ISSN: 2277-9655
Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

REFRIGERANT RECOVERY AND RECYCLING MACHINE: AN INNOVATION

Nolasco K. Malabago*

* Ph.D Mechanical Department, College of Engineering Cebu Technological University - Main Campus Cebu City, Philippines

DOI: 10.5281/zenodo.51439

ABSTRACT

The Philippines' Clean Air Act so provides the control of gas emissions into the atmosphere. To carry out such provisions the implementing arm of the government – Department of Energy and Natural Resources Energy Management Bureau calls for different sectors of the society to join the cause.

The University's share of the call in the implementation is to educate the youth and provide ample information on the provisions of the act. One important aspect of the Act is to reclaim the refrigerant right at the source prior to disposal at the Solid Waste Landfill. The school having none of such equipment, prompted the professors of the Refrigeration and Air conditioning Department to innovate equipment that would recover and recycle refrigerant so that unnecessary venting could be prevented.

The study was then conducted in the aspects of acceptability and effectiveness of the innovated design and function to meet the required standards. Findings lay that the innovated refrigerant recycling machine met the technical requirements as to portability, rigidity and functionality. Though the acceptability was high there is a need to resolve issues on transportability. Also, there is a need to use a marketed (new) vacuum pump for better recovery of the refrigerant. Effectiveness on the functions were high and 88.71% efficient in recovering refrigerant.

Based on the results, the researcher recommends that this innovative design be utilized and however need further enhancements.

KEYWORDS: Gas emissions, refrigerants, retrofitting, efficiency, reclaim.

INTRODUCTION

As early as the 1980's, scientist linked the venting of the chlorofluorocarbon (CFC's) into the atmosphere as culprit in the ozone depletion leading to unintended global warming (ISRI, 1999). Such benign environmental effects force the 22 countries to compose the Montreal Protocol creating the Clean Air Act of 1990 under the Environmental Protection Agency. Section 608 of the act states:

- *Require service practices that maximize recovery and recycling of ozone-depleting substances (both chlorofluorocarbons [CFCs] and hydrochlorofluorocarbons [HCFCs] and their blends) during the servicing and disposal of air-conditioning and refrigeration*
- *Require the repair of substantial leaks in air-conditioning and refrigeration equipment with a refrigerant charge greater than 50 pounds.*
- *Establish safe disposal requirements to ensure removal of refrigerants from goods that enter the waste stream with the charge intact (e.g., motor vehicle air conditioners, home refrigerators, and room air conditioners).*

Each country then formulated refrigerant management plan that establishes local training centers and reclaiming stations and train custom officers that would carry out the safe disposal, recycling and prohibits releasing of the Ozone Depleting Substances (ODS) into the atmosphere (Tonko Ćurko, 1990) by tapping the universities for curriculum, equipment and laboratory experiments.

Also, strict policies were issued on Solid Waste Landfills and Material Recovery Facilities to check before disposal all air conditioners, refrigerators and freezers, water coolers, vending machines, ice makers and dehumidifiers making sure that the refrigerant has been properly removed.

Cognizant to the primary responsibility to deal such environmental problems the Philippines promulgated the Clean Air Act of 1999 (Republic Act 8749) that promotes and protects the global environment to attain sustainable development. The government's implementing arm – The Department of Environment and Natural Resources Energy Management Bureau (DENR – EMB) was mandated to formulate a comprehensive national program of air pollution management (**Rule 4, Section 1 of the IRR of RA 8749**).

The Act establishes with the participation of Local Government Units, Non-governmental Organizations, the academe and other concerned entities from the private sector, formulate and implement the Integrated Air Quality Improvement Framework. A strong and massive awareness campaign was then given to different barangay levels to ensure that everyone is educated of the policies.

Heeding the call, Cebu Technological University Management designated faculty and administrative personnel as Pollution Control Officers that studied the impact of pollution and volume of the solid waste generated every day. The Refrigeration and Air Conditioning Department being one of those affected due to the use of the refrigerant join the cause of the administration by providing the students necessary informations as to requirements of the law and train individuals for safe disposal and reclaim refrigerant for use in the laboratory (practical application) instruction.

Unluckily, the university does not have sufficient budget for the procurement of a brand new refrigerant recovery and recycling machine. Moved by such need, the Technical Educators of the university made innovations of an old window type airconditioners that could recover refrigerant and recycle for use. In so doing, functional parts of air conditioning units were retrofitted to suit the function of recovering and recycling of refrigerants.

Thus, the Technical educators of the university designed a machine that has the ability to recover and recycle the used refrigerant from various air conditioning equipment of the university at very affordable cost as an innovation.

MATERIALS AND METHODS

The study is conducted at the Refrigeration and Air conditioning laboratories of the University. The researchers made adaptations from the information sheets provided by the manufacturers for design, construction and maintenance of the innovated refrigerant recovery and recycling machine. It uses the population of the students and administrative staff in the practical application of evacuation and reprocessing and maintenance of refrigerating and air conditioning equipment.

The professors of the university were made to test the construction and possible improvements of the innovated design of the recycling machine. Inputs from multiple industry practitioners were solicited to have informations on the new technologies applied in the recovery and recycling of refrigerant.

Technical Requirements of the Innovated Refrigerant Recycling Machine

The technical requirements for the innovated equipment include the design, fabrication and cost. The design includes schematic diagram, list of parts and materials with cost, list of supplies with cost, and work implements. The fabrication includes the laying out, assembly and testing of the machine.

Design of the Equipment

Schematic Diagram (Figure 1A - B) for both the electrical and the mechanical cycle (refrigeration) shows the electrical wiring connections and parts together with the components of the refrigeration cycle.

ISSN: 2277-9655
Impact Factor: 3.785

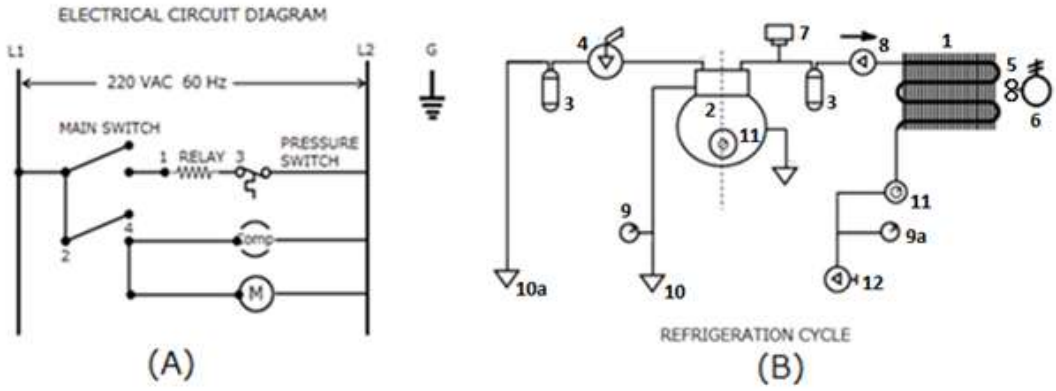
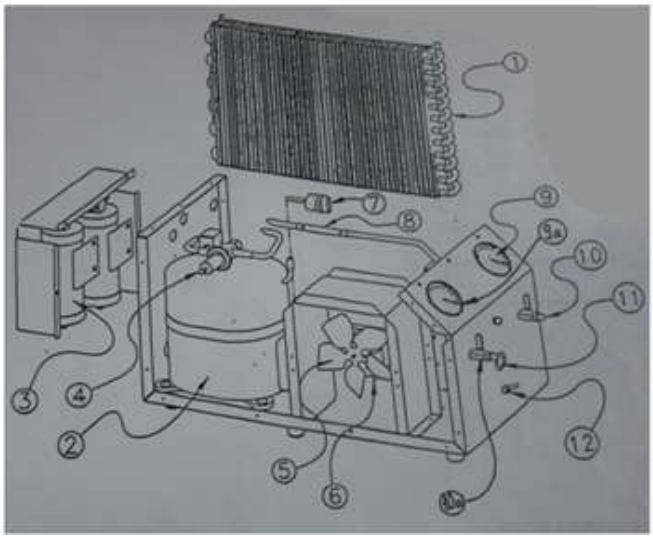


Figure 1. Schematic Diagram

After the schematic diagram for refrigeration cycle (Figure 1B), the assembly drawing with the parts list was made basis for procurement or securing of parts (Figure 2). Then the list of materials and the corresponding costs were prepared as shown in Table 1.



1. Condenser
2. Compressor
3. Oil Separator
4. Suction Pressure Regulator
5. Condenser Fan
6. Fan Motor
7. High Pressure Switch
8. Flow Pressure Regulator
9. Low Pressure Gage
9a. High Pressure Gage
10. Exit Valve
10a. Entrance Valve
11. Sight Glass
12. Main Switch

Figure 2. Assembly Drawing of Refrigerant Recovery Machine with Parts Lists

Materials and Costing.

The materials used in the innovation are functional parts of a recycled non-operational A/C unit for the purpose of maximization. Also, the fabrication of an Innovated Refrigerant Recycling Machine was done by the students as part of the intended RAC work exercises.

Table 1. List of Materials and Cost

Qty.	Unit	Description	Disposition	Price
1	piece	Motor Compressor 220V 2.0 HP	Bottom	Php 12,650.00
1	piece	Fan Motor 220V 60Hz	Front side	3,500.57
1	piece	Condenser	Back side	2,547.00
1	piece	Filter dryer/ Strainer	Discharge line	975.00
1	piece	Sight glass	Left Side	235.50

1	piece	Low Pressure Gauge	Left Side	157.30
1	piece	High Pressure Gauge	Left Side	157.30
2	pieces	Service Valve	Left Side	354.00
2	pieces	Refrigerant Tank	Right side	875.50
5	feet	Copper tube (Soft drawn 1/2diameter)	Inside	250.00
1	piece	Main Selector Switch 220V 12A	Inside	225.50
2	pieces	Pilot light 220V	Left side	168.75
2	pieces	Access Valves/ Processing valves	Upper side	.70.00
Sub-total Cost of Materials				**Php. 22,164.67**

***Supplies and Costing*.**
The supplies used for this project were purchased locally as it can be bought from many construction supplies near by.

Table 2. List of Supplies and cost

Qty.	Unit	Description	Uses	Price
2	length	11/4" x 1/8 dia. Angle Bar	It is used in bracketing and brazing for formation.	Php 750.00
1	Liter	Epoxy Enamel Paint w/ hardener	It is used to apply as a final painting for smoothness and clearness	267 .75
1	Kg.	1260x1/8dia.fuji Welding Rod	It is used in soldering metal and steel	160.50
2	sheets	Sand Paper # 80, 12"x12"	It is used for sanding semi-rough metals surfaces	12.50
2	sheets	Sand Paper # 120, 12" x 12"	It is used for sanding metals & tubes surfaces	12.50
1	bottle	Lacquer Thinner	It is used to mix in the paint for quick drying	45.00
3	pieces	Silver Rod	It is used soldering copper tube	47.50
Sub-total Cost of Supplies :				**Php 1,295.75**

***Work Implements and its Function*.**
The work implements as used in the construction of the Innovated Refrigerant Recycling Machine and their respective functions are shown in Table 3.

Table 3. Work Implements and its Functions

Work Implements	Functions
Multi- Tester	Use in getting the resistance and voltage reading.
Clamp Ammeter	Use to measure current (ampere).
Center punch	Marking tool to guide drill bit in drilling a hole.
Marker	Mark line in tubes, wood and metal to be cut.
Welding Machine	Use for welding and joining metals.
Mapp Gas Torch	Used for soldering Copper, Steel and Aluminum tubes.
Hacksaw	Used to cut angle, flat and round bars according to specifications.
Files	To Smoothen rough edges of Metals
Grinder	An electrical power tool use to grind welded area of object in order to flatten or soften rough surface.
Hand Drill	An electrical power tool used to drill a hole using a twist metal drill bits or to drill for a hole on objects like metal, wood and others.

Gauge Manifold	An instrument use in measuring pressure reprocessing the recycling machine.
Ball peen Hammer	For hammering metal tools such as punches and chisels.
Philip Screw Driver	For working with a Philips-head bolt or screw.
Standard Slot	For working with a slot-head bolt or screw.
Adjustable Wrench	For working with hex-head bolts, nuts, and screws of varied sizes.
Combination Wrench	A wrench with an open end and a box end, working with a hex-head bolts, nuts, and screws.
Long nose pliers	Used for holding small nuts, screws, or wires, or for reaching hard to reach places.
Vise Grip	For working where a tight grip is needed; also locks in place to free operator to use another tool.
Tube Cutter	Used for smoothly cutting tubes.
Swaging tool	Used to enlarge on one end so that another tube the same size will fit into it.

Fabrication of the Equipment

Fabrication of the Innovated Refrigerant Recycling Machine begins by laying - out, assembling the parts and testing as shown in Figure 3. It gives the sequence of information and operations needed. Laying out include the operations of marking, cutting, drilling, boring, sanding, painting and all other preparation made on piece parts ready for assembly.

After the preparation of individual parts, the assembly drawing (Figure 2) is used as the basis for assembling the parts. The main frame was welded while the refrigerant lines were soldered and brazed. The compressor, fan motor, refrigerant tanks were mounted together on the frame as ashown in figure 4.

Figure 3. Fabrication of the Innovated Refrigerant Recycling Machine

ISSN: 2277-9655
Impact Factor: 3.785

Figure 4. Assembled Innovated Refrigerant Recycling Machine with parts from old air conditioning units

Procedures for Mounting

Procedures for mounting the parts were provided on Table 4.

Table 4. Procedures in Mounting the Parts

1. The base of the machine was laid with supports and the angles were checked.	
2. The two panel board frames were positioned and screwed to the angle bar.	
3. The condenser and fan motor were mounted on the back and front side of the frame respectively.	

ISSN: 2277-9655
Impact Factor: 3.785

4. The compressor was mounted on the inside of the frame and the filter was attached into it.	
5. The vacuum pump and refrigerant cylinder were mounted under and left side of the frame respectively.	
6. The control panel circuit was assembled and positioned on the right side of the frame. 7. All screws attached to the angle bar frame and the components were tightened.	

Testing

Test run was made to check for presence of leaks on the refrigerant lines, grounded circuits and mechanical defects of the innovated refrigerant recycling machine. Testing was also done to check whether the innovated equipment functions as intended.

Table 5. Procedures in Testing

1. The Innovated Refrigerant Recycling machine was positioned on level ground for testing.	
2. Charging hoses of gauge manifold were connected to the disabled A/C unit; high and low pressure hose to Recycling Machine.	

ISSN: 2277-9655
Impact Factor: 3.785

3. The machine was started by checking the on and off control circuit through the pilot light.	
4. The gauge manifold hoses and valves were adjusted and checked for security.	 
5. The low and high pressure gauge valves were opened for recovering the refrigerant gas into the recycling machine and stored in the refrigerant tanks.	 
6. The machine was observed 10 to 15 minutes until the refrigerant has been recovered out from the disabled RAC unit.	

Testing for Acceptability and Efficiency of the Innovated Equipment

As the innovated refrigerant recovery machine became available for use it is then subjected to test for acceptability and efficiency. The educators of the university and multiple industry technicians were made to rate the level of acceptability (on a 5 point Likert scale) as to rigidity, portability and function. Rigidity refers to the strength of the fabricated machine without breaking or loosening after full operation. Portability is the ability of the machine to be transported at anyplace without hindrances by a single person with ease. The intended functions are leak testing, flushing, vacuuming and recovering refrigerants.

The extent of efficiency is rated as to its functions in terms of leak testing, flushing and vacuuming air conditioning and refrigerating units, and recovering refrigerant and recharging it back to the unit. The aforementioned functions have the same indicators such as quality of the work by; held pressure up to 150 psi, easy assembly of fittings, safe in using gage manifold and safe in charging refrigerant gas.

RESULTS AND DISCUSSION

Acceptability and Efficiency

Most failures in innovation are caused by inability to understand the context of changes that are preferred over the existing (Friedman, 2003). As such the machine has to be subjected to the acceptability and efficiency testing of the preferred functionality, portability and rigidity.

ISSN: 2277-9655
Impact Factor: 3.785

Acceptability

The acceptability of the innovated refrigerant recovery machine was validated by the respondent groups, 25 Industry Practitioner and 10 University Educators. The design was descriptively rated as Highly Acceptable with a mean rating of 4.48 (IP, 4.44 and UE, 4.52). The industry practitioners rated the Rigidity (4.56), Portability (4.36) and Intended function (4.52) described as Highly Acceptable. The university educators had it on 4.56, 4.43 and 4.57 Figure 5.

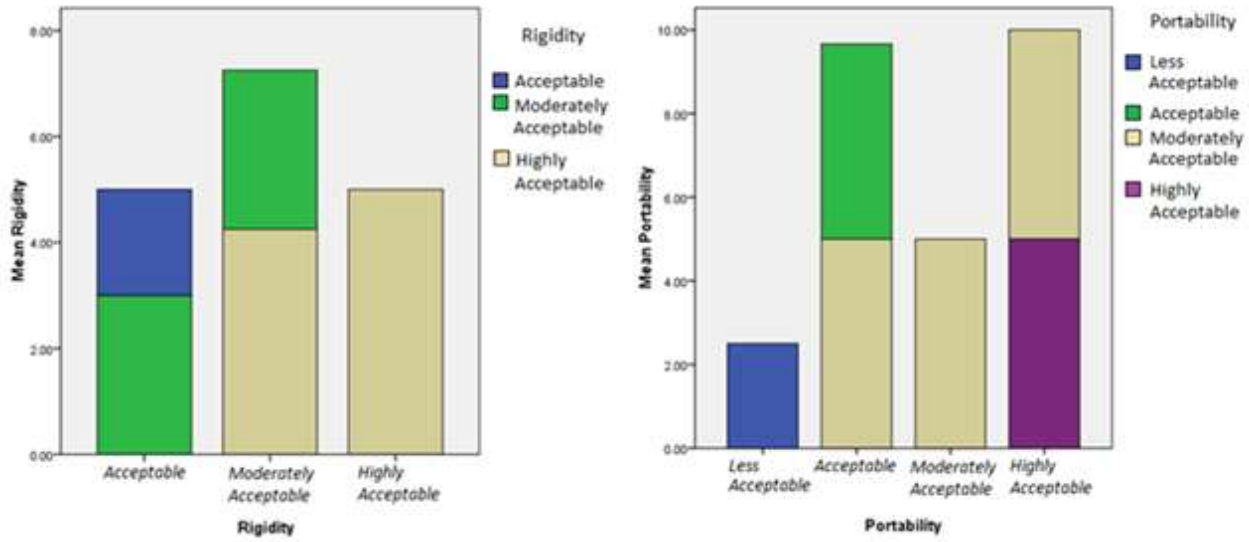


Figure 5. Mean Rigidity and Portability of the Innovated Refrigerant Recovery Machine validations of Industry Practitioners and University Educators

Portability details pertaining to machine being lifted by a single person (3.80, IP) and can easily be placed to another location without obstruction (4.00, UE) got the lowest rating. Although acceptable but needs to have a compact placement of parts so that portability issues can be resolved much alike with those sold in the market.

Generally, the extent of acceptability of the Innovated Refrigerant Recycling Machine in terms of design and construction met the requirements that reflect the rigidity, durability, comfort, and safety for use of the innovated device for refrigeration and air- conditioning.

Also, the presence of the Refrigerant Recycling Machine as a new device in RAC shops lessen the scarcity of the necessary tools and equipment that can help in the delivery of knowledge and skills in leak testing, flushing , vacuuming and reclaiming refrigerants from refrigerating and air- conditioning units all - in - one machine.

Feedback information provided by Industry Practitioners includes the replacements of filters once oil is seen on the inlet of the refrigerant containers, the use of marketed vacuum pump instead of the motor compressor to have lesser presence of contaminants of the reclaimed refrigerants and varied gage manifolds for use on different refrigerants (R-22, R-134a and R-410).

Series of filtering and re-evacuating of the refrigerant is necessary to ensure safety for use and total removal of contaminants (if not be minimized). Related studies conducted provide information on the wide variation of advantages and disadvantages of reclaiming refrigerant and that the type of system use is dependent on the reclaimers' needs (Damodaran and Donahue, 2010).

ISSN: 2277-9655
Impact Factor: 3.785

Efficiency

The preferred functionality of the Innovated Refrigerant Recovery Machine is used as the measure for effectiveness of the three attributes that is, Leak Testing, Flushing and Vacuuming. The aforementioned functions have the same indicators such as quality of the work by; held pressure up to 150 psi, easy assembly of fittings, safe in using gage manifold and safe in charging refrigerant gas. Recovery and recharging was done on 10 different refrigerating and air conditioning units having the original refrigerant charge weight found on the nameplate data as basis.

Leak Testing was rated by the three respondent groups as Highly Efficient (4.90), Flushing as Highly Efficient (4.85), and Vacuuming as Highly Efficient (4.90).

Flushing as a process of blowing dirt and impurities out of the system receives the lowest rating of the three functions. Although efficient but it does not have the capability of identifying the purity content of the recovered refrigerant. The innovated machine largely depends on the filters that are installed and usually collect traces of mixed refrigerants from servicing multiple systems even if using different cylinders for different types (Damodaran and Donahue, 2010).

Vacuuming lowers the pressure of the system causing the moisture to boil and evacuate the system was rated Highly Efficient much the same with Leak Testing since the two are opposites – Vacuuming (Low Pressure) ; Leak Testing (High Pressure).

Recovery and recharging was found to have an efficiency ranging from 74% to 96% as stipulated on Table 4. The equipment has an over-all efficiency of 88.71%.

Table 4. Recovery Efficiency

Type of Unit Serve	**Original Weight (grams)**	**Recovered**	**% Recovery**
Upright Freezer	150	140	93.33
Refrigerator (Single Door)	110	90	81.82
Refrigerator (Single Door)	80	65	81.25
Refrigerator (Double Door)	85	75	88.24
Water Dispenser	47	35	74.47
Window aircon 2hp	850	800	94.12
Window aircon 3/4 hp	400	385	96.25
Window aircon 1/2 hp	220	195	88.64
Floor Mounted 5TOR	5000	4750	95.00
Wall Mounted 1.5TOR	2500	2350	94.00
EFFICIENCY			**88.71**

Accordingly, there is no provision in servicing leak repairs on small units but there is no policy also if one repairs the units. Because the equipment was primarily used in the laboratory instruction of the university then it is limited to recovering smaller refrigerating and air conditioning units. As such the concerns on venting usually falls on human error more specifically on refrigerant handling thus, a limited amount only is released into the atmosphere (Damodaran and Donahue, 2010).

CONCLUSION

Based on the foregoing results, there is enough evidence to prove that the attributes and functionality of the recovery machine is highly acceptable. It is also 88.71% efficient in recovering refrigerant from refrigerating and air conditioning units setting aside the added features of leak testing, flushing and vacuuming.

ACKNOWLEDGEMENTS

The author expresses his heartfelt gratitude to the Office of the VP Research for the support extended and to his assistant Niño Jess Tomabiao. God bless.

REFERENCES

[1] Adams, K. (2005). The Sources of Innovation and Creativity. National Center on Education and the Economy (NCEE). Research Summary and Final Report
[2] Amabile, T. M. (2013). Componential theory of creativity. Harvard Business School, Sage Publications.
[3] Friedman, K. (2003). Theory construction in design research: criteria: approaches, and methods Norwegian School of Management, Postboks 4676, Sofienberg, 0506 Oslo, Norway
[4] Republic Act 8749, Philippine Clean Air Act of 1999.
Retrieved from http://www.chanrobles.com/philippinecleanairactrules.htm
[5] DENR AO No. 81, (2000). Implementing Rules and Regulations for RA 8749.
Retrieved from http://www.chanrobles.com/philippinecleanairactrules.htm
[6] Institute of Scrap Recycling Industries, Inc, (1999). Guidelines for Appliance Recycling.
[7] Damodaran, N. and Donahue, J., (2010). Analysis of Equipment and Practices in the Reclamation Industry. Stratus Consulting Inc. 1920 L St. NW, Suite 420 Washington, DC 20036 202-466-3731.
[8] U.S. EPA (2011). How to Properly Dispose of Refrigeration and Air-Conditioning Equipment. www.epa.gov.
[9] U. S. EPA (2006). Safe Disposal Procedures for Household Appliances that Use Refrigerants. www.epa.gov.
[10] Tonko Ćurko, PhD, (1990). Development of ODS/F-GAS Certification System in Croatia