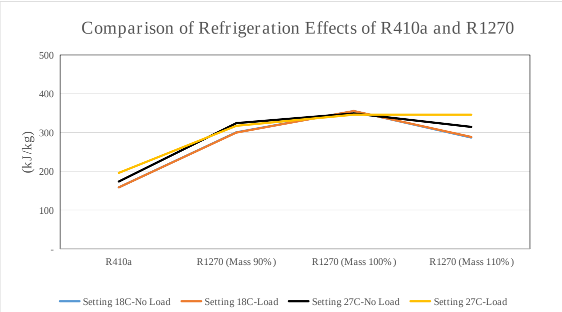

Figure 7: Comparison of Refrigeration Effects of R410a and R1270

From the description of the refrigeration capacity values, it can be seen that the refrigeration capacity of R1270 is greater than that of R32 and R410a. This condition illustrates that R1270 provides a cooling effect at cooler evaporator temperatures compared to R32 and R410a.

The increase in cooling effect is influenced by the ability of the evaporator to absorb heat from outside to evaporate it. The large refrigeration effect value has a significant impact on increasing the COP value.

4) The Actual Work of Compressor

The actual work of the compressor is the actual work supplied by the compressor to the refrigerant. The actual work of the compressor can be calculated as follows.

$$\dot{W}_{comp.} = \dot{m}_r \left(h_2 - h_1\right)$$

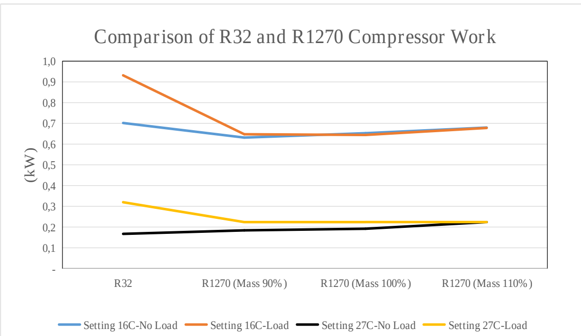

Figure 8: Comparison of R32 and R1270 Compressor Work

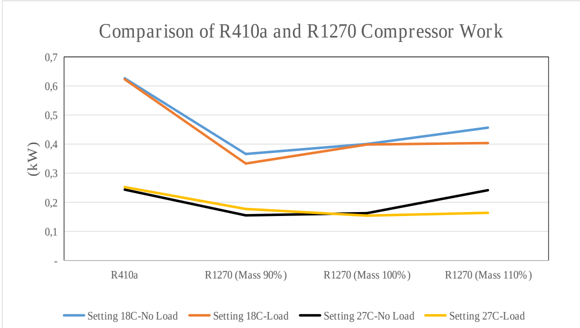

Figure 9: Comparison of R410a and R1270 Compressor Work

The actual operating values of the compressors for R32 and R410a are greater than those for R1270, respectively. In addition to the types of mass R32 and R410 which are larger than R1270, compressor work with large R32 and R410 will experience additional condensing capacity and affect the electricity consumption needs of the compressor.

5) Condenser Capacity

The capacity of the condenser is the ability of the condenser to release heat from the refrigerator to the environment. the value of the capacity of the condenser can be calculated as follows.

$$\dot{Q}_c = \dot{m}_r \left(h_2 - h_3\right)$$

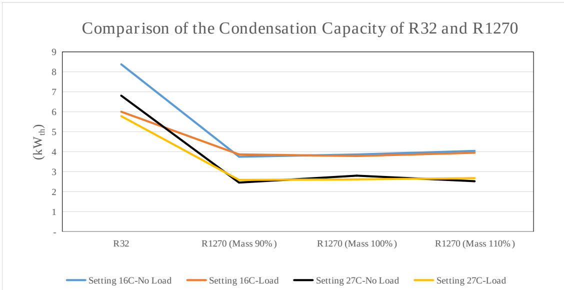

Figure 10: Comparison of Condensation of R32 and R1270

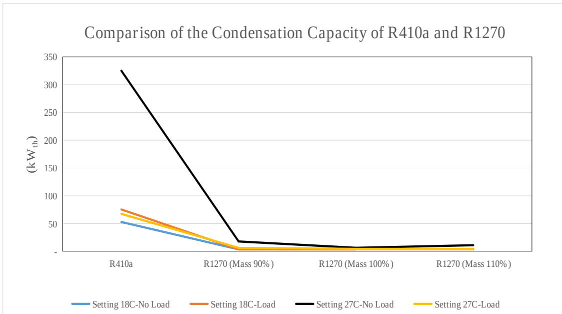

Figure 11: Comparison of Condensation of R410a and R1270

From the description of the condenser capacity values, it can be seen that R1270 is smaller than R32 and R410a. The R410a shows a very large condenser capacity compared to

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R1270. This is because the value of the refrigeration capacity of R410a is greater than that of R1270 so that the heat dissipation in the condenser is also greater.

The heat absorbed by the refrigerant in the evaporator and the power supplied to the compressor causes the amount of heat released by the refrigerant through the condenser to be proportional to the calorific value absorbed by the refrigerant in the evaporator plus the work supplied to the compressor. This shows that R32 and R410a emit more heat in the condenser than R1270.

6) Heat Rejection Ratio (HRR)

HRR is the withdrawal ratio owned by the system. HRR is the ratio between the capacity of the condenser and the capacity of the evaporator.

$$\text{HRR}= \dot{Q}_c / \dot{Q}_e$$

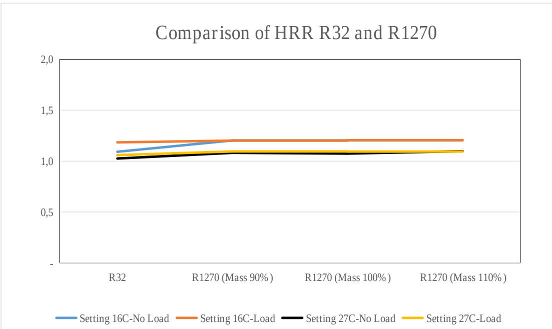

Figure 12: Comparison of HRR R32 and R1270

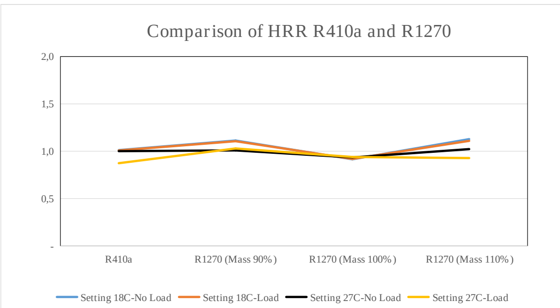

Figure 13: Comparison of HRR R410a and R1270

From the description of the HRR values, it can be seen that R32 and R410a are smaller than R1270. But in R1270 to replace R410a with 100% mass, the HRR value is lower than R410a.

HRR is the ratio of condenser capacity to evaporator capacity. Changes in condenser capacity are indirectly affected by an increase in evaporator load with an increase in compressor work. The more work the compressor does on the refrigerant, the more energy the refrigerant has to condense. In other words, a lot of waste heat is generated so that the capacity of the condenser increases. An increase in evaporator load also causes an increase in evaporator capacity.

7) Coefficient of Performance (COP)

Performance is a very important parameter, because the greater the price of performance (COP), the better the performance of the cooling system. To find out the performance of a split inverter AC, that is by using a comparison between the amount of heat absorbed from the environment by the system through the evaporator and the compression work done by the compressor.

In practice, the COP value is divided into 2 (two) parts, namely the COP carnot and the actual COP.

COP Carnot, namely the maximum COP that can be owned by a system. COP carnot can be known by using the following equation.

$$\text{COP}_{\text{carnot}} = \frac{T_e}{(T_c - T_e)}$$

Actual COP, namely COP that is actually owned by a system. The actual COP can be determined using the following equation.

$$\text{COP}_{\text{actual}}= \frac{\dot{Q}_e}{\dot{W}_c} = \frac{\dot{m}_r (h_1 - h_4)}{\dot{m}_r (h_2 - h_1)} = \frac{(h_1 - h_4)}{(h_2 - h_1)}$$

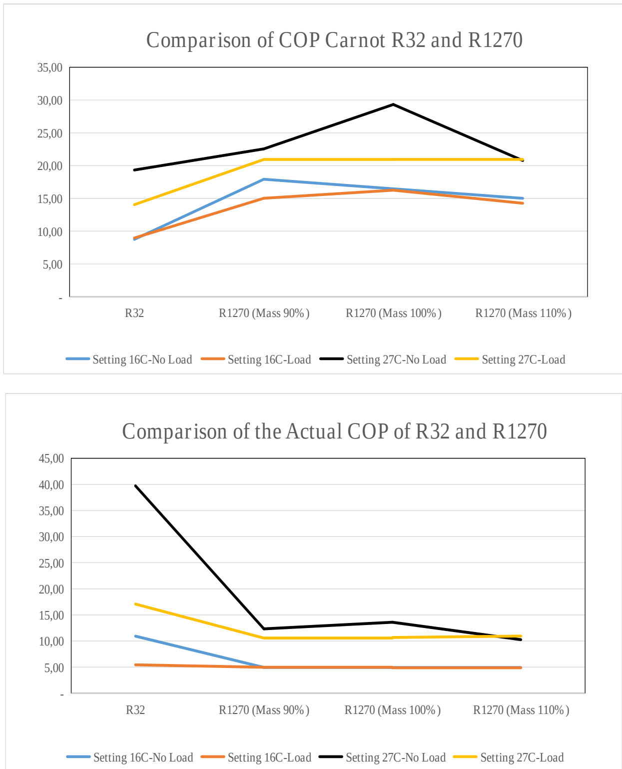

Figure 14: Comparison of COP values of R32 and R1270

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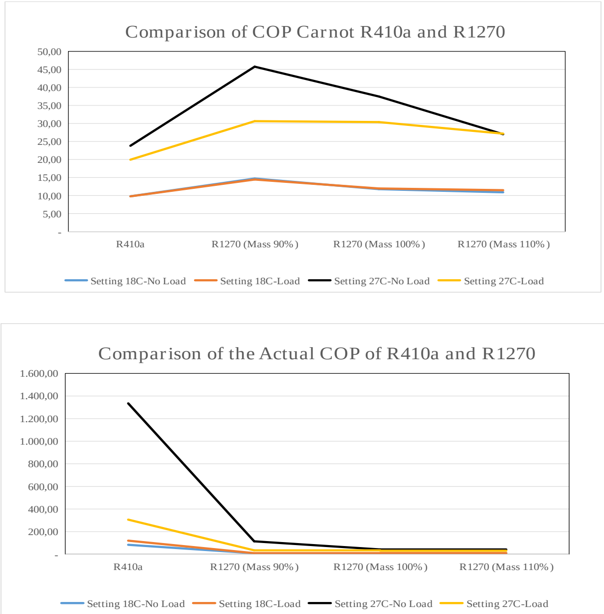

Figure 15: Comparison of COP values of R410a and R1270

From the description of the COP$_{carnot}$ values, it can be seen that R32 and R410a are smaller than R1270. However, when viewed from the COP$_{actual}$ value, it can be seen that R32 and R410a are greater than R1270.

From a system point of view, ideally the COP$_{carnot}$ value should be greater than the COP$_{carnot}$ value because COP$_{carnot}$ is the maximum limit for the COP$_{actual}$ value. The COP$_{actual}$ value which is higher than the COP$_{carnot}$ value is caused by the temperature data and pressure release in the compressor which are affected by the performance of the inverter. Especially on inverter AC equipment which is set at 27^{o}C.

8) Refrigeration Efficiency

Another performance measure of a cooling system is cooling efficiency which is defined as the ratio of COP$_{actual}$ to COP$_{carnot}$ at the same operating temperature. The value of refrigeration efficiency can be described as follows.

$$\eta_R = \frac{COP_{actual}}{COP_{Carnot}}$$

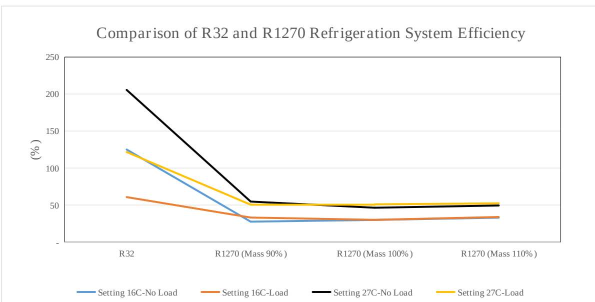

Figure 16: Comparison of R32 and R1270 Refrigeration System Efficiency

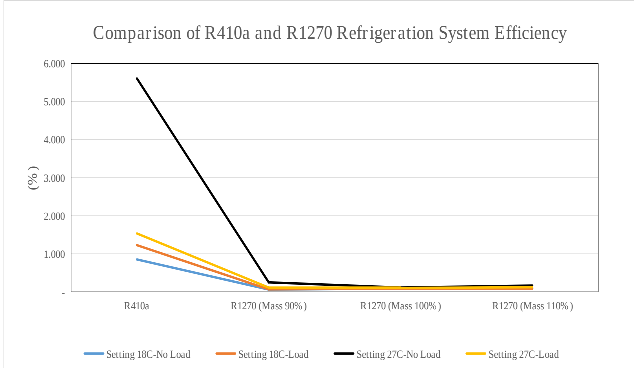

Figure 17: Comparison of R410a and R1270 Refrigeration System Efficiency

From the description of the refrigeration efficiency values, it can be seen that R32 and R410a have unusual values, this is because the COP$_{carnot}$ values of R32 and R410aare smaller than the COP$_{actual}$ values.

In terms of the system, the efficiency of R1270 in various conditions for the replacement of R32 is almost the same. For R1270 to replace R410a, the highest efficiency is at a temperature setting of 16^{o}C, namely at 100% mass condition.

9) Energy Efficiency Using VDMA 24247-2 Standard

The VDMA 24247-2 standard describes the performance and energy efficiency of cooling systems. Ratings are based on establishing correlations, or quality levels, which also allows evaluation of some system functions. To illustrate the principle of energy efficiency, first consider the Carnot cycle. Next, an extension to the actual vapor compression cycle.

- **Cooling Production Efficiency**

In consideration of this efficiency, the Carnot cycle is defined as cooling. It is assumed that only the compression process and the expansion process are related to entropy production. The COP ratio of the Carnot cycle between T$_e$ and T$_c$ is the COP of the irreversible cycle, operating between the heat source and the same ambient temperature, then the cooling production efficiency is defined as.

$$\eta_{CP} = \frac{\dot{Q}_e}{\dot{W}_c} \frac{T_c - T_e}{T_e}$$

- **Heat Transfer Efficiency**

In real systems, the temperature difference in the heat exchanger is required for heat insulation. Therefore, the temperature on the cold side of the refrigeration cycle (T$_e$) must be lower than the temperature of the heat source (T_U), while the temperature on the warm side of the cycle (T$_c$) must be greater than the ambient temperature (T_0).

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The Carnot cycle between temperatures T_e and T_c requires more driving force input than the Carnot cycle between temperatures T_U and T_0, if it is assumed that the two processes produce the same refrigeration capacity.

The cooling capacity of the two processes that carry out the same cooling results in a cooling heat value which is defined by:

$$\eta_{HT} = \frac{T_e}{T_U} \frac{T_0 - T_U}{T_c - T_e}$$

- **Fluid Transport Efficiency**

The total electrical power input of the refrigeration system consists of electrical power for the compressor (including oil sump heaters, fans, etc.) and for units that allow the transfer of liquid outside the refrigerant circuit (pumps, fans).

Fluid transport efficiency is defined as the ratio of the electric power to compressor operation to the total electric power supplied to the system which is defined as follows.

$$\eta_{FT} = \frac{\dot{W}_c}{\dot{W}_{tot}}$$

- **Cold Utilization Efficiency**

Electrical energy is supplied to a heat source, for example to a fan drive or to an electric defrost heater which is completely converted to heat. The cooling system must create this heat to maintain the cooling temperature. Thus, the useful cooling capacity is less than the cooling capacity produced by the compressor.

Cold usage efficiency is defined as the ratio of net cooling to cooling capacity which is defined as.

$$\eta_{CU} = \frac{\dot{Q}_U}{\dot{Q}_e}$$

Based on several types of efficiency values using the technical standard VDMA 24247-2 (Verband Deutscher Maschinen-und Anlagenbau e.V.) for each refrigerant condition, an overview of the efficiency values is obtained as follows.

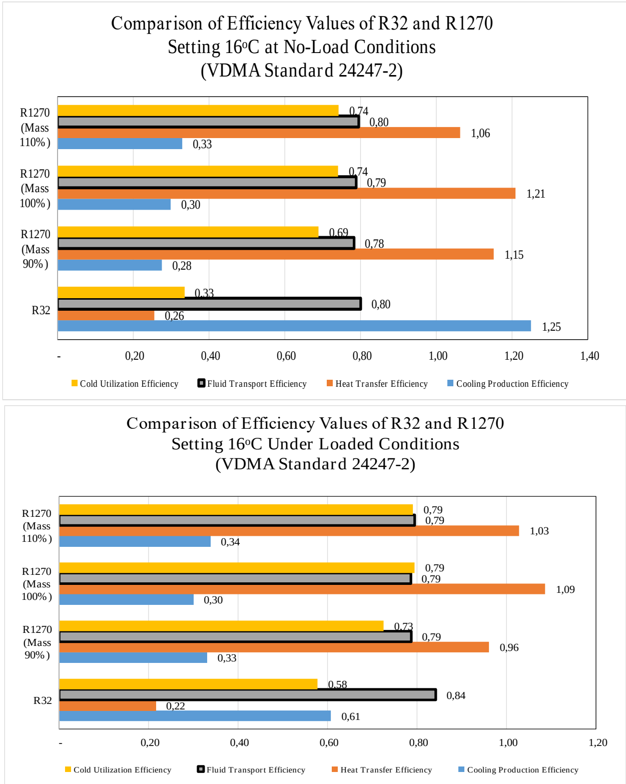

Figure 18: Comparison of Efficiency Values of R32 and R1270at 16ºC Settings (VDMA Standard 24247-2)

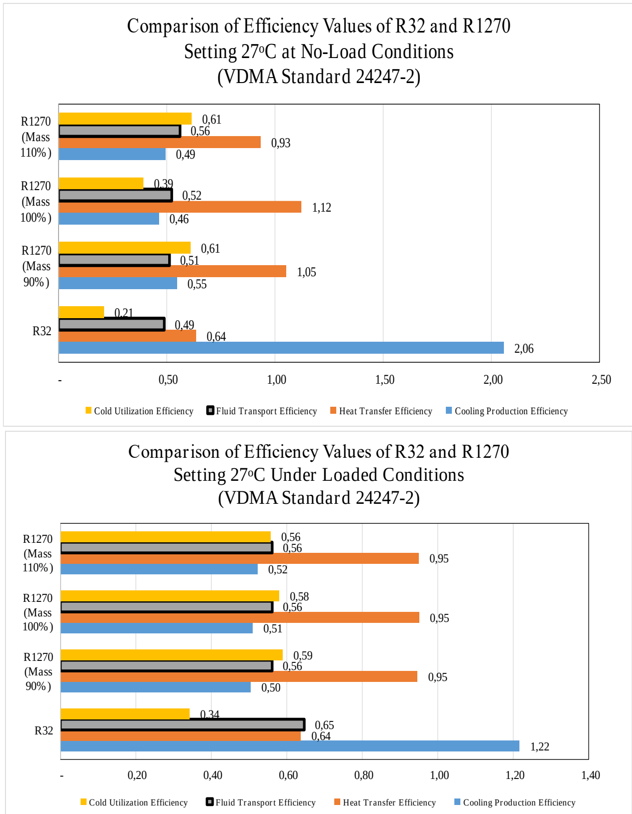

Figure 19: Comparison of Efficiency Values of R32 and R1270at 16ºC Settings (VDMA Standard 24247-2)

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From the elaboration of efficiency values based on the VDMA 24247-2 standard, it can be seen that the highest efficiency in the R1270 cooling system in every condition is heat saving. This efficiency describes the value of the effectiveness of the refrigeration system in the process of utilizing the heat absorbed by the evaporator against the environmental conditions around the conditioned room. Meanwhile, for the highest efficiency in the R32 refrigeration system, the highest efficiency is the cooling productivity efficiency value. This is due to the high temperature ratio of the condenser and evaporator resulting in a large efficiency value.

The value of transportation efficiency and cold use efficiency for R1270 in each condition is relatively the same. Whereas for R32 the value of cold utilization efficiency tends to be smaller. This is because the value of the cooling air capacity is still small compared to the heat absorbed by the evaporator.

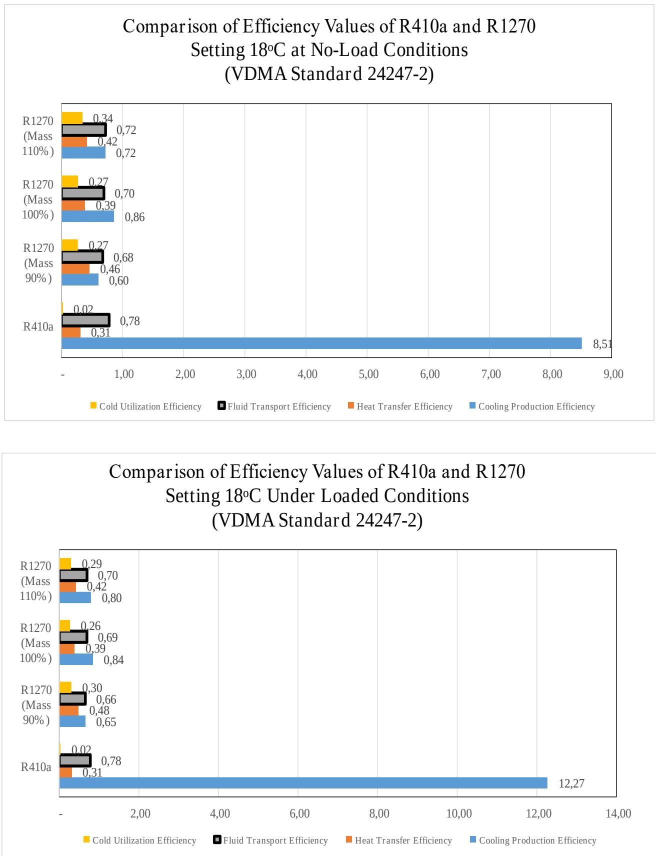

Figure 20: Comparison of Efficiency Values of R410a and R1270at 18°C Settings (VDMA Standard 24247-2)

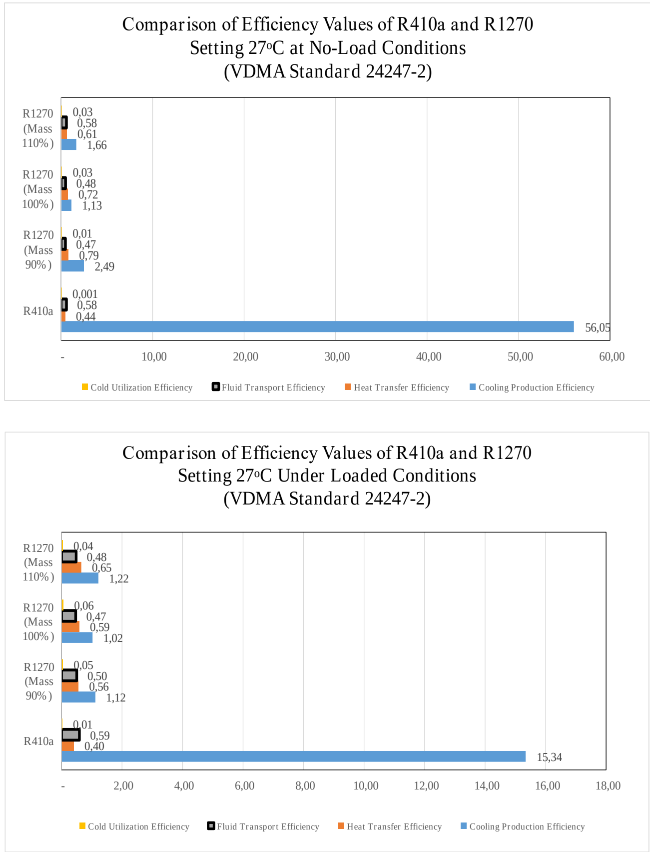

Figure 21: Comparison of Efficiency Values of R410a and R1270at 27°C Settings (VDMA Standard 24247-2)

From the description of the types of efficiency values based on the VDMA 24247-2 standard, it can be seen that the highest efficiency in the R1270 refrigeration system at a temperature setting of 18°C is cold productivity efficiency and liquid transportation efficiency. Whereas for the temperature setting of 27°C, the cold productivity efficiency value is the highest among other efficiency values. This is because at the 27°C setting, the compressor work is actually very small compared to the 18°C setting. For R410a, in all conditions the highest efficiency value is cold productivity efficiency, this condition is due to the relatively large comparison of the condenser and evaporator temperature values.

For cold utilization efficiency values at R410a and R1270 in each condition, cold utilization efficiency values tend to be smaller. This is because the value of the cooling air capacity is still small compared to the heat absorbed by the evaporator.

10) Total Energy Efficiency

The product of the derived efficiency calculates the energy efficiency of the entire system. This value is called the energy efficiency level which is defined as.

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$$\eta_{tot} = \eta_{CP} \cdot \eta_{HT} \cdot \eta_{FT} \cdot \eta_{CU} = \frac{\dot{Q}_U}{\dot{W}_{tot}} \frac{T_0 - T_U}{T_U}$$

The method described in VDMA 24247-2 is capable of evaluating energy efficiency under constant operating conditions. The end result is the same as exergetic efficiency even though the method does not change the exergy analysis, but this method is able to improve many systems. Because it seems easier, acceptance in application can be higher than exergetic analysis.

Based on several types of efficiency values using the technical standard VDMA 24247-2 for each refrigerant condition, an overview of the cooling system efficiency values is obtained as follows.

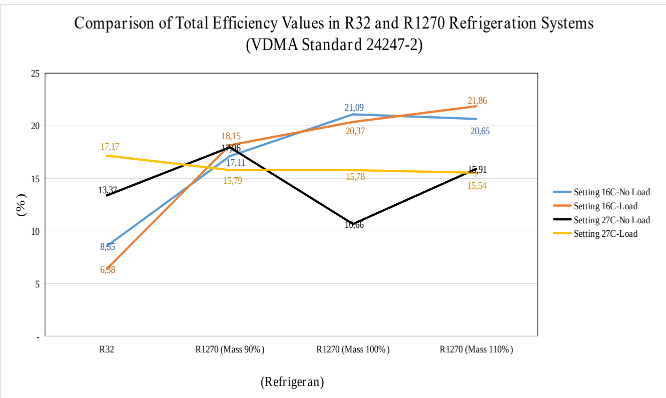

Figure 22: Comparison of Total Efficiency Values in R32 and R1270 Refrigeration Systems (VDMA Standard 24247-2)

From the description of the efficiency value of the refrigeration system based on the VDMA 24247-2 standard, it can be seen that the highest efficiency value in the R32 refrigeration system is 17.17% which occurs at a setting temperature of 27°C under loaded conditions, while the highest efficiency value in the R1270 refrigeration system is as following:

- R1270 mass is 90%, the highest efficiency of the refrigeration system occurs at a setting temperature of 16°C with a load of 18.15%.
- R1270 mass is 100%, the highest efficiency of the refrigeration system occurs at a setting temperature of 16°C without load, which is 21.09%.
- R1270 with a mass of 110%, the highest efficiency of the refrigeration system occurs at a setting temperature of 16°C with a load of 21.86%.

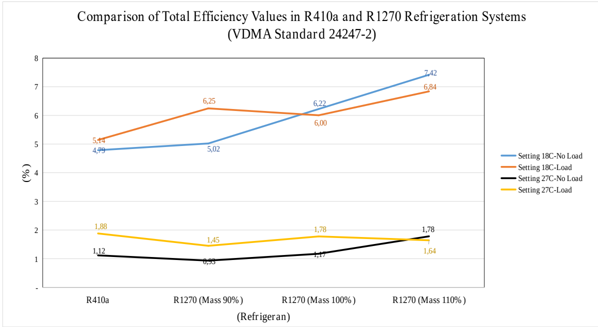

Figure 22: Comparison of Total Efficiency Values in R410a and R1270 Refrigeration Systems (VDMA Standard 24247-2)

From the description of the efficiency value of the refrigeration system based on the VDMA 24247-2 standard, it can be seen that the highest efficiency value in the R410a refrigeration system is 5.44% which occurs at a setting temperature of 18°C under loaded conditions, while the highest efficiency value in the R1270 refrigeration system is as following:

- R1270 mass is 90%, the highest efficiency of the refrigeration system occurs at a setting temperature of 18°C with a load of 6.25%.
- R1270 mass is 100%, the highest efficiency of the refrigeration system occurs at a setting temperature of 18°C without load, which is 6.22%.
- R1270 mass is 110%, the highest efficiency of the refrigeration system occurs at a setting temperature of 18°C without load, which is 7.42%.

11) Subcooling and Superheat Analysis

Based on this, the author will analyze the changes in subcooling and superheat temperatures in refrigerant types R32 and R410a and compare them with R1270 as a replacement refrigerant using the REFPROP (Reference Fluid Properties) program.

From the results of research on inverter AC equipment using R32, R410a, and R1270, the comparison of subcooling and superheat temperature values is as follows.

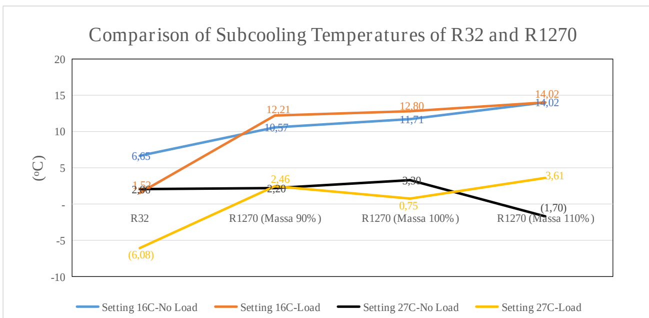

Figure 23: Comparison of Subcooling Temperature of R32 and R1270

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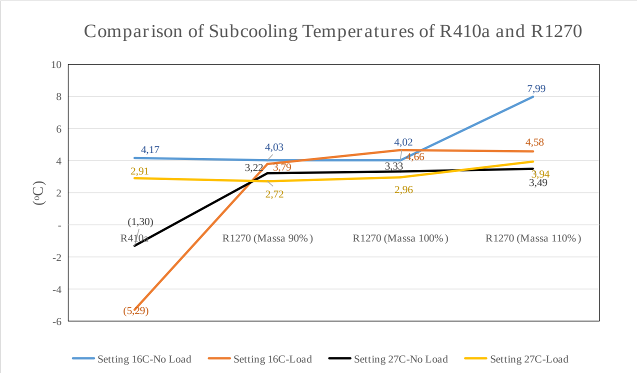

Figure 24: Comparison of Subcooling Temperature of R410a and R1270

In the comparative description of the subcooling temperature values of R32 and R1270, it can be seen that the lowest subcooling temperature value occurs in R32 with a temperature setting of 27°C with a load of -6.08°C while the highest subcooling temperature value occurs in R1270 with a mass load of 110%, which is 14.02°C at a temperature setting of 16°C with load.

For a comparison of the subcooling temperature values of R410a and R1270, it can be seen that the lowest subcooling temperature value occurs in R410a with a temperature setting of 16°C with a load of -5.29°C while the highest subcooling temperature value occurs in R1270 with a mass load of 110%, namely 7.99°C at a temperature setting of 16°C without load.

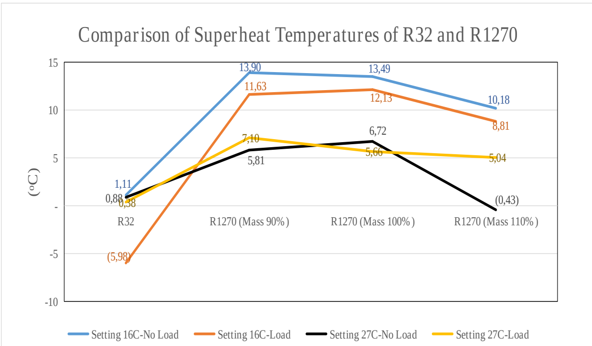

Figure 25: Comparison of Superheat Temperature of R32 and R1270

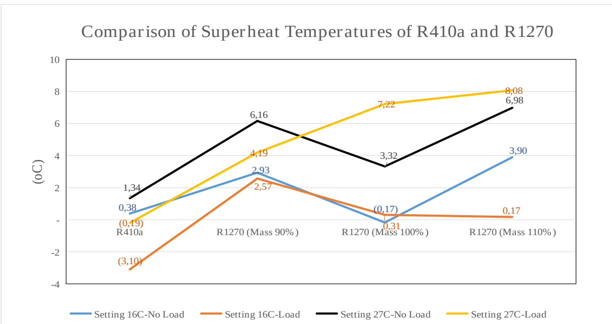

Figure 26: Comparison of Superheat Temperature of R410a and R1270

In the comparative description of the superheat temperature values of R32 and R1270, it can be seen that the lowest superheat temperature value occurs in R32 with a temperature setting of 16oC with a load of -5.98°C while the highest superheat temperature value occurs in R1270 with a mass load of 90%, namely 13.90°C at a temperature setting of 16°C without burden.

For a comparison of the R410a and R1270 superheat temperature values, it can be seen that the lowest superheat temperature value occurs in R410a with a temperature setting of 18°C with a load of -3.10°C while the highest superheat temperature value occurs in R1270 with a mass load of 110%, namely 8.08°C at a temperature setting of 27°C with a load.

Based on a comparative description of the relationship between subcooling and superheat to compressor work, it can be seen that the subcooling and superheat values for R32 are lower than R1270, in other words there is an increase in subcooling and superheat values if R32 is reinstalled to R1270. For compressor work values, at a temperature setting of 16°C, R32 is greater than R1270. At a temperature of 16°C with a load, the compressor work on R1270 is lower than R32 or it can be said that the use of R1270 can reduce the compressor work by around 30%.

In R410a to R1270 it can be seen that the superheat value in all conditions is lower than R1270. This condition illustrates that there is an increase in the superheat value if the use of R410a is refitted to R1270. For compressor work value, R410a is greater than R1270. In operation, the compressor work on R1270 is lower than R410a or it can be said that the use of R1270 can reduce compressor work by around 40%.

Based on actual conditions, the level of subcooling does not affect the actual work value of the compressor, but is affected by the difference in the enthalpy values entering and leaving the compressor, so that the compression work is more influenced by the level of superheat and is not related to the value of the level of subcooling.

In actual conditions, the increase in the value of the refrigeration effect apart from the magnitude of Δh (h_1-h_4) other factors that have an effect is the value of ΔP (P_3-P_4), in conditions where the value of ΔP is getting smaller it can be seen that the value of the refrigeration effect is also increasing. This is illustrated by R1270 with a mass of 100% where the smallest ΔP value can produce the greatest refrigeration effect value even though the superheat and subcooling levels are smaller than R1270 with a mass of 90% and 110%.

Related to the COP value, the increase in COP apart from the magnitude of Δh (h_1-h_4), another factor that affects it is the property value of the refrigerant. Based on this research, when

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viewed from the compression process (1-2) for the comparison of R32 to R1270 and R410a to R1270 the value of ΔT (T_2-T_1) tends to be the same in all conditions, but when viewed from the value of ΔP (P_2-P_1), R1270 tends to be smaller than R32 and R410a which in terms of compressor efficiency is greater than the large ΔP (P_2-P_1) value which directly increases the COP value. In theory, a small value of ΔP (P_2-P_1) can increase the value of COP.

In conditions where the type of refrigerant is different between R32, R410a, and R1270, it can be seen that in R1270 the value of ΔP (P_2-P_1) is smaller than R32 and R410a but when viewed from the value of Δh (h2-h1) it is actually greater than R32 and R410a. This indicates that the latent heat value of R1270 is greater than R32 and R410a, which has a large impact on Δh (h_2-h_1) even though the value of ΔP (P_2-P_1) R1270 is lower than R32 and R410a.

IV. CONCLUSION

From the results of this research which compares the performance of R32 and R410a to R1270 which is a replacement refrigerant in a split inverter AC system, the picture is that:

1) The thermodynamic, chemical, physical and transport properties of Breezon MC32 (R1270) match those of the thermodynamic, chemical, glass and transport properties of R32 and R410a.
2) Refrigerant charging must be based on mass, not based on compressor pressure or electric current.
3) The value of the mass flow rate of refrigerant R1270 is lower than R32 and R410a, this is because the cooling index value of R1270 is greater so that it can condition air with a small mass flow rate.
4) The refrigeration capacity of R32 and R410a is greater than R1270, this condition is because the density value of R1270 is lower than that of R32 and R410a.
5) The refrigeration effect value of R1270 is greater than R32 and R410a because the ΔP value between the evaporation and condensation processes in R1270 is smaller so that the cycle of the evaporation process is greater.
6) From the work side of the compressor, R1270 has a lower value than R32 and R410a because cyclically the value of ΔP (P2-P1) in R1270 is smaller so that the compressor work in the compression process is lower. In addition, the low density value of R1270 also makes the compression process faster.

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