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DEVELOPMENT OF MODULE FOR PRACTICAL SKILLS DELIVERY IN REFRIGERATION AND AIR-CONDITIONING LEAK DETECTION FOR VOCATIONAL AND TECHNICAL EDUCATION SCHOOLS

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ABSTRACT: *The study developed module for teaching leak detection skills in refrigeration and air-conditioning for use in Vocational and Technical Education institutions. To achieve its objectives, descriptive survey design was adopted. A population of 94 respondents (20 lecturers and 74 private industry professionals) of refrigeration and air-conditioning were used. There was no sampling. Five specific purposes and five RQs guided the study. The instrument for data collection was the: "Module for Skill Delivery in Refrigeration and Air-conditioning Leak Detection Questionnaire (MSDRALDQ)". The MSDRALDQ was face validated by three Experts. Cronbach Alpha Coefficient method was used to establish the reliability coefficient index at 0.88. The five stated RQs were analyzed using mean. The findings from the study suggested that the fifty items; and twenty-six steps/tasks identified in clusters for the refrigeration and air-conditioning leak detection module were all accepted. The study recommends that Vocational and Technical Education institutions; and other training centers should adopt the module for teaching skills in leak detection in refrigeration and air-conditioning prevent emission of ozone depleting refrigerants into the atmosphere.*

KEYWORDS: development of module, practical skills, refrigeration and air-conditioning, leak detection

INTRODUCTION

Development of module is the art of creating learning kits that enables an individual to study at his /her convenient pace. Module is seen as a self-instructional material that contain all the elements such as objectives content, instructional materials and evaluation techniques needed for the achievement of objectives of learning program. According to Gagne and Briggs (1992) modular packages can be sequenced in a variety of pattern to build unique courses of study, taking care of different student's interest and needs in using modular package for learning, the learner takes responsibility for learning shift from the teacher to the student. Yusup (2009) confirmed that students are able to increase skills in line with their sets of abilities, interests and intensive flow of information that is linked to the real world that is outside school provision. Osinem, and Nwoji (2005) added that individual teaching is possible, but it is more flexible for students to use materials outside the school experiences and knowledge related to their regular class subject. Onuka, (2008) opined that modular learning will enhance the capacity of technologists in leak detection.

Leak detection is one of the major technologies in the management of ozone depleting refrigerants. The new technology in leak detection, according UNEP (1999) includes adding glo- leak tracer into the compressor, for tracing refrigerant leaks with an ultraviolet lamp available only for mineral and polyester lubricant. Testing on regular basis with specialized leak detectors was recently produced to

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detect Hydro fluorocarbon (HFC) refrigerants, along with the use of Halide torch. Detection of leakage according to British Refrigeration Association (2007) is seen as the manual procedures carried out by a qualified technician, to check refrigeration systems in order to identify possible leaks in tubes, joints and connections. The Association recommended that, use of electronic refrigerant detector; ultra-violent lamp and halide torch are the main methods in management of ozone depleting refrigerants. When a leak is detected, good practice requires that the system is evacuated before charging

Technologists in refrigeration and air-conditioning who do not acquire the expected skills in tightness for leakage in refrigeration and air-conditioning system can conveniently improve in the needed skills through the use of module. According to the British Refrigeration Association (2010), its code of practice, stresses the need for those installing, designing, commissioning and maintaining refrigeration and air-conditioning system to take all reasonable steps to minimize leakages. VTECH (2010) affirmed that in the refrigeration industry, component and system must be tested to ensure that refrigerant leakages are below specified limits. United Nation Environmental Protection (2010) concludes that refrigerant leakage contributes to the ozone layer depletion; hence refrigeration and air-conditioning industries has to take on new skills in ensuring zero leakage is achieved.

Statement of the problem

Tightness testing for leakage in refrigeration and air-conditioning system is taken as one of the code of practice in refrigeration and air-conditioning industry. Precise responsibility is placed on personnel that install, maintain, and commission refrigeration and air-conditioning plants in ensuring zero leakage of refrigerants especially ozone depleting ones.

But unfortunately, technologists and instructors of vocational and technical schools whose services are engage for the teaching of the practices in refrigeration and air-conditioning, lack basic leak detection skills. This gap in knowledge is currently contributing to release of large volume of refrigerants to the atmosphere that is capable of causing ozone layer depletion. Therefore, it becomes necessary to prepare guidelines to be followed in vocational and technical schools in the practices of refrigeration and air-conditioning to enhance skill in leak detection. Hence, the study tends to develop module for imparting practical skills in refrigeration and air-conditioning leak detection for VTE schools.

Research question

The following research questions guided the study;

1. What are the specific objectives of leakage detection module for refrigeration and air-conditioning?
2. What is the content of module for leakage detection in refrigeration and air-conditioning?
3. What are the equipment/facilities required for leakage detection in refrigeration and air-conditioning?
4. What are the teaching strategies required for implementation of module for leakage detection in refrigeration and air-conditioning?
5. What are the evaluation techniques needed for leakage detection module in refrigeration and air-conditioning?

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METHODOLOGY

The study adopted Research and Development (R&D) method by applying system approach procedures which includes: (a) identification of goal then translated in specific objectives; (b) identification of specific skills; (c) development of training facilities; (d) determination of teaching strategies; and (e) development of evaluation technique.

The research was conducted in Port Harcourt, Rivers State, South-South geopolitical region of Nigeria. The population for this study was 20 lecturers from the Department of Mechanical Engineering, Ken Saro-wiwa Polytechnic, Bori; and 74 identified private industry professionals in the area of refrigeration and air-conditioning; bringing the total respondents to 94. The entire population was studied, so there was no sampling. The "Module for Practical Skills Delivery in Refrigeration and Air-Conditioning Leak Detection Questionnaire (MPSDRALDQ)" was the only data collection instrument used for this study. The instrument was a five-point rating scale with response coding options: Most Agreed (MA); Agreed (A); Undecided (U); Not Agreed (NA); Strongly Not Agreed (SNA) with numerical values: 5, 4, 3, 2 and 1 assigned to the respective respond categories.

The "MPSDRALDQ" was face validated by three experts; suggestions from these experts were used to produce the final copy of the instrument. The reliability index of the instrument was established using Cronbach Alpha Coefficient in the following order: Module objectives (0.89), content of leak detection (0.87), facilities for leak detection (0.89), teaching strategies (0.88), and evaluation techniques (0.86); and the entire instrument (0.88). Thirty-five copies of the instrument were trial tested at Federal University of Technology, Owerri, Imo state in South-East region of Nigeria. The instrument for data collection was personally administered to the respondents. Out of the 94 copies of the questionnaire administered, all were withdrawn representing 100% return rate; and were analyzed to obtain results for the study.

The statistical instrument used for analyzing the research questions was the mean. The decision rule holds that any mean rating with 3.50 and above was regarded as agreed item for development of module for leak detection in refrigeration and air-conditioning for tertiary vocational and technical education technologists; while mean rating below 3.50 was regarded as not-agreed item.

RESULTS AND FINDINGS

Research Question 1: What are the specific objectives of leakage detection module for refrigeration and air-conditioning?
Data for answering research question 1 on content are presented in Table 1.

Table 1: Mean Responses of Lecturers and Industry professionals on specific Objectives of Module for Leak Detection

S/N	Specific Objectives	$\bar{X}$	SD	Remark
1.	Identify causes of leakage	4.12	.403	Agree
2.	Identify types of leakage	4.42	.377	Agree
3.	Select equipment for carrying out leak detection	4.65	.438	Agree
4.	Carry out different methods of leak detection	4.20	.441	Agree
	Grand Mean and SD	**4.35**	**0.41**	

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Table 1 above represents data for specific objectives for leak detection module with grand mean and SD ($\overline{X} = 4.35$, SD = 0.41). Among the objectives, "selection of equipment for carrying out leak detection" with ($\overline{X} = 4.65$, SD = 0.438) was the most rated by the respondents. While the least one is "identification of causes of leakage with ($\overline{X} = 4.12$, SD = 0.403). In all the four stated specific objectives are all suited to be included as specific objectives for development in refrigeration and air-conditioning leak detection module.

Research Question 2: What are the contents of module for practical training of refrigeration and air-conditioning?
Data for answering research question 2 on content are presented in Table 2.

Table 2: Mean Responses of Lecturers and Industry professionals on Leak Detection content

S/N	Leak Detection Content	$\overline{X}$	SD	Remark
1.	Causes of leakage	4.79	.407	Agree
2.	Types of leakage	4.82	.390	Agree
3.	Mixing of soap solution	4.74	.465	Agree
4.	Soap swap at piping's joints	4.75	.437	Agree
5.	Mirror view of swap joints	4.72	.450	Agree
6.	Starting electronic leak detector	4.76	.430	Agree
7.	Probing of joints with detector	4.76	.430	Agree
8.	Leak identification through light and sound	4.79	.407	Agree
9.	Dye injection for leak detection	4.76	.430	Agree
10.	Ultra violet light for leak detection	4.61	.491	Agree
11.	Symptoms for leak through light glow	4.75	.437	Agree
12.	Halide leak detector for detection.	4.71	.455	Agree
13.	Lighting of halide torch	4.71	.455	Agree
14.	Operate halide torch to identify leakage	4.71	.455	Agree
15.	Symptoms of leakage with color of flame	4.75	.437	Agree
16.	Nitrogen charge for leak detection	4.74	.444	Agree
	Grand Mean and SD	**4.74**	**0.43**	

The data presented Table 2 revealed 16 tasks as content for leak detection module for practical training of technologists in refrigeration and air-conditioning in VTE. The mean for the content is from 4.71 to 4.79. Each mean above meets the cut-off point of 3.5. This shows that all the items on leak detection content were required for the development of capacity building module for leak detection in refrigeration and air-conditioning.

Research Question 3: What are the equipment/facilities required for leakage detection in refrigeration and air-conditioning?
Data for answering research question 3 on equipment/facilities are presented in Table 3.

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Table 3: Mean Responses of Lecturers and Industry professionals on Equipment/Facilities

S/N	Training Equipment/Facilities	$\bar{X}$	SD	Remark
1.	Instructional guide	4.93	.255	Agree
2.	Soap	4.68	.470	Agree
3.	Clean water	4.75	.437	Agree
4.	Container	4.70	.460	Agree
5.	Mirror	4.60	.493	Agree
6.	Electronic leak detector	4.80	.399	Agree
7.	Ultra violet lamp	4.52	.503	Agree
8.	Dye	4.32	.470	Agree
9.	Halide torch	4.85	.359	Agree
10.	Workman glove	4.63	.485	Agree
11.	Refrigerators	4.56	.499	Agree
12.	Air-conditioners	4.85	.359	Agree
13.	Nitrogen set	4.77	.423	Agree
14.	Manifold gauge	4.90	.306	Agree
15.	Vacuum pump	4.71	.455	Agree
16.	Service hose	4.86	.347	Agree
	Grand Mean and SD	**4.71**	**0.41**	

The data presented on Table 3 revealed 16 items as equipment/facilities for leak detection module for practical training of technologists in refrigeration and air-conditioning in VTE. The respondents agreed that "Instructional guide" with mean (4.93) is one of the highest facilities needed for leak detection module. This is followed by service hose (4.86). All the identified items meet the cut-off point of 3.5. This shows that all the items selected for leak detection were required for the development of capacity building module for leak detection in refrigeration and air-conditioning for VTE schools.

Research Question 4: What are the teaching strategies required for implementation of module for leakage detection in refrigeration and air-conditioning?
Data for answering research question 4 on teaching strategies are presented in Table 4 below.

Table 4: Mean Responses of Lecturers and Industry professionals on teaching strategies

S/N	Instructional strategies	$\bar{X}$	SD	Remark
1.	Demonstrate skills through depicting procedural task outlined in the particular module on the expected skills then allow trainee to practice	4.98	.000	Agree
2.	Create experimental conditions relating to the expected skills and allow trainee to analyze the result and relate it to real situation	4.83	.389	Agree
3.	Use guided discussion with active participation of trainee to narrate specific skill on the module to allow trainee to practice	4.67	.492	Agree
4.	Create small groups, give project on problems relating to stated skills on module and supervise trainee on steps to achieve result.	4.50	.522	Agree
	Grand Mean and SD	**4.73**	**0.35**	

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Table 4 has a grand mean of 4.75. Teaching strategy on item 1(demonstration of skills through depicting procedural task outlined in the particular module on the expected skills then allow trainee to practice) has the highest mean score of 5.00. The least is item 4 "creating small groups and giving project on problems relating to stated skills on module and supervise trainee on steps to achieve result" with mean score 4.75. This shows that all the teaching strategies selected for leak detection were apt for development of capacity building module for leak detection in refrigeration and air-conditioning for VTE schools.

Research Question 5: What is the evaluation techniques needed for leakage detection module in refrigeration and air-conditioning?
Data for answering research question 5 on evaluation techniques are presented in Table 5.

Table 5: Mean Responses of Lecturers and Industry professionals on evaluation techniques

S/N	Evaluation Techniques	$\bar{X}$	SD	Remark
1.	Laboratory tests	4.66	.209	Agree
2.	Short answer questions	4.21	.481	Agree
3.	Systematic testing	4.33	.442	Agree
4.	Task-oriented test	4.10	.471	Agree
5.	Scenario tests technique	4.22	.482	Agree
6.	Problems/Computational tests assessment method	4.59	.379	Agree
7.	Matching questions test technique	4.11	.512	Agree
8.	Project assignments	4.72	.462	Agree
9.	Practical project technique	4.85	.360	Agree
10.	Projects technique	4.23	.477	Agree
	Grand Mean and SD	**4.40**	**0.43**	

The data presented on Table 5 revealed 10 items as evaluation techniques for leak detection module for practical training in refrigeration and air-conditioning in VTE. The respondents agreed that "practical project technique" with mean (4.85) is one of the highest evaluation techniques needed for leak detection module. This is followed by project assignments (4.72). All the identified evaluation strategies meet the cut-off point of 3.5. This shows that all the evaluation strategies selected for leak detection were needed for development of capacity building module for leak detection in refrigeration and air-conditioning for VTE schools.

Research Question 6: What are the practical methods for leakage detection in refrigeration and air-conditioning?
Data for answering research question 6 on practical steps/tasks for leakage detection in refrigeration and air-conditioning are presented in Table 6.

Table 6: Mean Responses of Lecturers and Industry professionals on practical methods for leakage detection methods

S/N.	Sequential Practical Tasks for leak detection methods	$\bar{X}$	SD	Remark
Steps	**(a.) Manual Leak Detection Method**			
1.	Inspect oil residues round the system for signs of leakage.	4.29	.288	Agree
2.	Ensure there is pressure in the system	4.51	.472	Agree
3.	Collect small quantity of soap either powered, tablet or liquid	4.82	.403	Agree
4.	Pour small quantity of water into a container	4.88	.461	Agree
5.	Form soap and water solution	4.72	.442	Agree
6.	Swap soap solution at piping joints with brush	4.40	.390	Agree

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7.	Use mirror to view swap joints for symptoms of leakage	4.18	.555	Agree
Steps	**(b.) Electronic Leak Detection Method**			
1.	Start electronic leak detector by turning on the start button	4.28	.432	Agree
2.	Allow detectors to warm up for one minute	4.90	.311	Agree
3.	Probe joints with detector by slowly run sensing tip closely around suspected areas	4.39	.431	Agree
4.	Identify symptoms of leakages by adjusting sensitivity knob	4.19	.471	Agree
5.	Symptom of leakage is given by increase tickling noise	4.29	.479	Agree
Steps	**(c.) Dye Injection Leak Detection Method**			
1.	Connect dye can at the low side through manifold gauge.	4.31	.489	Agree
2.	Open dye's can to release content into the system and start system	4.60		Agree
3.	Identify symptom of leakage by viewing dye color appearance at leaking spot after few minutes of system operating.	4.39	.441	Agree
Steps	**(d.) Halide Leak Detector Method**			
1.	Light torch and allow copper plate to heat up	4.12	.477	Agree
2.	Hold detector upright	4.61	.432	Agree
3.	Slowly pass the hose around all suspected areas	4.72	.491	Agree
4.	Identify symptom of leakage with small greenish trait flame indicate small leak.	4.33	.471	Agree
5.	A bright blue flames indicates large leak	4.70	.430	Agree
6.	Close propane valve after check	4.60	.487	Agree
Steps	**(e.) Nitrogen Change Method**			
1.	Connect Nitrogen gauge	4.12	.470	Agree
2.	Connect Nitrogen to system through high pressure gauge	4.40	.499	Agree
3.	Gently open nitrogen; allow (30 to 100 psi) pressure	4.20	.424	Agree
4.	Close valves and observe per one hour for pressure drop.	4.64	.433	Agree
5.	If no pressure drops; gently increase pressure to 170 psi.	4.23	.378	Agree
	Grand Mean and SD	***4.30***	***0.43***	

Table 6 shows the results for practical methods for leakage detection in refrigeration and air-conditioning. A grand mean of 4.30 were derived from five identified practical leak detection methods. The data indicated that all the practical methods and associated steps/tasks found for the leakage detection methods are appropriate to train trainees; and suited to be included in refrigeration and air-conditioning leak detection module for VTE schools.

DISCUSSION

Table 1 identified four items as specific objectives for refrigeration and air-conditioning leak detection module. Among the objectives, "selection of equipment for carrying out leak detection was highly rated by the lecturers and industry professionals. In all the four stated specific objectives are all suited to be included as specific objectives for development in refrigeration and air-conditioning leak detection module.

Table 2 revealed 16 tasks as content for leak detection module for practical training of technologists in refrigeration and air-conditioning in VTE. This shows that all the items on leak detection content were required for the development of capacity building module for leak detection in refrigeration and

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air-conditioning. This is in line with the assertion of Onuka (2008) that modular learning will enhance the capacity of trainees in leak detection; and that leak detection is one of the major technologies in the management of ozone depleting refrigerants.

Table 3 showed that the 16 selected equipment/facilities for leak detection module for practical training of technologists in refrigeration and air-conditioning in VTE are appropriate. This shows that all the items selected for leak detection were required for the development of capacity building module for leak detection in refrigeration and air-conditioning for VTE schools.
Table 4 revealed teaching strategies. "Demonstration of skills through depicting procedural task outlined in the particular module on the expected skills then allow trainee to practice" has the highest rated. The study revealed that all the teaching strategies selected for leak detection were apt for development of capacity building module for leak detection in refrigeration and air-conditioning for VTE schools. This is in congruent with Yusup (2009) opinion that students are able to increase skills in line with their sets of abilities, interests and intensive flow of information that is linked to the real world that is outside school provision.

Table 5 revealed 10 items as suited evaluation techniques for leak detection module for practical training in refrigeration and air-conditioning. "Practical project technique" is the most rated evaluation techniques for leak detection module. But all the identified evaluation strategies were accepted. This shows that all the evaluation strategies selected for leak detection were needed for development of capacity building module for leak detection in refrigeration and air-conditioning for VTE schools.

Table 6 shows the results for practical methods and steps for leakage detection in refrigeration and air-conditioning. The data indicated that all the practical steps/tasks found for the leakage detection methods are appropriate to train trainees; and suited to be included in refrigeration and air-conditioning leak detection module for VTE schools. The findings agreed with VTECH (2010) that confirmed methods of leak testing to be electronic detector, and soap solution tracer. Again, UNEP (2010) confirmed use of electronic, and bubble method for testing leak. Also, British Refrigeration Association (2010) recommended electronic leak detector, ultraviolet indicator fluid and use of soap solution as practical methods for leaking testing.

IMPLICATION TO RESEARCH AND PRACTICE

The implication of this study is that the developed module, if utilize in Technical Colleges and Polytechnics by trainers or instructors of refrigeration and air-conditioning for practical teaching, trainee's or student's capacity development in refrigeration and air-conditioning course will be enhanced. Also, the package satisfies the purpose of instructional aid that will guide students' skills acquisition in leak detection in refrigeration and air-conditioning leading to reduction in emission of ozone layer depleting refrigerant to the atmosphere.

CONCLUSION/ RECOMMENDATION

The study described methods of development of module for effective practical training in leak detection in refrigeration and air-conditioning practices. In addition, the research revealed that the development of module in refrigeration and air-conditioning can contribute to effective training and mastery of skills among the trainees.

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Therefore, this study recommends that this learning package (module) should be used in vocational and technical education institutions for training of students in the areas of leak detection in refrigeration and air-conditioning. With the adoption of this module, students will learn at their individual pace and mastery of skills that will prevent emission of ozone depleting refrigerants into the atmosphere will be guaranteed. Again, the study suggests that VTE schools should train all teaching staff in the area of refrigeration and air-conditioning within the institution to acquire skills in development, and use of modules in teaching. This will enhance employability skills acquisition among the trained students.

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APPENDIX 1

DEVELOPED MODULE FOR DELIVERY OF LEAK DETECTION IN REFRIGERATION AND AIR-CONDITIONING

Introduction

Good maintenance of refrigeration and air-conditioning requires that minimization of emission of refrigerants into the atmosphere is carried out through regular inspection of the piping system and joints with the aid of leak detectors. When a system is suspected to have leakage, the whole system should be checked; and when the leaking spot is found, the spot is marked for repair and recharged. It is not recommended by good environmental practice to add refrigerant without first locating leaking spot and repairing leakage.

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Specific Objectives

At the end of the training, trainee should be able to:

1. Identify causes of leakage
2. Identify types of leakage
3. Select equipment for carrying out leak detection
4. Carry out different methods of leak detection

Leak Detection Content

1. Causes of leakage
2. Types of leakage
3. Mixing of soap solution
4. Soap swap at piping's joints
5. Mirror view of swap joints
6. Starting electronic leak detector
7. Probing of joints with detector
8. Leak identification through light and sound
9. Dye injection for leak detection
10. Ultra violet light for leak detection
11. Symptoms for leak through light glow
12. Halide leak detector for detection.
13. Lighting of halide torch
14. Operation of halide torch to identify leakage
15. Symptoms of leakage with color of flame
16. Nitrogen charge for leak detection.

Training Equipment/Facilities

1. Instructional guide
2. Soap
3. Clean water
4. Container
5. Mirror
6. Electronic leak detector
7. Ultraviolet lamp
8. Dye
9. Halide torch
10. Workman glove
11. Refrigerators
12. Air-conditioners
13. Nitrogen set
14. Manifold gauge
15. Vacuum pump
16. Service hose.

Instructional Strategies

1. Demonstrate skills through depicting procedural task outlined in the particular module on the expected skills then allow trainee to practice.
2. Create experimental conditions relating to the expected skills and allow trainee to analyze the result and relate it to real situation.

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3. Use guided discussion with active participation of trainee to narrate specific skill on the module to allow trainee to practice.
4. Create small groups, give project on problems relating to stated skills on module and supervise trainee on steps to achieve result.

Evaluation Techniques

1. Laboratory tests
2. Short answer questions
3. Systematic testing
4. Task-oriented test
5. Scenario tests technique
6. Problems/Computational tests assessment method
7. Matching questions test technique
8. Project assignments
9. Practical project technique
10. Projects technique

PRACTICAL SESSION

Practical Methods and Sequential Tasks/steps for Leak Detection Methods

Steps (a) Manual Leak Detection Method

1. Inspect oil residues round the system for signs of leakage.
2. Ensure there is pressure in the system
3. Collect small quantity of soap either powered, tablet or liquid
4. Pour small quantity of water into a container
5. Form soap and water solution
6. Swap soap solution at piping joints with brush
7. Use mirror to view swap joints for symptoms of leakage.

Steps (b) Electronic Leak Detection Method

1. Start electronic leak detector by turning on the start button
2. Allow detectors to warm up for one minute
3. Probe joints with detector by slowly run sensing tip closely around suspected areas
4. Identify symptoms of leakages by adjusting sensitivity knob
5. Symptom of leakage is given by increase tickling noise.

Steps (c) Dye Injection Leak Detection Method

1. Connect dye can at the low side through manifold gauge.
2. Open dye's can to release content into the system and start system
3. Identify symptom of leakage by viewing dye color appearance at leaking spot after few minutes of system operating.

Steps (d) Halide Leak Detector Method

1. Light torch and allow copper plate to heat up
2. Hold detector upright
3. Slowly pass the hose around all suspected areas
4. Identify symptom of leakage with small greenish trait flame indicate small leak.
5. A bright blue flames indicates large leak
6. Close propane valve after check.

Steps (e) Nitrogen Change Method

1. Connect Nitrogen gauge
2. Connect Nitrogen to system through high pressure gauge

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3. Gently open nitrogen; allow (30 to 100 psi) pressure
4. Close valves and observe per one hour for pressure drop.
5. If no pressure drops; gently increase pressure to 170 psi.

Note: Do not release excess pressure to avoid explosion. It is used with only Halogenated refrigerant.

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