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"A REVIEW ON PERFORMANCE OF SUBCOOLED VCR CYCLE UTILIZING DIFFERENT REFRIGERANTS"

[1]Vaibhav Upadhyay, [2]Dr.Sanjay Katare, ,[3]Mr. Kamlesh Sharma

[1]M.Tech Scholar, [2] Prof. , [3] Asst.Prof.

[1]Department of Mechanical Engineering

[1]Samrat Ashok Technological Institute (SATI), Vidisha, India

ABSTRACT

In Refrigeration & Air Conditioning systems, the VCR cycle is commonly utilized. Sub cooling is utilized to increase the Refrigeration & Air conditioning systems, COP by increasing cooling efficiency. This paper discusses concept of sub cooling, several sub cooling technologies that have been developed and used to boost the effectiveness of the VCR Cycle. The benefits and cons of each strategy, as well as possible future research directions in this research subject, were thoroughly explored. The literature review acquired from many known data sources demonstrates that substantial research has been done on the simple VCR cycle. Among them, certain experiments focused on dedicated mechanical sub cool cycles have been investigated to improve the cycle's performance. There has been little research into the effectiveness of dedicated mechanical sub cool cycles employing HFO refrigerants such as R1234yf and R1234ze.That's why I choose My Proposed Research Work on dedicated mechanical sub cool cycle employing HFO refrigerants. For the computation of the performance outcomes, an Engineering Equation Solver software based computer programme will be developed.

Keywords: VCR cycle, dedicated mechanical sub cool cycle, COP, HFO.

1. INTRODUCTION

The need for refrigeration systems, as well as air conditioners, will rise as the economy and infrastructure develop. Aside from that, given the increasingly expensive & limited energy supplies, energy reductions in R&A systems (refrigeration & air conditioning systems) are critical. Air Conditioning (A.C) systems utilize roughly 50 percent of total energy in commercial buildings, whereas refrigeration systems use approximately 50 to 60 percent of total energy in supermarkets. As a result, improving the R&A systems' performance can result in considerable energy savings. The need for high-quality energy in emerging nations, such as India, is steadily increasing. Power costs are rising in tandem with demand. The usage of high Global Warming Potential refrigerants such as Hydro fluorocarbon in RAC systems is now causing environmental disruption. The **Mechanically Sub Cooling** of the VCR cycle has been proven by several researches to increase its efficiency [1].

2. CONCEPT OF SUB COOLING OF VCR CYCLE

A refrigeration system may be required to operate at a very high temperature differential seen between condenser & evaporator in hotter climates like INDIA. This sort of issue occurs frequently in the dairy and chemical sectors. A only one or single stage refrigeration system becomes useless in these situations because it requires a lot of compressor power and also has a low cooling effect. As a result, the compressor's COP & volumetric efficiency are diminished. To boost the effectiveness of the Vapour Compression Refrigeration system, a dedicated Mechanical Sub cooling Cycle is used. In these conditions, researchers are attempting to enhance the system's Coefficient of performance (COP) by experimenting with various ways for sub cooling condensed liquid refrigerants. A dedicated Mechanical Sub Cooling cycle employs a secondary VCR cycle specifically to provide sub cooling to the primary refrigeration cycle [2]. Different ways of excess sub cooling enhance the quantity of liquid refrigerant before it reaches the evaporator. This lowers the refrigerant's mass flow rate for a given cooling demand. As a result, the compressor's power consumption drops & the cycle's performance increases.

3. VARIOUS METHODS OF SUBCOOLING OF VCR CYCLE

There are generally four methods of sub cooling of VCR cycle:

a. LIQUID-SUCTION HEAT EXCHANGER SUB COOLING.
b. CONDENSATE ASSISTED SUB COOLING
c. INTEGRATED MECHANICAL SUB COOLING
d. DEDICATED MECHANICAL SUB COOLING

In **LIQUID-SUCTION HEAT EXCHANGER SUB COOLING**, a heat exchanger is used to transmit heat energy from the condenser output to the suction intake. The use of sub cooler heat exchanger increases the suction temperature. Superheating helps to keep liquid refrigerant out of the suction compressor. In certain severe circumstances, liquid phase refrigerant reaching the suction creates problems with the compressors bearings & rings, as well as valve failure.

In **CONDENSATE ASSISTED SUB COOLING**, the temperature of the condenser air face as well as the temperature of the compressor discharge is usually around 30°C & 60°C, accordingly [20]. As a result of the peripheral devices, such as the water pump and sub-cooler, the condensate water has a substantial potential to take heat load, whether from hot compressed refrigerant at the inlet condenser or from hot compressed refrigerant at the outlet condenser. As a result, it may be used to lower the temperature of the condenser air face and the compressor discharge temperature. The air conditioning system's performance can be increased by lowering the condenser air face temperature & compressor discharge temperature.

In **INTEGRATED MECHANICAL SUB COOLING,** there is use of a third-party Vapour Compression Refrigeration System. Only one condenser is utilized by both the main & sub-cooler systems.

In **DEDICATED MECHANICAL SUB COOLING,** there is also use of a third-party Vapour Compression Refrigeration System. Each system, i.e., the main and sub-cooler systems, uses one of the two condensers.

Criteria	Liquid-section heat exchanger	Dedicated mechanical sub-cooling	Integrated mechanical sub-cooling	Condensate assisted sub-cooling
Required significant additional energy input	No	Yes, for secondary compressor	Yes, for secondary compressor	Yes, for condensate water pump*
System complexity	Low	High	High	Medium
Technological status	Already commerciali zed	Research stage	Research stage	Research stage
Superheating status	Produces super-heating	No super-heating	No super-heating	No super-heating
COP improvement potential	Low	Medium	Medium	High

TABLE1 VARIOUS METHODS OF SUBCOOLING OF VCR CYCLE

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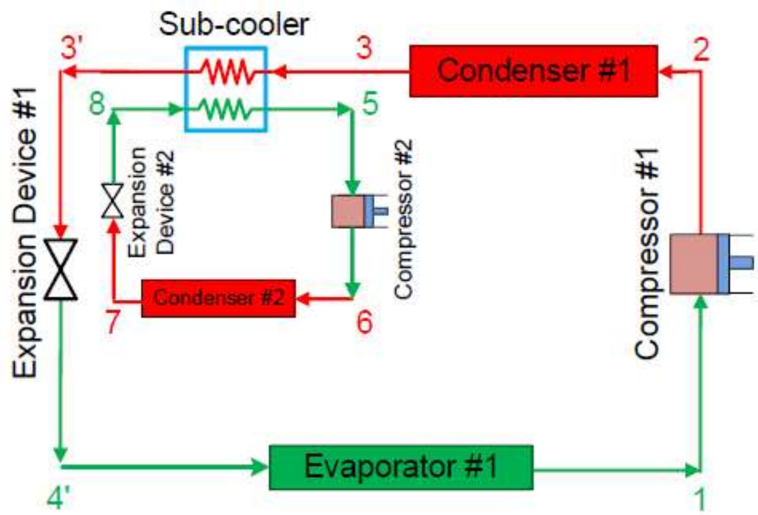
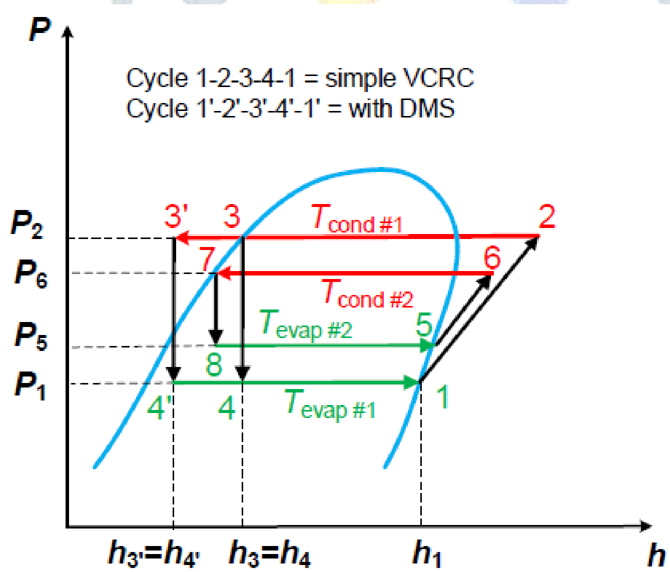
4. DEDICATED MECHANICALLY SUB COOLED VCR CYCLE

To supply sub cooling to the main **VCR** refrigeration system, dedicated mechanical sub cooling processes use a small mechanical VCR cycle connected to the main cycle near the condenser's outlet. Dedicated mechanically sub cooled VCR system is used where medium to large refrigeration effect is required.



(a)



(b)

Fig1.(a).SCHEMATIC DIAGRAM OF DEDICATED MECHANICALLY SUB COOLED VCR CYCLE

(b).p-h DIAGRAM OF DEDICATED MECHANICALLY SUB COOLED VCR CYCLE AT STEADY STATE

The diagram depicts two VCR cycles the main & sub cooler cycles. The main cycle has a bigger capacity than the sub cooler cycle. Both cycles might employ the same refrigerant or a separate refrigerant. The main cycle's evaporator temperature must be greater than the sub cooler cycles'. The main cycle's evaporator temperature is determined by the temperature limit. Furthermore, the evaporation temperature (T_{evap}) is set to be a few degrees lower than the main system's condenser temperature

(T_{cond}). Furthermore, the main cycle's condenser temperature is not necessarily greater than the sub cooler cycle's. Both temperatures will be the same if the main and sub cooler cycles are located in the same location. Several investigations were conducted by researchers to identify the best sub cooling in order to get the highest COP in the Dedicated Mechanically Sub Cooled VCR System.

5. LITERATURE REVIEW

REVIEW OF PAST STUDIES:

KASNI SUMERU Et al. (2019) paper presents various sub-cooling methods, which have been established and applied to enhance the performance of the VCRC. In the present study, four sub-cooling methods are reviewed, which are liquid-suction heat exchanger, dedicated mechanical sub-cooling, Further cooling of the exit condenser to the sub-cooled region can result in an increase in the cooling capacity due to low vapor quality refrigerant entering the evaporator. As a result, the refrigerant absorbs more heat in the evaporator. The lower the quality of the refrigerant entering the evaporator, the higher the cooling capacity that is produced by the evaporator. This cooling capacity improvement results in an increase in the COP.

RANENDRA ROY Et al. (2021) study shows that a single-stage vapor compression refrigeration system becomes inefficient and impractical when the temperature lift between the evaporator and the condenser becomes large. Under the high-temperature lift, different losses in the system increase, and more refrigerant vapor is formed at the end of the throttling process. This problem can be overcome by integrating a single stage vapor compression refrigeration system with a dedicated sub cooler for high-temperature lift applications using R134a in the main cycle and four low global warming potential (GWP) refrigerants in the sub cooler cycle. The modeling of the proposed system has been carried out in Engineering Equation Solver (EES) considering the energy, exergy, and economic aspects for the simulation of the system. The predicted results show that the use of the proposed system is more beneficial from both performance and economic point of view for high-temperature lift. Nearly 27% improvement in both energetic and energetic performances are noted whereas cost is reduced by 2% when the proposed system is
used instead of a typical refrigeration system.

N. A. ANSARI Et al. (2020) conducted a thermal analysis on a mechanically sub cooled Vapour compression refrigeration system employing R1234ze, R134a & R1234yf in both cycles & discovered that the dedicated sub cooler cycle outperformed a standard Vapour compression refrigeration system . For the functioning of a specialized cycle in the system, they discovered that R1234ze performed better than the other two refrigerants.

DAI B. Et al. (2017) conducted a thermodynamic study on transcritical CO_2. Mechanical sub cooler refrigeration systems cooling the co_2 entering the gas cooler using an aided VCRS cycle can improve the thermal performance of the co_2 transcritical cycle. For scenarios with greater ambient temperatures and lower evaporation temperatures, co_2 transcritical aided with mechanical sub cooling is advised.

DE PAULA C H Et al. (2020) paper presents a steady-state model of a VCRS that generates 1200 liters of chilled water at 5 °C for an indirect expansion air-conditioning system & 600 liters of hot water at 40 °C .The suggested model was utilized to create a Vapour Compression Refrigeration System with a more compact geometric structure & also to evaluate the environmental energy as well as exergy performance of R290, R1234yf & R744 to R134a. This model also takes into account the volumetric & global efficiency curves for each refrigerant collected from commercial compressors. Finally, in order to evaluate the refrigerant charge in the improved systems, a comparison analysis was conducted. For the specified thermodynamic condition, the refrigerant charge in the systems with R744, R1234yf, & R134a is 102.4 percent, 126.9%, & 114.2 percent greater, respectively, than the refrigerant charge in the system with R290.

SUN J Et al. (2020) research investigates the energetic and exergetic performance of R513a as a drop-in replacement for R134a using an economized-cycle VCRS as an example. Unlike earlier studies, this study investigates the full system operating zone to uncover performance differences between R513a & R134a systems in terms of capacity, COP, exergy destruction rate, & exergy efficiency.

According to the study, a system with drop-in R513a has a lower capacity & efficiency (up to 9% with COP and 14% with exergy efficiency) in the majority of operating conditions, while having less irreversibility (5 percent to 13 percent) in high-ambient, high-space temperature conditions and a better exergy efficiency of 3% in low-ambient conditions. The study results show that the compressor should be the first component to be changed or reselected to increase the energy & exergy efficiency of an R513a system followed by the economizer, valves & other components.

LLOPIS R. Et al. (2018) used a specialized mechanical sub-cooling cycle to potentially improve the energy performance of a CO2 transcritical refrigeration system. Internal heat exchangers, economizers, thermoelectric systems, plus specific sub-cooling techniques of the CO2 refrigeration cycle saw a 20% gain in COP as well as a 28.8% increase in cooling capacity when they merged and assessed sub-cooling methods. They came to the conclusion that sub-cooling is a worthwhile strategy for improving the refrigeration cycle's performance and that it merits further research. Many researchers have recommended that R134a be replaced in refrigeration systems with R1234ze & R1234yf.

QURESHI B. A Et al. (2012) investigated the influence of DMS on the VCRC's performance numerically in their paper. They used R134 as the liquid in the main cycle and R134a, R407C, and R410A as the sub-cooler cycle in the first simulation, and R717 as the main cycle and R134a, R407C, and R410A as the sub-cooler cycle in the second simulation. They claimed that the DMS was more suited to utilise R134a as a refrigerant in the primary cycle than R717. They also included two dimensionless measures, sub-cooler saturation temperature -θ and heat exchanger performance -f. The optimal sub-cooling via DMS might be established by employing these dimensionless parameters. As a result of the necessity for an extra sub-cooler, DMS incurred significant costs. Despite this, they came to the conclusion that the payback period would be determined by the size of the systems. The payback for air-cooled refrigeration and air conditioning systems with capacities more than 100 kW was also shown in their paper.

THORNTON J. W Et al. (1994) model , they used two Vapour compression refrigeration cycle cycles including an ambient temperature of 26.7C for the main and sub-cooler, & evaporator temperatures of -28.9C and -1.1C for the main cycle & sub-cooler respectively. Their approach was chosen to determine the optimal temperature of the sub-cooling, resulting in the greatest COP increase. In their model, the influence of heat exchanger characteristics on performance was also explored. The findings revealed that the optimal temperature for sub-cooling was substantially dependent on the condensing and evaporating temperatures. The heat exchanger variables, on the other hand, were only slightly reliant on the optimal sub-cooling, condensing, & evaporating temperatures. It was determined by the heat exchanger's design.

ZUBAIR, S. M.(1990) discussed energy saving methodology that can be applied to new or existing Refrigeration & air conditioning installations to increase system performance & reduce energy consumption. A mechanical sub cooling loop is added to a typical vapor-compression cycle. Three separate applications are used to show the performance of a redesigned system. The system performance peaks at a sub-cooler saturation temperature halfway between both the condensing & evaporating temperatures, according to the findings. Simulations demonstrate that air-conditioning systems can enhance performance by up to 20% during peak periods of high condensing temperatures, but primary and secondary refrigeration systems will save energy by 20% and 40%, respectively, under the same conditions.

ZUBAIR, S. M. Et al. (1996) investigated IMS numerically using R134a. They displayed a plot of normalised COP (improvement) vs sub-cooler saturation temperature for the eva. and sub-cooling temps. of -30 and 3 degrees Celsius, correspondingly. The graph demonstrates that as the condenser temperature rises, so does the COP improvement. Their figure has four curves at four different condenser temperatures, notably 40, 50, 60, & 70 degrees Celsius. When the condenser temperature is raised, the COP improves dramatically, especially when the sub-cooler saturation temperature is raised from 0.3 to 0.6. Furthermore, the COP improves as the temperature difference between condensing and evaporating rises.

QURESHI B. A Et al. (2013) conducted an experimental study of the energy consequences of using a dedicated mechanical sub cooling phase with a domestic 1.5ton basic VCR system. When the room temperature is held between 18 to 22°C a comparison of the experimental cycle performance with and without the specialized sub cooler cycle is undertaken. This one is conducted to identify the percentage gain in efficiency that may be achieved by using a dedicated sub cooling loop. In the main cycle, R22 is used as the refrigerant, whereas R12 is used in the specialized sub cooling cycle. The load bearing capacity of the evaporator rose by around 0.5kW when R22 was sub cooled by 5–8°C in the main cycle according to the results. It was also discovered that by applying sub cooling, the cycle's second law efficiency rose by a mean of 21%.

POTTKER G Et al. (2012) studied experimentally and theoretically influence of condenser sub cooling on the efficiency of vapor-compression systems. The COP reaches a maximum when condenser sub cooling rises, owing to a trade-off between rising refrigerating effect & particular compression effort. The thermodynamic parameters of liquid specific heat plus latent heat of vaporization, which are related with a relative increase in refrigerating effect, are prominent in determining the max. COP increase with condenser sub cooling. Condenser sub cooling is less beneficial for refrigerants with a high latent heat of vaporization. Because of its lower latent heat of vaporization, the R1234yf would gain the most from condenser sub cooling in a conventional Air Conditioning system when compared to R410A, R134a, & R717.

KHAN, J. R. Et al. (2000) presented a vapour compression refrigeration system(VCRS) in which sub cooling the refrigerant at the condenser's departure allows the refrigerant to gain entry the main cycle evaporator with a lower quality, allowing the refrigerant to absorb heat in the evaporator & thus improving the system's COP. A tiny dedicated vapour compression refrigeration (VCR) cycle is used to accomplish sub cooling in a specialized mechanical sub cooling VCRS(vapour compression refrigeration system). At the condenser's outflow, this cycle is connected to the main cycle. Thermodynamic models of dedicated mechanical-sub cooling systems are created in this study to replicate the system's real performance, particularly with regard to the sub cooler saturation temperature & heat exchanger regions. The total cycle's performance is better than the comparable simple cycle and so this improvement is linked to the sub cooler's refrigerant saturation temperature.

POTTKER G Et al. (2015)) experimental findings demonstrated that the inclusion of an internal heat exchanger greatly lowers the COP increase caused by condenser sub cooling, as both improvements competed to minimize throttling losses. Despite the interaction between IHX & condenser sub cooling, using both at the same time results in a more effective air conditioning system, particularly for R1234yf. The COP for both refrigerants reaches a maximum as a result of the trade-off among growing refrigerating effect with rising specific compression effort. At a given operating temperature, the system COP rose by up to 18% for R1234yf & 9% for R134a. These findings matched the patterns seen in a prior theoretical analysis, suggesting that a system using R1234yf can gain more from condenser sub cooling than a system using R134a.

6. CONCLUSIONS

A review of the literature as well as an assessment of sub-cooling technologies in the VCR cycle for energy savings were carried out. The key aspects of each approach are discussed in order to determine their benefits in increasing the Refrigeration & Air conditioning system's efficiency. The Liquid Suction Heat Exchanger Sub Cooling technology is the only one of the four that has been commercially marketed. The remaining approaches inside this paper are being researched or are in the ideation or research stages. So I will be go with **DEDICATED MECHANICAL SUB COOLING** approach for improving the performance of VCR cycle in my further research work. This is in the research stage. Sub cooling methods boost COP in a modest way, which is better than using an ejector as an expansion device or using nanoparticles. Researchers are attempting to enhance the COP of the VCR system by employing various ways for sub cooling condensed liquid refrigerants. Excessive sub cooling provided by various sources increases the quantities of liquid refrigerant available before it enters the evaporator. This decreases the refrigerant's mass flow rate for a given cooling demand. As a result, the compressor's power consumption falls, and the cycle performance increases. Additional research study in this area is expected.

REFERENCES

1**. KASNI SUMERU, ANDA FALAHUDDIN, MOHAMAD FIRDAUS SUKRI and ANDRIYANTO SETYAWAN** (August 2019)" A review on sub-cooling in vapor compression refrigeration cycle for energy saving**"** Jurnal Teknologi (Sciences & Engineering)*ISSN–170* ISSN 2180–3722.

2 . **RANENDRA ROY , ARUP JYOTI BHOWAL AND BIJAN KUMAR MANDAL** (2021),"Thermo economic Analysis of Vapor Compression Refrigeration System with Dedicated Subcooler for High-Temperature Lift Applications" Vol. 13 / 061005-3.

3. **ANSARI, N. A., ARORA, A., AND MANJUNATH K**., (2020), "The Effect of Eco-Friendly Refrigerants on Performance of Vapor Compression Refrigeration System with Dedicated Mechanical Sub cooling," Advances in Energy and Built Environment "Springer, Singapore, pp. 43–54.

4. **DAI, B., LIU, S., SUN, Z., AND MA, Y., (**2017), "Thermodynamic Performance Analysis of CO_2 .
Transcritical Refrigeration Cycle Assisted With Mechanical Sub cooling," Energy Procedia, 105, pp. 2033–2038.

5. **DE PAULA C H, MOREIRA DUARTE W, MARTINS ROCHA T T, DE OLIVEIRA R N AND TORRES MAIA A A**(2020) Optimal design and environmental, energy and exergy analysis of a vapor compression refrigeration system using R290, R1234yf, and R744 as alternatives to replace R134 *International Journal of Refrigeration* **113** 10-20

6. **SUN J, LI W AND CUI B (2020**) Energy and exergy analyses of R513a as a R134a drop-in replacement in a vapor compression refrigeration system *International Journal of Refrigeration* **112** 348-356
.

7. **LLOPIS, R., NEBOT ANDRÉS, L., SÁNCHEZ, D., CATALÁN-GIL, J., AND CABELLO, R.** (2018). Subcooling methods for CO 2 refrigeration cycles. A Review. International Journal of Refrigeration

8. **QURESHI, B. A., AND ZUBAIR, S. M**.(2012) "The Effect of Refrigerant Combinations on Performance of a Vapor Compression Refrigeration System with Dedicated Mechanical sub-Cooling," Int. J. Refrig., 35(1), PP .47–57.

9. **THORNTON, J. W., KLEIN, S. A., AND MITCHELL**, **J. W**.(1994), "Dedicated Mechanical Sub cooling design Strategies for Supermarket Applications," Int. J. Refrig,17 (8), pp. 508–515
.

10. **ZUBAIR, S. M**.(1990) "Improvement of Refrigeration/air-Conditioning Performance With Mechanical sub- Cooling," Energy, 15(5), pp. 427–433.

11. **ZUBAIR, S. M., YAQUB, M., AND KHAN, S. H. (1996).** Second-law-based thermodynamic analysis of two- stage and mechanical-subcooling refrigeration cycles. International Journal of Refrigeration, 19(8), 506-516.

12. **QURESHI, B. A., INAM, M., ANTAR, M. A., AND ZUBAIR, S. M.** (2013). Experimental energetic analysis of a vapor compression refrigeration system with dedicated mechanical sub-cooling. Applied Energy, 102, 1035-1041.

.
13.**POTTKER G., HRNJAK** P. (2012) Effect of Condenser Subcooling of the Performance of Vapor Compression Systems: Experimental and Numerical Investigation. *Proceeding of International Refrigeration and Air Conditioning Conference*, *Purdue University, USA 2012*. 1-10.

14. **KHAN, J. R., ZUBAIR, S. M.** (2000.) Design and Rating of Dedicated Mechanical Subcooling Vapor-Compression System. *Proceedings of the Institution of Mechanical Engineering*. 214: 455-472.

15. **POTTKER, G., HRNJAK, P**. (2015). Experimental Investigation of the Effect Condenser Subcooling in R134a and R1234yf Air-conditioning Systems with and without Internal Heat Exchanger. *International Journal of Refrigeration.* 50(1): 104-113.

16. **SAWANT, A. P., AGRAWAL, N., NANDA, P.** (2011). Performance Assessment of an Evaporative Cooling Assisted Window Air Conditioner. *International Journal of Low-Carbon Technology*. 7: 128-136.

17. **YANG, L., ZHANG, C. L**.(2011). On Sub-cooler Design for Integrated Two-temperature Supermarket Refrigeration System. *Energy and Buildings.* 43(1): 224-231.

.

18.**THORNTON, J. W., KLEIN, S. A., MITCHELL, J. W.** (1994). Dedicated Mechanical- sub cooling Design Strategies for Supermarket Applications. *International Journal of Refrigeration.* 17 (8): 508-515.

19. **QURESHI, B. A., ZUBAIR, S. M**. (2013). Cost Optimization of Heat Exchanger Inventory for Mechanical Subcooling Refrigeration Cycles. *International Journal of Refrigeration. 36*(4): 1243-1253.

20. S**UMERU, K., CECEP SUNARDI, SUKRI, M. F.** (2018). Effect of Compressor Discharge Cooling Using Condensate on Performance of Residential Air Conditioning System. *AIP Conference Proceedings 2001*. 020002-1–020002-6.