Refrigeration System Innovation

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Abstract

Developmental research to design and fabricate the Refrigeration System Innovation, and to evaluate its efficiency on processing time, repair cost, operating cooling temperature, and operating current rating of the unit on removing, discharging, and refilling of lubricating oil as compared with adapting the Conventional Method (CM) and using the Original Refrigeration and Air-Conditioning (ORAC) Unit. The solenoid's installation of the valve, access valves, and pressure switches interconnected functions with the original components of the system to ease the entire operation of discharging and refilling lubricating oils for maximum usage of the unit. Results revealed that the processing time of removing, discharging, and refilling the lubricating oil is six times faster; repair cost efficiency of 2 ¼ times lower; efficiency on operating cooling temperature was 10% improvement; efficiency in the operating current by 4% improvement. Adapting the RSI is a highly recommended HVAC-RT program to produce globally competitive RAC technicians.

Keywords: Access Valve, Air-Conditioning, Compressor, Cost, Domestic RAC, HVAC-RT, Innovation, Lubricant, Power Consumption, Refrigeration System

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1. Introduction

Refrigeration systems make the area within the boundary of operation cooler colder than the atmospheric surrounding. This system reduces the temperature of an object at a lower temperature and even to the desired temperatures (J3 Heat-mPEC.,2019). According to Newton's law of cooling or the second law of thermodynamics, it is possible to transfer heat from a colder body to a hotter body by doing work. Under the above law, a refrigerator works by repeatedly bringing fluids maintained at a shallow temperature in contact with the stored objects. Thus, it can maintain objects at a desired low temperature.

Research and development were adopted in the development of the RSI, referring to the previous state-of-the-art technologies in refrigeration. The apparatus developed by Scarfone & Syracuse (1993) provides a method and apparatus wherein the lubricating oil in a rotary compressor for withdrawn refrigerants, and a new oil charge is returned to the compressor in a neat, simple, and efficient manner. Regardless of the efficiency of the purification system, however, contaminants reach the recovery compressor and, with time, contaminate the lubricating oil of the recovery compressor. Byrne, Yost, and Del (1997) developed an efficient process for removing lubricant from evaporators, condensers, and associated tubing in refrigeration and air-conditioning systems when a new lubricant of a different type was used. Bertva and Wheeler (1995), their technology was on the process and method of changing the lubricating oil. These designs offer the best solution process for the effective means of removing and changing the lubricants in the RAC system but never present the most efficient process in changing the contaminated system lubricating oil for a short period, solving the lubricant volatility, cost-efficiency in both materials and labour and minimising a very costly operation downtime of the company.

2. Synthesis

In this study, the RSI was properly designed a drain access valve in every specific location on the main mechanical parts of the refrigeration system for repair and maintenance of defective units efficiently and effectively. Installation of access valve in top and bottom of motor compressor for draining and filling of lubricating oil can eliminate very tedious means of cutting, silver brazing of pipe, dismantling of the motor compressor and general system reprocessing. Installation of the solenoid and access valve in every intake and discharge tube of the system connecting the compressor, condenser, and evaporator was beneficial for the effective and efficient repair of clogging and leaking of the system. Minimal refrigerants wastage and scattering in the atmosphere prevent the ozone layer from depleting.

3. Research Significance

The RSI introduces a straightforward, practical concept and ideas by isolating every central mechanical part of the refrigeration and air conditioning units by adapting access valves before and after to concentrate on repairing and maintaining defective parts. The efficiency in repair and maintenance of the refrigeration system ensures better results, which mainly addresses the limitations of some mentioned prior arts such as more extended time of repair, high operation downtime cost, complicated method of system reprocessing, promotes savings in the long run after innovation and increases the life span of the unit. This concept of RSI encouraged students to conduct more research studies on RSI and widen more knowledge opportunities in refrigeration system processing. The information on RSI benefits the end-users to generate considerable savings in the long run for a very effective repair and maintenance and countless downtime cost. This study added value in making the repair and maintenance more accessible to school facilities included in this University's implementation and for future researchers of RAC. The professors consider the available information in this study of RSI to produce excellent, quality and well-trained industrial technology students of the University.

4. Purpose of the Research

Generally, this study aimed to design and fabricate RSI. Specifically, this study aimed to design and fabricate RSI and evaluate the efficiency of RSI compared to the CA of repair and maintenance of ORAC units in terms of processing time, repair cost, cooling temperature, and current rating.

5. Description of the Device

5.1 Design Criteria

5.1.1ASHRAE and SAE Standards

Purposely, the design of RSI improves the effectiveness and the efficiency of the repair and maintenance of refrigeration and air conditioning units. RAC systems comprised four major mechanical components, the compressor, condenser, capillary tube, and evaporator. All are interconnected with tubes equipped with protective cases. The sizes, capacities, and material of all significant parts, protective cases, and tubing were designed according to the American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE) and Air Conditioning Refrigeration Institute (ARI). RSI had a standard designed capacity of lubricating oil both in the intake and discharge of main mechanical parts of the system. Access valve sizes and locations were designed according to the accepted standard to have a convenient access port for repair, maintenance and processing of the refrigeration system. Access and solenoid valves were installed on either the high or low sides for quick testing, pressure checking, purging or charging. SAE male flare access ports were furnished with a cap and gasket preventing any leakage. Each cap was machined to have a valve core quick remover. The accuracy of RSI was set at standard measurement with access valves and solenoid valves. The sizes, capacities, and materials of all added innovative parts were at the same standard unit design. RSI provides ease during the working process and easy monitoring of the pressure on each system, such as the evaporator, condenser, and compressor.

5.2 Limitations and Constraints

RSI was designed to shorten the usual number of hours of system reprocessing by a maximum of 2 hours. This innovative process was designed for quick draining of motor compressor lubricating oil. It focused on straightforward and effective repairing and maintaining refrigeration and air conditioning units and, particularly, system processing efficiency, changing contaminated refrigeration oil, lowering costly operation downtime and repair cost, and maintaining the designed cooling temperature and power current rating after adopting the innovation.

5.3 Design Preparation, Testing, and Revisions

The assembly of the RSI was done in the Heating, Ventilating, Air-Conditioning-Refrigeration Technology (HVAC-RT) Laboratory Area of the College of Industrial Technology (CIT) of Iloilo Science and Technology University (ISAT U), La Paz, Iloilo City in the second semester of the academic year 2019-2020. Experts from the field of HVAC-RT

are composed of the technical evaluating team. Suggestions and recommendations are applied to the device to enhance its performance.
The design and plan preparation of all additional components and parts for the RSI was based on the design criteria of ASHRAE and ARI (Lewis and Menzer, 2006). The very significant innovations were the installation of an access valve and solenoid valve in the intake and discharge of the condenser, evaporator and compressor.
The researcher formulated several phases for the preparation of this study. The preparation includes planning and identifying suitable solutions for the problem—collecting relevant data and information related to the study. Construction of design of the system and plan of a workable solution for the easier fabrication of the machine. Finalisation of the design. Furthermore, the researcher gathered all the needed materials, tools and equipment. Also, testing the materials' quality, standard and durability; fabricating the machine based on the standard guidelines of fabrication and design; testing and verifying the system quality, and introducing the product are considered. The device was constructed based on the blueprints designed by the researcher. The working drawings were made using an AutoCAD.

6. Results and Discussions

6.1 Technology

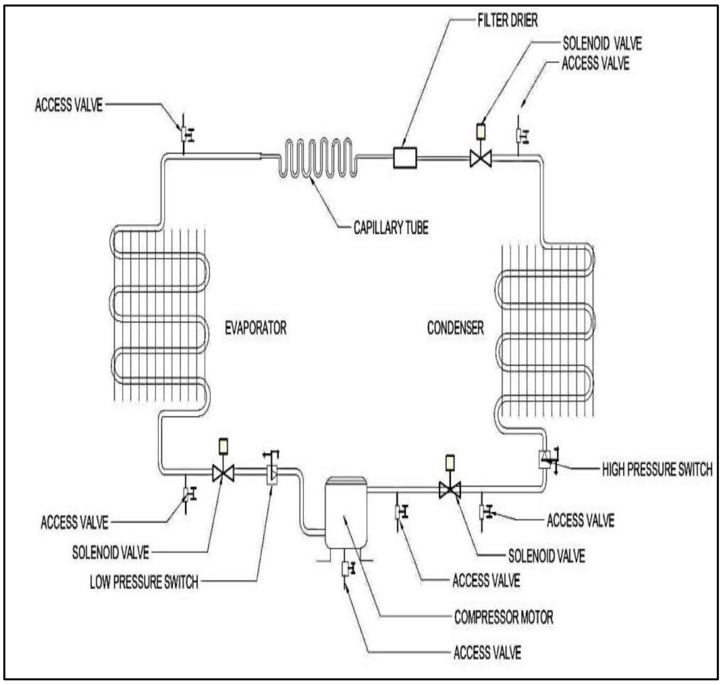
6.6.1 Refrigeration System

The present study of Refrigeration System Innovation significantly improved the effectiveness and efficiency in repairing and maintaining the Refrigeration and Air Conditioning units, specifically in the refrigeration system processing. It dramatically reduces a very costly operation downtime losses of the company, reduces labour and materials costs and minimises wastage of refrigerants as mandated by the Department of Environmental and Natural Resources (DENR).
Refrigeration systems According to Newton's law of cooling or the second law of thermodynamics, it is possible to transfer heat from a colder body to a hotter body by doing work. The study by Evans (2003) found that most refrigerators use a compressor to compress low-pressure refrigerant gas into a higher-pressure refrigerant gas to a condenser. The condensed refrigerant is then forced into a jet that allows it to expand quickly by the expansion valve of the refrigerator. When refrigerant gases expand, it cools down quickly. The cold air surrounding the coils is circulated in the refrigerator. The expanded gas is collected and compressed again to complete the cycle outside the refrigerator. According to Maxon (2017), oil was used in a refrigeration system to lubricate the compressor and keep the refrigeration unit running smoothly. Unique oil formulations were required to lubricate the internal components, adding to the expense of manufacturing and operating cooling equipment, including environmental issues of waste oil disposal and ozone depletion that contributes to global warming. Refrigeration systems require the foreseeable future food preservation and keeping people comfortable. Engineering advances in oil-free compression systems change the way of producing cold air at a higher cost in the short term. The new technologies mentioned have surpassed the process and method of Bertva and Wheeler's

(1995) "Method for Removing Original Type Lubricant from Air Conditioning System and Injecting Replacement Oil" with a patent no. US 5415003A.

6.2 Brief Description of the Drawing

The RSI introduced the attachment of solenoid valves installed along with the suction and discharge of the motor compressor to drain and fill the lubricating oil to eliminate usual cutting, silver brazing of pipes and dismantling of pipes motor compressor and the general system reprocessing. Installed solenoid valve and access valve in the tube in every intake and discharge of the system, which was connected to the compressor, condenser, and evaporator. The significance of the solenoid valve and access valve increases the efficiency of the procedure to repair the clogging and leaking of the system, thus, minimising the lubricant



wastage and scattering in the atmosphere. The mechanical diagram shows three units of the solenoid valve and six access valves added and attached to the system with one each of high- and low-pressure switch, as shown in Figure 1.

Figure 1. Mechanical Diagram of RSI.

6.3 Detailed Description of the Technology

Each part of RSI was interconnected to each other in order to show the functions as a system.

Referring to Figure 2, parts of the RSI were illustrated as: 1Aluminum fins filter cold temperature and act as cold and heat absorbent from the mechanical piping system. 2Evaporator coil creates to compress the cooling chemicals like Freon to evaporate from liquid to gas while absorbing heat. 3Sirocco fan has a centrifugal fan with a forward-curved blade for low pressure and extensive discharge use. 4Shaft was usually circular in cross-section, used to transmit power from one part to another. 5Fan motor cools down the hot refrigerant gas to liquid. 6Propeller fan was used as an exhaust and condenser fan and used in applications where pressure differentials but large volumes of air movement were low.

7Plastic housing was used to house the refrigeration system. 8Capillary tube was used as a throttling device which has a copper tube with a tiny internal diameter. 9Condensate drain pan was used to collect water from the air conditioning process. 10Compressor moves the refrigerant between the evaporator and condenser coil and ensures that the refrigerant changes from gas or liquid. 11Insulated Partition separates the compartment room and hot air. 12Air insulation outlet cools down the temperature outlet. 13Louver directs the airflow in the direction of the user's choice. 14Control Panel carries various control buttons as an operating panel. The isometric view shows that the RSI has the following accessory parts, as shown in Figure 2.

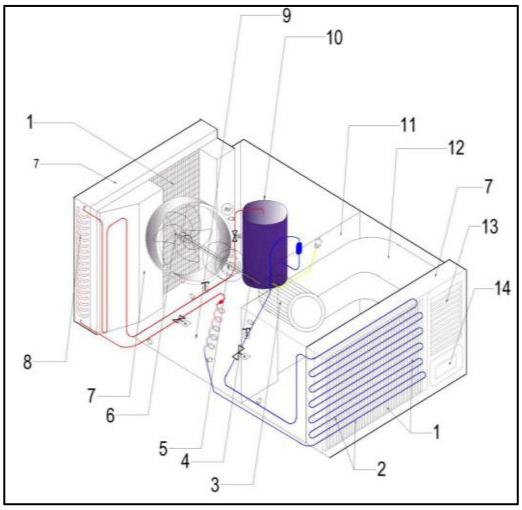


Figure 2. Isometric View of RSI.

1 Aluminum fins
2 Evaporator coil
3 Sirocco
4 Shaft
5 Fan motor
6 Propeller Fan
7 Plastic housing
8 Capillary coils
9 Condensate drain pan
10 Compressor
11 Insulated partitions
12 Air insulation outlet
13 Louver
14 Control panel

Likewise, the isometric view of RSI shows the accessory parts which have significant functions in achieving the purpose of the innovative system in Figure 3.

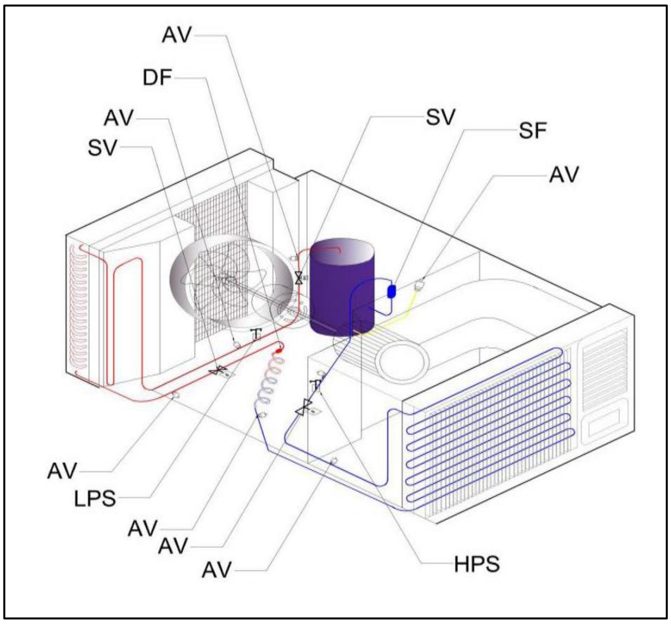


Figure 3. Isometric View of RSI.

Legend: AV- Access Valve; DF - Drier Filter; SV - Solenoid Valve; SF - Suction Filter; LPS- Low-Pressure Switch HPS - High-Pressure Switch

The electrical diagram of RSI shows that the significant parts and electrical flow distributions were interconnected arrangements. Figure 4 shows the electrical plan of RSI shows how these accessory parts were interconnected that backed up the system's functions.

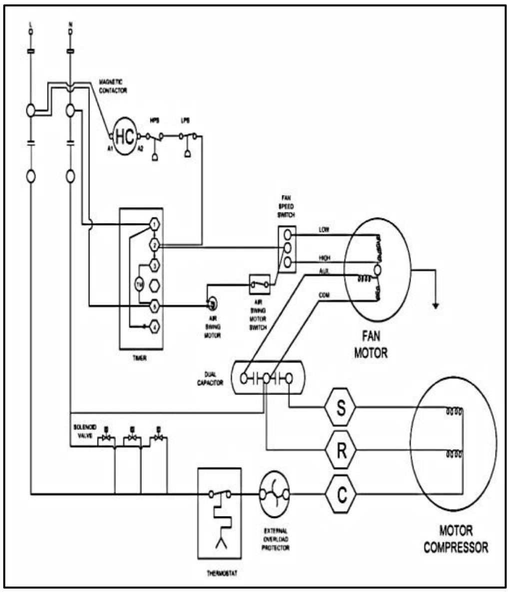


Figure 4. Electrical Plan of RSI.

The RSI found that the attached solenoid coil, as one of the primary attachments, responded to the objectives of this study, as shown in Figure 5.

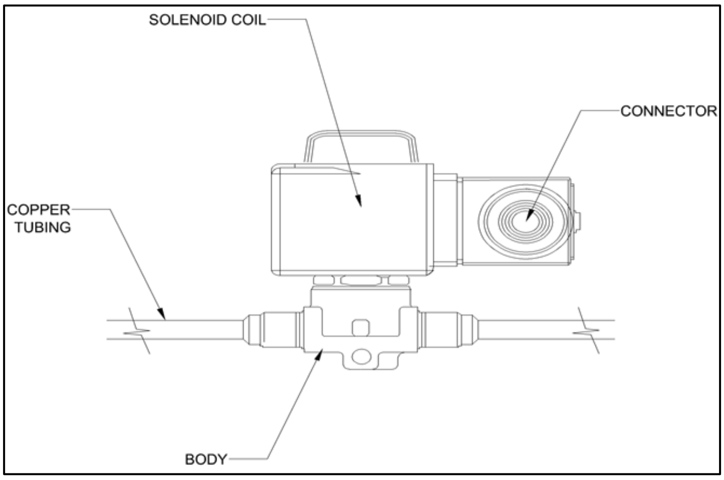


Figure 5: Solenoid Attachment of RSI.

The RSI found that each attached access valve has a vital function necessary to the system, as shown in Figure 6.

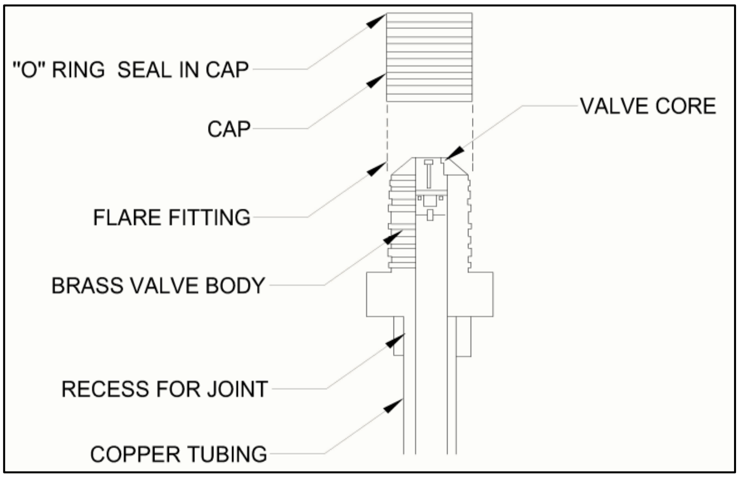


Figure 6. Access Valve Attachment of RSI.

6.3.1 Claims

The researcher of RSI has the following claims:

1. From the existing prior arts and patents, the solenoid valve, access valve, and pressure switch were significant in the system for removal, discharging, and refilling lubricating oil.
2. The efficiency of repair time is 24 hours, with an average repair time of 1hr and 20 minutes found faster than the Conventional method.
3. As claimed in Claim 1, the installed solenoid valve along the pipe of every intake and discharge of lubricating oil controls the pressure.
4. As claimed in Claim 1, the installed access valve was purposely for intake and discharge of the lubricating oil.

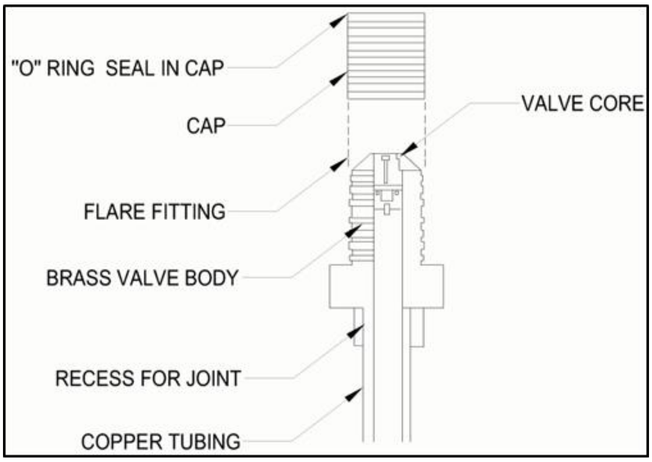


Figure 37. Access and Solenoid Valves Modification of RSI.

5. As claimed in Claim 1, the installed pressure switches used to control gaseous elements were not available to domestic RAC Systems.
6. As claimed in Claim 2, the running time of the entire process for RSI runs with an average of 1hour and 20 minutes.

6.4 Interpretation of the Data
6.4.1 Comparison of Efficiency

The RSI was operated for actual testing to determine efficiency on processing time, cooling a temperature, and using the timer during unit removal, discharge, and refilling lubricating oil. Table 1 compares efficiency in the processing time of unit removal, discharge and refilling of lubricating oil for process and repair using the RSI compared to the CM and ORAC Units.

A. Processing Time
The efficiency of processing time includes the removal, discharge and refilling of lubricating oil in the entire unit of window type 0.75hp Carrier 2014 using the RSI Innovation and compared to the Conventional Method concerning processing time.

Table 1: Efficiency of Processing Time

Trial	Processing Time in Hour: Minute			Efficiency (%)
	Conventional RAC System	Refrigeration System Innovation	Difference	
1	8:37	1:45	6:52	492.38%
2	8:59	1:30	7:29	598.88%
3	8:45	1:20	7: 25	656.26%
Average	8:47	1:31	7:16	579.12%

Table 1 compares the efficiency of processing time of the entire process of removing, discharging, and refilling lubricating oil using the RSI and compared using the CM in window type 0.75hp Carrier 2014 Unit. The processing time using the CM were 8 hours and

37 minutes, 8 hours and 59 minutes, 8 hours and 45 minutes for trials 1, 2, and 3, respectively, with an average processing time of 8 hours and 47 minutes, while using the RSI were 1 hour and 45 minutes, 1 hour and 30 minutes, and 1 hour and 20 minutes for trials 1, 2, and 3, respectively with an average processing time of 1 hour and 31 minutes. The processing time differences were 6 hours and 52 minutes, 7 hours and 29 minutes, 7 hours and 25 minutes with trials 1, 2, and 3, respectively, with an average of 7 hours and 16 minutes processing time of the entire unit removing, discharging, and refilling of lubricating oil of window type 0.75hp Carrier 2014 unit using the RSI and the CM.

The results further show that the processing time's efficiency is 492.38%, 598.88%, and 656.26%, with an average of 579.12% for trials 1, 2, and 3, respectively. This result further shows that using the RSI was more or less six times faster in the processing time of removing, discharging, and refilling the oil lubricants into the system than using the CM. This finding supports the invention of Scarfone & Syracuse (1993), which seeks to provide a method and apparatus wherein the lubricating oil in a rotary compressor for refrigerants may be withdrawn and a new charge of oil returned to the compressor in a neat, simple, and efficient manner.

B. Repair Cost

The processing time's cost-efficiency of removing, discharging, and refilling lubricating oil of the window type 0.75hp Carrier 2014 using the RSI was determined and compared to CM, as shown in Table 2.

Table 2. Comparison of Efficiency in Repair Cost

Repair Cost in Php		Difference	Efficiency (%)
Conventional RAC System	Refrigeration System Innovation		
Php4,500.00	Php2,000.00	Php2,500.00	225%

Data in Table 2 shows the cost efficiency on repair incurred after repair innovation of the window type 0.75hp Carrier 2014 using the RSI compared to CM. The cost of repair using the CM was Php4,500.00 compared to using the RSI of Php2,000.00. The cost difference of Php2,500.00 resulted in repairing cost efficiency of 225%. This finding shows that the cost of repair using the RSI was cost-efficient or lower by 2 ¼ times in repair of window type 0.75hp Carrier 2014 than using the CM.

This finding supports the statement of Bostock (2013) that the labour cost is unlikely to be significantly higher for most commercial-sized systems unless the location is tough to isolate from the rest of the system or the reason for the leak requires the replacement of a high-cost component.

C. Cooling Temperature

One of the objectives of this study was to determine the efficiency of cooling running temperature of the entire processing of removing, discharging, and refilling lubricating oil in the window type 0.75hp Carrier 2014 using the RSI compared to CM, as shown in Table 3.

Table 3. Comparison of Efficiency on Cooling Temperature

Trial	Cooling Temperature in °C			
	Conventional RAC System	Refrigeration System Innovation	Difference	Efficiency (%)
1	21.1 °C	20.4 °C	0.7°C	103.43%
2	18.3 °C	16. 2°C	2. 1°C	112.96%
3	12.6 °C	10.5 °C	2.1°C	120.00%
Average	17.33 °C	15.7 °C	1.63 °C	110.38%

Table 3 shows the efficiency of operating cooling temperature in window type 0.75hp Carrier 2014 using CM of 21.1°C, 18.3°C, 12.6°C for Trials 1, 2, and 3, respectively, with an average of 17. 33°C cooling temperature. In comparison, using the RSI of 20.4°C, 16.2°C, 10.5°C for trials 1, 2, 3, respectively, with an average of 15.7°C cooling temperature. The cooling temperature difference of zero and 0.7°C, 2.1°C, 2.1°C in trials 1, 2, and 3, respectively, with an average of one and 1.63°C.

It shows efficiency in operating cooling temperature of 103.43%, 112.96%, and 120% for Trials 1, 2, and 3, respectively and average efficiency in operating cooling temperature of 110.38%. Thus, the operating cooling temperature of the RSI was found to be almost the same when using the Conventional RAC System in the repair of window type 0.75hp Carrier 2014 unit. This efficiency proved that the operating cooling temperature produced by the two systems were comparable.

This finding promotes the invented methods of Bertva (1995), which is a method for recovering original type oil from a system that has been charged with an original type of refrigerant, eliminating the need for removing and cleaning individual components, including the temperature in the system.

D. Current Rating

Another objective of this study was to determine the efficiency of operating the current rating of the entire process of removing, discharging, and refilling lubricating oil in the window type .75hp Carrier 2014 using the RSI and compared to the Conventional RAC system, as shown in Table 4.

Table 4: Comparison of Efficiency on Current Rating

Trial	(Running time, amp)		Difference	Efficiency (%)
	Conventional RAC System	Refrigeration System Innovation		
1	4.2 amp	4.1 amp	0.1amp	102.44 %
2	4.1 amp	3.8 amp	0.3 amp	107.89 %
3	4.1 amp	4.0 amp	0.1 amp	102.50 %
Average	4.13 amp	3.97 amp	0.17 amp	104.03 %

Data in Table 4 shows the comparison of efficiency on the repair of operating current rating (amp) in window type 0.75hp Carrier 2014 using the Conventional RAC System were 4.2 amperes, 4.1 amperes, 4.1 amperes for Trials 1, 2, and 3 respectively and in using the RSI Innovation were 4.1 amperes, 3.8 amperes, 4.0 amperes for Trials 1, 2, and 3 respectively. Furthermore, the operating current rating difference shows 0.1 amperes, 0.3 amperes, and 0.1 amperes for Trials 1, 2, and 3. It shows that there was efficiency in operating current rating of 102.44%, 107.89%, and (102.5%) per cent, respectively, which signifies a slight significant improvement on the average efficiency of 104.03% between the current operating rating in using the RSI as compared with Conventional RAC system. The current modification has a minimal improvement and changes in the system's operating current rating, which signifies an acceptable standard operating current rating requirement.

7. Findings

The findings of the study are as follows:

- The efficiency of processing time of removing, discharging, and refilling the lubricating oil using the amperes was compared using the CM in window type 0.75hp Carrier 2014 unit in three (3) trials. The processing time using the CM was 8hours and 37 minutes, 8 hours 59 minutes, and 8 hours and 45 minutes, with an average processing time of 8 hours and 47 minutes, while using the RSI were 1 hour and 45 minutes, 1 hour and 30 minutes, and 1 hour and 20 minutes with an average processing time of 1 hour and 31 minutes. The processing time differences were 6 hours and 52 minutes, 7 hours and 29 minutes, and 7 hours and 25 minutes, with an average of 7 hours and 16 minutes processing time of the entire unit removing, discharging, and refilling of lubricating oil of window type 0.75hp Carrier 2014 unit. The efficiency of the processing time of 492.38%, 598.88%, and 656.26%, with an average of 579.12%, signifies further that using the RSI was more or less six times faster in the processing time of removing, discharging, and refilling the lubricating oil into the system than using of the CM.
- The efficiency of repair cost of the window type 0.75hp Carrier 2014 for three RSI trials was compared using the CM. The cost of repair using the RSI of Php2,000.00 was less costly than using the CM of Php4,500.00. The cost difference of Php2,500 resulted in an efficiency on repair cost of 225% or 2 ¼ times lower repair cost.
- The efficiency of operating cooling temperature using the RSI was compared using the Conventional RAC system in window type 0.75hp Carrier 2014 for three trials. The average RSI's cooling temperature of 15.7°C was comparable with the cooling temperature using the average Conventional RAC system of 17.33°C, in which the average cooling temperature of 1.63°C. The average efficiency on cooling temperature of 110.38% shows minimal improvement in operating cooling temperatures.
- Finally, the current operating rating efficiency using the RSI Innovation was compared using the Conventional RAC system in window type 0.75 Carrier 2014 for three trials. The RSI's current rating uses 4.1 amperes, 3.8 amperes, and 4.0 amperes compared to the current rating of the Conventional RAC system of 4.2 amperes, 4.1 amperes, and 4.1, which has the current rating differences were 0.1 amperes, 0.3 amperes, and 0.1 amperes. The efficiency of

102.44%, 107.89%, and 102.5% per cent and average efficiency on the current rating of 104.03% signifies a very slight significant difference, thus, minor improvement between the current operating ratings.

8. Conclusions

Based on the findings, the following conclusions are as follows:

- The repair cost of using the RSI was more or less twice lower or more cost-efficient in the repair of Window type .75hp Carrier 2014 than using the CM.
- The operating cooling temperature of the Refrigeration System Innovation found a minimal improvement when using the Conventional RAC system in the repair of window type 0.75hp Carrier 2014 unit. This result proved that the operating cooling temperature produced by the two systems were comparable.
- The current operating rating in using the RSI, in which the current rating modification as compared with Conventional RAC system has minimal improvement and changes in the system operating current rating which signifies an acceptable operation standard.

9. Recommendations

By the findings and conclusions of this study, the following recommendations are offered:

- The HVAC - RT manufacturing industries should consider the suggested design of this innovation, particularly on the processing time of repair and maintenance while maintaining the required cooling running's standard a temperature, operating current rating and very minimal repair cost compared to the CM and ORAC Units.
- The RAC processing of removing, discharging, and refilling the lubricating oil in any system must be given attention at this age of technology so as the RAC technician becomes globally competitive and luckily to have employment abroad.
- The academe must appreciate this modification and innovation introduced in the RAC system with HVAC - RT Courses to analyse, adapt, or reflect in future research.

10. Implications of the Refrigeration System Innovation Technology

- The possible future effect or result of the innovative ideas on the Refrigeration System focused on the prevention or reduction of the greenhouse gases - water (H2O), ozone (O3), and carbon dioxide (CO2). Invisible rays of energy get passed back and forth between the atmosphere and the spheres below the lithosphere, biosphere, hydrosphere, and cryosphere before the energy finally migrates to the top of the atmosphere and escapes to the relative calm and vacuum of outer space.
- Today, the notorious environmental crises in the refrigeration process like the presence of the chlorofluorocarbons are not only ozone-eaters, and even at concentrations of less than a part per billion, they have captured a significant of heat hold it. Adding a single molecule of CFC - 11 to the atmosphere traps 17.500 times more heat than adding a carbon dioxide molecule. Moreover, a CFC - 12 traps 20,000 times more heat than a molecule of carbon dioxide than adding a molecule of CO2.

- The technology of RSI will significantly minimise the wastage of Freon during the unforeseen troubles and repair of air-con and refrigerator, thus, preventing Global Warming (Weiner, 1990).

11. Acknowledgment

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