

“Development and Acceptability of Innovative R410A Refrigerant Recovery Kit”

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ABSTRACT

This project development study aimed to design, construct, and evaluate an R410A Recovery Kit for application in the refrigeration and air conditioning industry. The device integrates a refrigerant recovery machine and a pressure washer, providing technicians with essential tools for efficient system servicing and maintenance. Evaluation was conducted with HVACR faculty members who assessed the kit's design and functionality using standardized criteria. Findings revealed a high level of acceptability, with an overall mean rating of 4.48, indicating strong endorsement. Portability (mean = 4.57), use of durable locally sourced materials, and clear labeling of component parts were identified as key strengths, contributing to ease of operation and reduced errors. The results confirm that the kit is a practical, cost-effective, and user-friendly alternative to imported equipment. The study concludes that the R410A Recovery Kit meets both technical and user expectations, offering a valuable contribution to sustainable refrigerant management and technical training. Recommendations include integrating digital monitoring features, enhancing ergonomics, and conducting further development studies to refine safety and functionality.

Keywords: R410A Recovery Kit, Refrigerant Recovery Kit, Refrigerant handling and safety, Refrigeration and Air Conditioning Technology

INTRODUCTION

The Heating, Ventilation, Air Conditioning, and Refrigeration (HVACR) industry plays a vital role in maintaining human comfort, ensuring food preservation, and supporting industrial productivity. As energy efficiency and environmental sustainability continue to shape global priorities, the choice of refrigerants has become a critical consideration in both domestic and commercial applications. Among the most commonly used refrigerants is R410A, a hydrofluorocarbon (HFC) recognized for its high energy efficiency and zero ozone depletion potential (Bivens & Gage, 2004). Despite these advantages, R410A also possesses a significantly high Global Warming Potential (GWP), making its safe handling, recovery, and recycling essential to mitigating greenhouse gas emissions and promoting environmental stewardship (Montzka et al., 2018).

In the Philippines, the Clean Air Act of 1999 (Republic Act 8749) and the Philippine Ozone-Depleting Substances (ODS) Management Act of 2004 establish the legal foundation for regulating the use, recovery, and disposal of refrigerants. The Department of Environment and Natural Resources (DENR) is the primary government body responsible for enforcing these environmental regulations (DENR, 2019). However, despite the existence of these frameworks, the HVACR sector still faces several challenges, including the limited availability of proper recovery equipment, insufficient technician training, and the high cost of imported recovery systems. These challenges hinder compliance with environmental standards and restrict local technicians from practicing sustainable refrigerant management.

To address these gaps, this study developed an Innovative R410A Recovery Kit, a locally fabricated device that integrates a refrigerant recovery machine with a pressure washer. The kit was designed to enhance the safe handling and recovery of R410A refrigerants, reduce operational costs for technicians and educational institutions, and promote adherence to environmental and occupational safety standards. By utilizing locally available materials and engineering expertise, the project seeks to demonstrate that indigenous innovation can meet global standards of efficiency, safety, and sustainability in HVACR servicing.

This study followed a project development research design, consisting of four major phases: (1) Creation of isometric and orthographic views of the R410A Recovery Kit, ensuring compatibility with the high-pressure requirements of R410A; (2) Assembly of components such as a motor compressor, condenser, pressure washer, filter drier, valves, and safety features using locally available materials; (3) Functional trials of the recovery kit, revision of design weaknesses, and validation of operational safety; and (4) Acceptability of the kit was evaluated by HVACR faculty from Zamboanga Peninsula Polytechnic State University using a structured survey instrument with 5 point-Likert scales on design and functionality.

The evaluation criteria included assembly quality, material durability, portability, safety, and capacity to recover R410A refrigerant. Data were analyzed using descriptive statistics (mean scores and qualitative interpretation).

Review of Related Literature

The growing demand for environmentally friendly refrigerants has accelerated the transition from chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) such as R-22 to hydrofluorocarbon (HFC) alternatives. Among these, R410A has become one of the most widely adopted due to its zero-ozone depletion potential (ODP) and superior energy efficiency (Calm, 2008). However, its high global warming potential (GWP) has made the safe handling, recovery, and management of this refrigerant a critical concern (Montzka et al., 2018). The literature reviewed can be categorized thematically into six interrelated domains: environmental sustainability, recovery technologies, technical challenges, training and competency, regulatory compliance, and cost-effectiveness.

Environmental Sustainability and Refrigerant Recovery

Several studies emphasize the environmental implications of refrigerant management. Henze (2016) highlights the role of recovery machines in preventing the direct release of refrigerants into the atmosphere, thereby minimizing greenhouse gas emissions. Similarly, Johnson et al. (2016) developed portable recovery and recycling systems that enable the capture, storage, and reuse of refrigerants during servicing. These innovations directly contribute to climate change mitigation and compliance with environmental protocols. The literature collectively stresses that proper recovery is not merely a technical requirement but a cornerstone of sustainable refrigeration practices.

Recovery Technologies and Innovation

Technological advancements have enhanced the precision and efficiency of recovery equipment. Henze (2016) observes that modern gauges and recovery units incorporate improved monitoring capabilities, reducing leakage risks and ensuring correct servicing. Rabelo (2017) further notes that global attention to emission reduction has stimulated continuous innovation in recovery systems, integrating environmental protection with operational efficiency. The inclusion of specialized tools in recovery kits therefore represents a necessary evolution in response to both environmental and industrial demands.

Technical Challenges of R410A

Unlike older refrigerants such as R-22, R410A operates at much higher pressures, necessitating specialized service equipment. Domanski and Didion (2007) warn that conventional tools are insufficient for the unique pressure demands of R410A, while Godwin and Raffan (2012) point to the increased risk of equipment failure or leakage when improper tools are used. This indicates that the design of an R410A-specific service kit must prioritize pressure resistance, material durability, and system compatibility, ensuring safety and reliability in actual field applications.

Training and Competency Development

Safe handling of high-pressure refrigerants requires not only appropriate equipment but also adequate technician training. Parker and Burgess (2014) stress that theoretical knowledge alone is insufficient, and that technicians must engage in practical, hands-on learning. McQuiston, Parker, and Spitler (2005) reinforce the role of service kits as educational tools, bridging the gap between classroom learning and real-world

application. Literature therefore identifies competency development as an essential component of innovation in recovery kits, ensuring both workforce readiness and system safety.

Regulatory and Environmental Compliance

Refrigerant management is not only a technical and educational issue but also a legal and regulatory imperative. In the Philippine context, the Clean Air Act (RA 8749) and the Ozone-Depleting Substances Management Act (RA 9275) provide legislative guidance on refrigerant use, recovery, and disposal (DENR, 2019). Service kits designed for R410A support technicians in complying with these laws, ensuring that local practices align with both national and international standards. The literature thus situates innovative service kits as practical tools for operationalizing environmental policy.

Cost-Effectiveness and Accessibility

Finally, affordability and accessibility emerge as significant considerations in the literature. Lemmon and McLinden (2010) note that cost-effective recovery kits lower the financial barriers for small-scale technicians and enterprises, particularly in developing economies. Locally fabricated kits, designed with readily available materials, can deliver comparable functionality to imported models while being more accessible and affordable. This theme emphasizes that innovation must not only address environmental and technical challenges but also ensure economic sustainability for end-users.

The reviewed literature affirms the necessity of an Innovative R410A Service Kit that integrates sustainability, advanced recovery technology, technical adaptability, training utility, regulatory compliance, and affordability. Each theme underscores a critical dimension of refrigerant management, thereby establishing a strong foundation for the present study. By addressing gaps in accessibility and contextualizing solutions within local materials and resources, the proposed innovation contributes not only to industry advancement but also to environmental stewardship and capacity-building in HVACR practice.

METHODOLOGY

Research Design

This study employed a project development research design, which is appropriate for creating, testing, and evaluating a prototype device. The research process was structured into four phases: design, development, testing and revision, and evaluation. The design phase involved creating isometric and orthographic views of the kit to ensure its compatibility with the high-pressure characteristics of R410A refrigerant. The development phase focused on the assembly of essential components—including a motor compressor, condenser, filter drier, valves, and a pressure washer—using locally available materials. In the testing and revision phase, functional trials were conducted to identify weaknesses and validate operational safety, followed by revisions to improve performance. Finally, the evaluation phase involved expert assessments to determine the acceptability of the developed kit in terms of design and functionality.

Research Locale

The study was conducted at College of Engineering and Technology of Zamboanga Peninsula Polytechnic State University (ZPPSU) where the kit was designed, assembled, and evaluated. The university provided access to the necessary facilities, tools, and expertise in HVACR (Heating, Ventilation, Air Conditioning, and Refrigeration). The choice of locale is significant, as it not only supports the development process through institutional resources but also situates the project in a context where HVACR education and environmental compliance are highly relevant.

Respondents of the Study

The respondents were faculty members specializing in HVACR from Zamboanga Peninsula Polytechnic State University (ZPPSU). Respondents evaluated the acceptability of the R410A Recovery Kit in terms of design and functionality. Faculty evaluators were chosen due to their expertise in refrigeration and air-conditioning systems, ensuring that the feedback provided was technically sound and academically informed. Their

assessments allowed the researchers to validate the prototype against established educational and industry standards.

Research Instrument

A structured survey instrument utilizing a five-point Likert scale was used to gather data on the acceptability of the recovery kit. The instrument included evaluation criteria such as assembly quality, material durability, portability, safety, and recovery capacity. Respondents rated each criterion from “Unacceptable” to “Highly Acceptable,” providing both quantitative measures and qualitative interpretations of the kit’s performance. This instrument ensured that data collection was systematic, measurable, and aligned with the study’s objectives

Data Gathering Procedure

The data gathering followed a step-by-step process. First, the researchers constructed and refined the recovery kit through iterative testing. Once finalized, the prototype was presented to the HVACR faculty for evaluation. Respondents were asked to test the kit’s design and functionality, after which they completed the structured survey instrument. Collected data were then organized and analyzed using descriptive statistics, particularly mean scores and qualitative interpretation, to determine the overall acceptability of the R410A Recovery Kit. This process provided a clear, evidence-based assessment of the prototype’s strengths and areas for improvement

RESULTS AND DISCUSSION

Development of R410A Recovery Kit

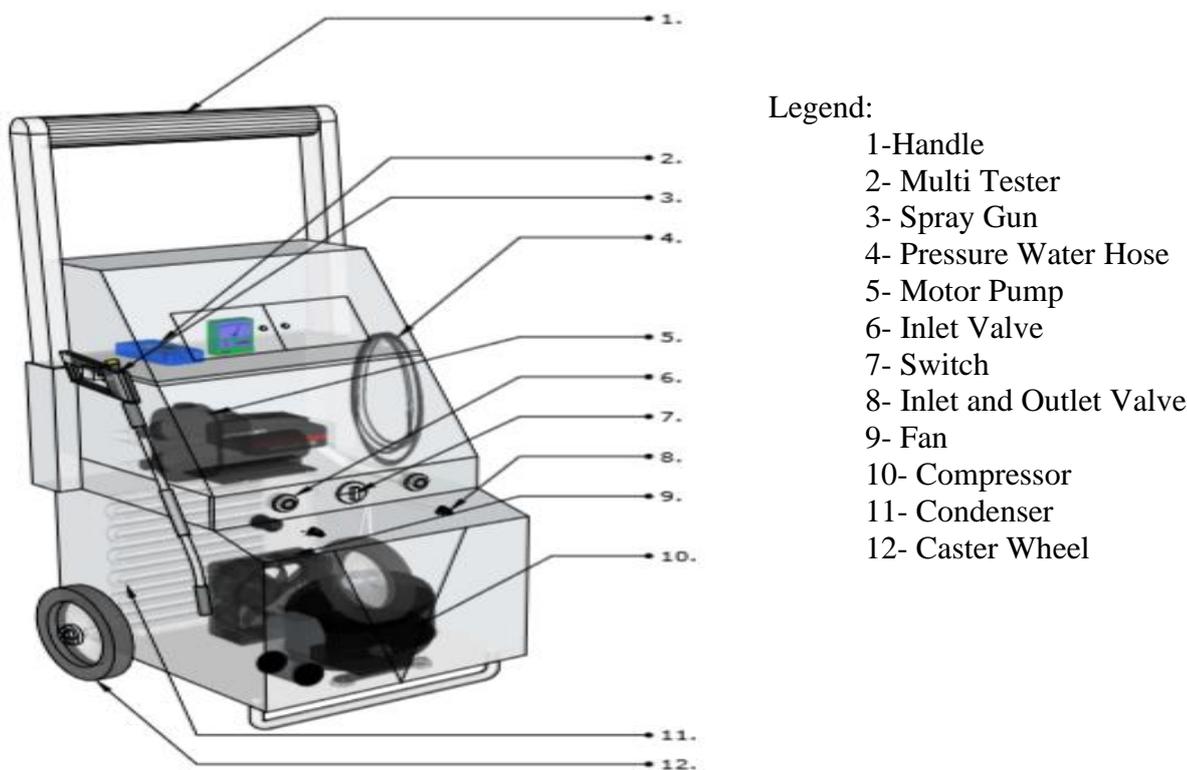


Figure 1. The Innovative R410A Recovery Kit

The Refrigerant 410A Recovery Kit is a comprehensive and specialized set of tools designed to facilitate the safe recovery, evacuation, and recharging of refrigerant systems. It includes several critical components, each serving a distinct function in the recovery process. Among these, the recovery unit functions as a high-efficiency vacuum pump that extracts refrigerant from the system and directs it into a designated recovery tank, thereby preventing environmental release. The manifold gauge set enables precise monitoring of refrigerant pressures and flow throughout the recovery, recycling, and charging processes, ensuring system

performance and safety compliance. Supporting accessories such as hoses and fittings establish secure connections, while the vacuum gauge provides an accurate measurement of evacuation levels during system preparation. To safeguard technicians, safety glasses and protective gloves are included to mitigate risks associated with refrigerant and chemical exposure. Additionally, the kit is equipped with a power washer, which plays a vital role in maintaining optimal functionality by removing accumulated debris from air-conditioning units prior to service operations. Collectively, these components provide a systematic, professional-grade solution for refrigerant handling in compliance with regulatory and industry standards.

Equally essential to the operation of the Refrigerant 410A Recovery Kit are the safety protocols and operational procedures that guide its proper use. These include strict adherence to personal protective equipment (PPE) requirements, such as wearing safety glasses and gloves, and ensuring that the kit is never applied to live or pressurized systems without adequate preparation. Environmental and occupational safety are prioritized through guidelines that prohibit atmospheric discharge of refrigerants and stress the importance of proper ventilation in workspaces. Detailed operational steps—ranging from system preparation and refrigerant recovery to evacuation and recharging—ensure that technicians can systematically manage refrigerant cycles with precision. Furthermore, routine maintenance practices, such as cleaning, inspection, and safe storage, sustain the kit’s long-term reliability, while troubleshooting protocols assist in diagnosing issues with critical components like the recovery unit or vacuum pump. Together, these measures establish a holistic framework that not only enhances technical efficiency but also ensures regulatory compliance, worker safety, and environmental responsibility in refrigerant recovery and management processes

Evaluation on the Design of R410 Recovery Kit

Table 1. Instructor and Professor’s Evaluation on the Design of R410 Recovery Kit

Statement	Mean	Description
1. The R410A Recovery Kit is assembled based on lay-out and design.	4.14	Highly acceptable
2. The R410A Recovery Kit is well assembled and presentable.	4.14	Highly acceptable
3. The R410A Recovery Kit uses quality materials that are available in the local market.	4.42	Highly acceptable
4. The R410A Recovery Kit is easy to transfer of area/location.	4.57	Highly acceptable
5. The R410A Recovery Kit is labelled with components parts.	4.14	Highly acceptable
Grand Mean	4.48	Highly Acceptable

Parameter: 1-1.5 Unacceptable, 1.6-2.0 Slightly Acceptable, 2.1-3.0 Moderately Acceptable, 3.1-4.0 Acceptable, and 4.1-5.0 Highly Acceptable.

The table 1 shows data results of Instructor and Professors’ Evaluation on the Design of R410A Recovery Kit. This data results indicate a strong level of acceptance regarding the R410A Recovery Kit, with an overall grand mean of 4.48, categorized as "Highly Acceptable." Each statement reflects a positive assessment, particularly in terms of the quality and usability of the service kit. Specifically, the highest rating of 4.57 for the statement on ease of transfer suggests that user’s find this feature particularly advantageous, enhancing the kit's practicality for various applications. This high level of acceptance likely reflects the effectiveness of the design and functionality that meets user expectations.

Furthermore, the consistency of the ratings, with all individual statements falling within the "Highly Acceptable" range (4.14 to 4.57), indicates a well-rounded product. The positive feedback on the assembly

quality and material sourcing points to a thoughtful approach in both design and manufacturing processes. The emphasis on using locally available materials (mean of 4.42) may also highlight a commitment to sustainability and community support, which could resonate well with users. Overall, these results suggest that the R410A Recovery Kit is not only well-received but also positions itself as a reliable option in the market.

Evaluation on the Functionality of R410 Recovery Kit

Table 2. Instructor and Professors’ Evaluation on the Functionality of the R410A Recovery Kit

Statement	Mean	Description
1. The R410A Recovery Kit is completely functional.	3.85	Acceptable
2. All component parts of the R410A Recovery Kit are functional and safe to use.	4.0	Acceptable
3. The R410A Recovery Kit can service an Air Conditioner unit that uses 410A refrigerant.	4.42	Highly Acceptable
4. The R410A Recovery Kit can be operated by single person.	4.42	Highly Acceptable
5. The R410A Recovery Kit can be used for maintenance (cleaning of Air Conditioner units).	4.28	Highly Acceptable
Grand Mean	4.19	Highly Acceptable

Parameter: 1-1.5 Unacceptable, 1.6-2.0 Slightly Acceptable, 2.1-3.0 Moderately Acceptable, 3.1-4.0 Acceptable, and 4.1-5.0 Highly Acceptable.

The table 2 displays the data results for the R410A Recovery Kit reflect a generally positive perception in terms of functionality, with a grand mean of 4.19 classified as "Highly Acceptable." The statement regarding the kit's ability to service an air conditioner using 410A refrigerant received a notable mean score of 4.42, suggesting that users have a strong confidence in its effectiveness for this specific application. Additionally, the kit's operability by a single person, also rated at 4.42, highlights its user-friendly design, making it accessible for individual technicians. This level of functionality indicates that the service kit is well-suited for its intended purpose.

On the other hand, while the results indicate an overall satisfactory assessment, the mean of 3.85 for the statement on complete functionality suggests there may be room for improvement in ensuring that all features consistently meet user expectations. The score of 4.0 for the safety of all component parts indicates that while users generally feel confident about the kit’s safety, further emphasis on reliability and functionality could enhance user satisfaction. Overall, these findings suggest that while the R410A Recovery Kit is well-received, addressing the concerns related to complete functionality could further elevate its reputation and effectiveness in the market.

Summary of the Evaluation Results

Table 3. Summary of the Evaluation Results for the R410A Recovery Kit Based on Design and Functionality as Assessed by Instructors and professors

	Grand Mean	Description
Design	4.48	Highly Acceptable

Functionality	4.19	Highly Acceptable
Over all Grand Mean	4.34	Highly Acceptable

Parameter: 1-1.5 Unacceptable, 1.6-2.0 Slightly Acceptable, 2.1-3.0 Moderately Acceptable, 3.1-4.0 Acceptable, and 4.1-5.0 Highly Acceptable.

The table 3 emphasizes data results indicate that the overall performance of the instructors is viewed as "Highly Acceptable," with an overall grand mean of 4.34. The specific areas of evaluation, including design and functionality, received high ratings of 4.48 and 4.19, respectively. This suggests the develop R410A Recovery Kit excel in their design-related competencies, which may encompass aspects such as structure, materials, and presentation. Meanwhile, the functionality score indicates a solid performance, though it is slightly lower than the design aspect. Collectively, these results reflect a positive assessment, highlighting strengths in design while also identifying an opportunity for further enhancement in instructional delivery or engagement methods.

CONCLUSION

The study successfully designed, developed, and evaluated an Innovative R410A Recovery Kit intended for use in refrigeration and air-conditioning systems that utilize high-pressure refrigerants. Following a systematic project development approach—comprising design, development, testing and revision, and evaluation—the researchers produced a prototype that integrates a refrigerant recovery machine and a pressure washer. The evaluation conducted by HVACR faculty at Zamboanga Peninsula Polytechnic State University revealed a high level of acceptability, with overall ratings of 4.48 for design and 4.19 for functionality, both interpreted as "Highly Acceptable." These findings affirm that the recovery kit is a cost-effective, user-friendly, and practical alternative to imported equipment. It not only meets technical requirements but also aligns with environmental and occupational safety standards, making it a valuable contribution to sustainable refrigerant management and technical training.

Limitations Of the Study

Despite its successful outcomes, the study was bounded by several limitations. First, the evaluation was confined to a limited group of HVACR faculty members within a single academic institution, which may restrict the generalizability of the findings across broader industry applications. Second, the kit was tested under controlled academic and laboratory conditions; thus, its long-term durability and performance under varied commercial and industrial environments remain unverified. Third, the study primarily focused on R410A refrigerant; the applicability of the kit for other refrigerants with similar or higher pressures was not explored. Finally, while the kit demonstrated high acceptability, some evaluators noted minor concerns regarding its complete functionality and safety reinforcement, suggesting that further refinements are necessary before widespread adoption.

RECOMMENDATIONS

In light of the findings and the limitations identified, the researchers strongly recommend further refinement and enhancement of the Innovative R410A Recovery Kit to maximize its functionality, safety, and long-term usability. Future iterations of the kit should integrate digital monitoring systems, such as pressure and temperature sensors, to provide technicians with more precise data during operation. The incorporation of reinforced safety features, including circuit breakers, fuses, and protective casings, would further strengthen operational reliability and user protection. Additionally, ergonomic modifications should be considered to improve portability and ease of handling, ensuring that the kit is not only efficient but also user-friendly in various service contexts. These technical improvements, combined with broader field testing in commercial and industrial HVACR environments, would validate its durability and performance under real-world conditions, moving beyond controlled academic settings.

Moreover, expanding the kit's applicability beyond R410A to include other high-pressure or eco-friendly refrigerants will future-proof its utility and relevance in the evolving HVACR industry. Its integration into training programs within universities and technical institutions is equally essential, as it will serve as both a teaching tool and a bridge between classroom instruction and professional practice. For wider adoption, collaborations with local industries, manufacturers, and regulatory agencies are recommended to refine design features, ensure compliance with international safety standards, and support large-scale production. Finally, maintaining a focus on sustainability and affordability by utilizing locally available materials will make the kit more accessible to technicians and small enterprises, particularly in developing economies, thereby strengthening its role as a cost-effective, environmentally responsible, and industry-aligned innovation.

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