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Development of Competency Instrument for HVAC Maintenance Technical Executor of Oil and Gas Industry in Malaysia

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ABSTRACT

Heating, ventilating, and air-conditioning (HVAC) are critical mechanical systems maintained in the oil and gas (O&G) industry. However, there are no guidelines to define and measure the competencies of the personnel who execute HVAC maintenance in the O&G industry in Malaysia. The research objective is to develop a competency instrument for HVAC maintenance technical executors in the O&G industry in Malaysia. A questionnaire survey was designed in the study by using a quantitative approach. The developed instrument has been distributed to 163 respondents using cluster sampling based on four regions. The analysis results through Winstep Software V.3.69.1.11 identified 19 competencies with 119 sub-competencies in technical skill, three competencies with 30 sub-competencies in non-technical skill, and four competencies with 18 sub-competencies in core personality. These competency instruments were pertinent to academic and professional communities based on perspectives from the industry. For practical purposes, the HVAC competency instruments may assist the employees in their career advancement to be competent.

Keywords:
Heating; Ventilating and air-conditioning (HVAC); Oil and gas (O&G) industry; Competency; Skills

1. Introduction

Malaysia is the 14th largest natural gas in the world and the world's 25th largest crude oil reserve [1]. Malaysia's availability of domestic hydrocarbons will become a significant petrochemical exporter in the ASEAN region and a natural boost for oil and gas development (Malaysian Investment Development Authority). The upstream consists of the exploration and production (E&P) of hydrocarbons, which can be either oil, gas, or a combination of the two explained as offshore [38].

The Oil and Gas (O&G) industry is a capital-intensive industry, and the offshore and onshore plants should be with high reliability and availability, as system failure downtime has a significant

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effect on production activity and the degree of safety [2,3]. In the O&G industry, the maintenance strategies tend to be the same as in other heavy industries [4,5]. Even though the high hazards, risks, and safety requirements are associated with processes, and operations in the O&G industries [6]. Hazardous areas have been classified based on the risk of explosion, and safety precautions towards electrical components become a priority and crucial. A hazardous area is an area in which an explosive gas atmosphere is or is obviously to be present in quantities such as to require special precautions for the construction, installation, and use of equipment [7]. Table 1 shows the hazardous classification according to the zone.

Table 1
Hazardous area classification [7]

Hazardous area	Description
Zone 0	An area in which an explosive gas atmosphere is present continuously for a long time or frequently.
Zone 1	An area explosive gas atmosphere is likely to occur periodically or occasionally in standard operation.
Zone 2	Areas of explosive gas atmospheres are unlikely to occur in standard operations. However, if it does happen, it will happen for a short time.

The HVAC system is one of the systems maintained in the O&G industry. HVAC systems are also necessary to supply cool air to the rooms containing sensitive electrical equipment, such as battery rooms, radio equipment rooms, switchgear rooms, and central control rooms. Malfunctions of the sensitivity equipment caused by a hot environment to sensitive electrical equipment can result in an electrical failure and cause the offshore production platform to shut down. The effect of an unexpected shutdown will become huge losses for the O&G industry [8].

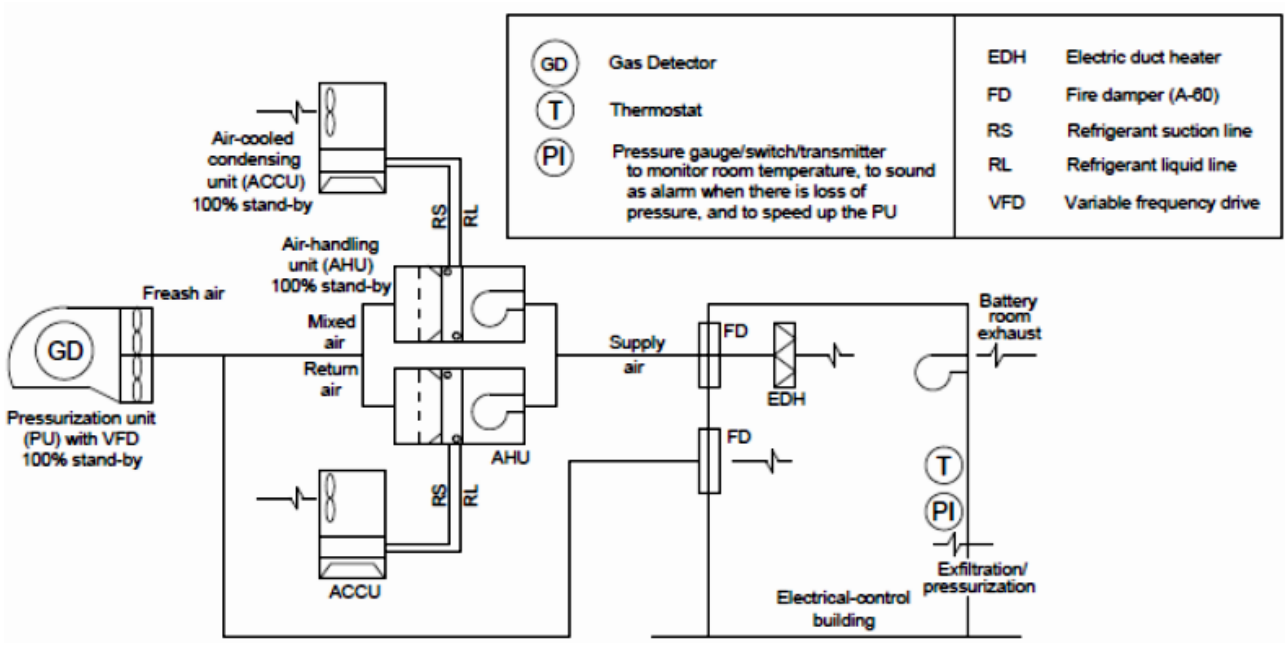

Fig. 1. HVAC schematic diagram in O&G industry [8]

In this research context, the quality of maintenance is related to the competency of the personnel who execute the maintenance tasks. Commonly, all maintenance tasks are accomplished by the executor team consisting of a technical executor, and this team considers a skilled and semiskilled worker. Competence refers to the combination of knowledge, skills, talents, action styles,

personality, principles, interests, and attitudes that an individual needs to have to meet the performance standards required to achieve success job [9-12]. The executor team will lead by a supervisor for HVAC maintenance tasks and communicate the progress of maintenance work to the platform's regular operator. The competence of the executor team is required to verify that HVAC maintenance tasks offshore and onshore can be achieved [13]. The incompetence of the executor team to perform HVAC maintenance tasks may affect the company organization performance. Hence could impact the maintenance cost due to repetitive failure, lack of detection of unwanted failures and mistakes by executors [14].

The O&G industry is an industry that has a crucial correlation with strict safety requirements. Safety management tools such as JHA, Permit to Work (PTW), and risk assessment are to be adapted before any work execution. Any hazard and risk need to be identified, evaluated, and measured based on the work procedure that needs to be performed [15]. PTW consists of the details of work that need to be achieved, safety precautions to be taken, identification of all foreseeable risks and hazards, implementation of control measures, and assurance of leaving the worksite in a safe condition when finishing a job [16]. There are still accidents reported in Malaysian news. A summary of fire and explosion accidents in the O&G industry is shown in Table 2 [17-19].

Table 2
Summary of fire and explosion accident in O&G industry

Location	Year	Cause	Type of work
Bekok C (Terengganu)	2010	Six persons injured	Maintenance
Island of Pulau Enoe, near Labuan	2012	Five persons die	Maintenance
Long Ugui, Lawas	2022	One person dies, two injured	Maintenance

Cost-effective maintenance also depends on the competence of personnel who correctly delivers the maintenance task concerning the schedule and timeline maintenance [20]. Negligence of consideration in manpower competencies in maintenance subsequently leads to repetitive failure, a non-reliable and inefficient system, hence escalating the maintenance cost and safety perspectives, injuries, explosions, and fatalities may occur in the O&G industry [21]. Malaysia government has introduced Malaysia Skill Certification (SKM) competency-based training program to recognize competency in work performance. National Occupational Skill Standards (NOSS) were established by the Department of Skill Development (Ministry of Human Resources) and the Ministry of Education Malaysia to determine the level of employment and critical competency level that need to be fulfilled by industrial employees. NOSS is the primary criterion for the Malaysia Occupational Skills Qualification (MOSQ) certification to determine the level of skills the trainee requires.

Mechanical engineering is one of the sectors listed in the NOSS directory for skill professions and sub-sectors that address HVAC. Table 3 shows the five-level category of MOSQ in the sub-sector of HVAC and the occupational profile for HVAC personnel. Reviewing the NOSS for the HVAC sub-sector, it essentially applied to the conventional building and conventional HVAC system where the O&G industry is different in safety, critical environment, and HVAC system [22]. The global economy relies substantially on the oil and gas (O&G) industry. The supply chain of O&G is complex elements ranging from oil discovery sites to fuel stations. Meanwhile, the midstream segment of O&G is a distribution system that comprises pipelines and tankers to deliver crude oil to petroleum refineries [23]. Therefore, the last stage downstream is onshore and includes refining, marketing, wholesaling, and retailing [24]. These three streams are chain and sequential set activities to ensure that crude oil and gas as raw materials become high-quality products, such as gasoline and natural gas, for international marketing [25]. The O&G sector is part of the global supply chain, encompassing foreign and domestic transport, IT equipment, material processing, export/import services, inventory visibility and control,

and ordering. Therefore, the research objective is to identify the validity and reliability of competency instruments for technical implementers of HVAC maintenance in the O&G industry in Malaysia.

Table 3
Sub-Sector (HVAC)

SECTOR: MECHANICAL ENGINEERING SUB SECTOR: HEATING VENTILATION AIR-CONDITIONING (HVAC)		
L5	ME-020-5 :2012 Heating Ventilation Air Conditioning (HVAC) Design, Installation and Maintenance Management	Engineer
L4	ME-020-4 :2012 Heating Ventilation Air Conditioning (HVAC) Design, Installation and Maintenance Management	Assistant Engineer
	F432-008-3:2021	Service
L3	Heating Ventilation Air Conditioning (HVAC) Installation and Maintenance Supervision	Supervisor
L2	ME-021-2:2012 Heating Ventilation Air Conditioning (HVAC) Three Phase Air Conditioning Equipment Installation, Servicing, Troubleshooting & Repair (Domestic & Commercial)	Service Technician
L1	No level	

2. Methodology

A questionnaire survey was designed in the study using a quantitative approach. This study focuses on the pointed service provider in HVAC maintenance in the O&G industry in Malaysia. The developed instrument has been distributed to 158 respondents using cluster sampling based on four regions as shown in Table 4.

Table 4
Respondents' demographic profile

Demographic	Criteria	Frequency	Percentage (%)
Gender	Male	158	100%
	Female	0	0
Race	Malay	116	73.4 %
	Bumiputera Sabah	15	9.5 %
	Bumiputera Sarawak	27	17.1 %
Education	Diploma	44	27.8 %
	Certificate	114	72.2 %
Working Experience	0-5 years	64	40.5 %
	6-10 years	63	39.9 %
	11-15 years	17	10.7 %
	> 15 years	14	8.9 %
Position	Junior Technician	68	43.0 %
	Senior Technician	51	23.3 %
	Supervisor	39	24.7 %

In conducting research, ethical standards carried on by the researcher during the selection of participants, data collection, data analysis, and reporting study [26]. Respondents were informed about the purpose of the research. Rasch measurement model analyses the instrument questionnaire using Winsteps software V.3.69.1.11 to test the reliability and validity of items. In this research, the items of the competency instrument were developed using the Delphi method to explore the competencies and sub-competencies of the HVAC instrument. This research used Rasch measurement model analysis because the Rasch model is a significant analysis tool to confirm the

instrument development's usability [27,28]. The HVAC instrument also has been reviewed by two TVET educators and accepted for the develop a competency instrument for HVAC maintenance. The instrument consists of three constructs, namely: technical skills (115 items), non-technical skills (30 items), and core personality (18 items).

Table 5
Research instrument

Technical Skills	
I. Safety, Health and Environment	
Carry out potential risk and hazard assessment (SHE1)	Understanding operation and implications of the fire and gas control systems (SHE6)
Use personal protection equipment (SHE2)	Actions in the event of critical and emergency situations (SHE7)
Apply Environmental Legislation, Working Practices and Principles (SHE3)	Carry out safety briefing / toolbox meeting (SHE8)
Carry out Safe Electrical Working Practices on Electrical Control (SHE4)	Apply company safety policy (SHE9)
Identify hazardous area, control/minimise hazard, and reduce risks to as low as reasonably practicable (SHE5)	Apply safety rules and regulation as stated in permit to work (PTW) (SHE10)
Understanding operation and implications of the emergency shutdown (ESD) control systems (SHE6)	
II. Heating	
Maintain three phase heating equipment motor (HT1)	Maintain filter system (HT4)
Maintain three phase heating equipment heat pump/heat recovery system (HT2)	Record three phase heating equipment maintenance activities (HT5)
Maintain heating piping system (HT3)	
III. Tools and Equipment	
Use general loading and lifting equipment (TE1)	Perform refrigeration copper tubing work (TE5)
Apply basic bench fitting techniques and use small typical hand tools (TE2)	Select, use, and care for engineering marking-out equipment (TE6)
Use air conditioning and refrigeration instrument tools (TE3)	Join metals using torch brazing and soldering (TE7)
Use typical electrical meters (TE4)	
Technical Skills	
IV. Roof Top Package Unit	
Identify the capacity and tag number of roof top package unit (RTPU1)	Pre-commissioning Roof Top Package Unit (RTPU5)
Perform roof top package unit servicing (RTPU2)	Perform basic installation of condensate drainpipes (RTPU6)
Inspect roof top package unit troubleshooting (RTPU3)	Pre-commissioning air cooled split unit (RTPU7)
Perform roof top package unit repair (RTPU4)	
V. Water Cooled Package Unit	
Identify the capacity and tag number of water-cooled package unit (WCPU1)	Perform water cooled package unit repair (WCPU4)
Perform water cooled package unit servicing (WCPU2)	Pre-commissioning Water Cooled Package Unit (WCPU5)
Inspect water cooled package unit troubleshooting (WCPU3)	
VI. Water- or Air-Cooled Chiller	
Identify the capacity and tag number of water cooled or air-cooled chiller (<100 TR) unit (WACC1)	Repair and maintain reciprocating chiller (WACC4)
Perform water cooled or air-cooled chiller (<100 TR) servicing (WACC2)	Repair and maintain centrifugal chiller (WACC5)

Inspect Small Package-Water Cooled or Air-Cooled Chiller (<100 TR) unit troubleshooting and repair (WACC3)	Repair and maintain screw-type chiller (WACC6)
VII. Air Handling Unit (AHU)	
Identify the capacity and tag number of air handling unit (AHU1)	Inspect air handling unit troubleshooting (AHU3)
Perform air handling unit servicing (AHU2)	Perform air handling unit repair (AHU5)
VIII. Ventilation Fan	
Identify types of ventilation fan (VF1)	Inspect ventilation fan troubleshooting (VF4)
Determine ventilation fan is properly install (VF2)	Pre-commissioning ventilation fan (VF5)
Perform ventilation fan servicing (VF3)	Perform ventilation fan repairing (VF6)
IX. Air Cooled Split Unit	
Identify types of air-cooled split unit (ACSU1)	Safe handling refrigerant (ACSU7)
Perform air cooled split unit servicing (ACSU2)	Apply the knowledge of refrigerants, secondary refrigerants and refrigerant oil (ACSU8)
Inspect air cooled split unit troubleshooting (ACSU3)	Perform refrigerant recovery for the specific service (ACSU9)
Perform air cooled split unit installation (ACSU4)	Demonstrate knowledge of ozone and how it relates to the refrigeration and air conditioning industry (ACSU10)
Perform air cooled split unit repair (ACSU5)	Demonstrate knowledge of refrigeration and air conditioning principles and applications (ACSU11)
Assemble piping air cooled split unit (ACSU6)	
X. Window Unit	
Perform window unit installation (WU1)	Perform window unit troubleshooting (WU3)
Perform window unit servicing (WU2)	Perform window unit repairing (WU4)
XI. Refrigeration System	
Perform servicing of refrigerators, freezers and display coolers (RS1)	Perform repair of refrigeration system (RS4)
Perform repair of refrigerators, freezers and display coolers (RS2)	Apply the knowledge of refrigeration system of cold storage (RS5)
Perform service of refrigeration system (RS3)	Install refrigeration system (RS6)
Technical Skills (Cont.)	
XII. Piping and Ducting System	
Assemble piping for air-conditioning and refrigeration engineering (PD1)	Perform balancing air and commissioning piping and ducting system (PD4)
Install pipework and ducting for HVAC systems (PD2)	Air Flow and Room pressure understanding (PD5)
Install external insulation to pipework and ducting for HVAC system (PD3)	Ducting fabrication and installation (PD6)
XIII. Water Pump	
Identify the types, capacity and tag number of water pump unit (WP1_	Inspect water pump unit troubleshooting (WP3)
Perform water pump unit servicing (WP2)	Perform water pump unit repair (WP4)
XIV. Cooling Tower	
Identify the types, capacity and tag number of cooling tower (CT1)	Inspect cooling tower troubleshooting (CT3)
Perform cooling tower servicing (CT2)	Perform cooling tower repair (CT4)
XV. Refrigeration Handling	
Perform types of system approach identification (RH1)	Perform refrigerant recovery for the specific service (RH4)
Safe handling refrigerant (RH2)	Demonstrate knowledge of ozone and how it relates to the refrigeration and air conditioning industry (RH5)
Apply the knowledge of refrigerants, secondary refrigerants and refrigerant oil (RH3)	Demonstrate knowledge of refrigeration and air conditioning principles and applications (RH6)

XVI. Electrical Component	
Perform basic wiring up of electrical control circuit of air-handling units (EC1)	Perform electrical and mechanical installation and testing according to the drawings and specifications of electrical devices and wiring (EC8)
Perform basic wiring of electric motor starting circuits for air-conditioning and refrigeration (EC2)	Repair and maintain electrical control system of central air-conditioning systems (EC9)
Wire up electrical control circuit of a fan coil unit (EC3)	Cable sizing and selection by voltage drop
Wire up pressure control and pump down control circuits of refrigeration system (EC4)	Protection devices and sizing (MCB, MCCB and over current) (EC10)
Perform basic repair of electric motors for air-conditioning and refrigeration (EC5)	Type of load control panel used (D.O.L, Auto trans, star delta, soft starter and variable speed drive) (EC11)
Perform basic testing of electrical wiring for air-conditioning and refrigeration (EC6)	Drawing and symbols for HVACR electrical (EC12)
Wire up and repair electrical control components and starting circuits for air-conditioning and refrigeration (EC7)	Troubleshooting HVAC Panel (EC13)
XVII. Equipment Explosion Atmosphere	
Understanding of the general principles of explosion protection (EEA1)	Understanding of certification and relevant parts of this standard (EEA4)
Understanding of the general principles of types of protection and marking (EEA2)	Comprehensive understanding of the selection and erection requirements (EEA5)
Understanding of those aspects of equipment design which affect the protection concept (EEA3)	General understanding of the repair and reclamation requirements (EEA6)
XVIII. Instrument Component	
Understanding instrument function in HVAC system (IC1)	Calibration Instrument system (IC3)
Troubleshooting instrument system (IC2)	Repair HVAC instrument system (IC4)
XIX. Indoor Environment	
Understanding basic indoor air quality and indoor environment requirement (IE1)	Identify indoor air quality and indoor environment problem (IE3)
Understanding basic of thermal comfort (IE2)	Observe thermal comfort and requirement (IE4)
Non-technical Skills	
I. Basic Fundamental	
Using numbers (Mathematics) (BF1)	Write all kinds of electrical and mechanical engineering reports in English (BF4)
Using technology (computer) (BF2)	Understanding basic refrigeration component and accessories (BF5)
Draw simple air-conditioning and refrigeration engineering drawings (BF3)	
II. Engineering Skill Set	
Communication skill (ESS1)	Management (ES7)
Teamwork (ESS2)	Technology Skill (ES8)
Lifelong learning (ESS3)	Thinking Skill (ES9)
Problem Solving Skill (ESS4)	Teaches others new skill (ES10)
Ethics and professionalism (ES5)	Serves client/customer (ES11)
handling co-worker (ES6)	
III. Industrial Revolution 4.0 (IR 4.0)	
Analytical thinking and innovation (IR1)	Negotiation skill (IR8)
Active learning and learning strategies (IR2)	Coordination and time management (IR9)
Creativity, originality and initiative (IR3)	Attention to detail and trustworthiness (IR10)
Critical thinking and analysis (IR4)	Judgment and decision making (IR11)
Leadership and social influence (IR5)	Service orientation (IR12)
Reasoning, problem solving and ideation (IR6)	Cognitive flexibility (IR13)
System analysis and evaluation (IR7)	Collaboration skill (IR14)
Core personality	

I. Physical State	
Physical fitness (PS1)	Practice Sports (PS3)
Regular exercise (PS2)	Balanced diet (PS4)
II. Personal Quality	
Openness (PQ1)	Agreeableness (PQ4)
Neuroticism (emotional stability) (PQ3)	Self-efficacy (PQ5)
Extrovert (PQ3)	Conscientiousness (PQ7)
III. Self-concept	
Attitude (SC1)	Discipline (SC4)
Meticulous (SC2)	Values (SC5)
Compliance (SC3)	
IV. Motives	
Sense of worth (M1)	Relationship management (M3)
Achievement motivation (M2)	

3. Results

3.1 Person and Item Reliability and Separation Index

For instrument testing (refer Table 6), the person reliability value was 0.98 with a person separation index of 6.68. The person separation index demonstrated seven (7) levels of a person's ability. In addition, the item reliability value for the instrument was 0.94, indicating that the item has a consistent reliability. This finding revealed the item separation index of 4.02 and categorised into four (4) groups of item ability.

Table 6
Person and item reliability and separation index for instrument

Person	158 Input		158 Measured		Infit		Outfit	
	Score	Count	Measure	Error	MNSQ	ZSTD	MNSQ	ZSTD
Mean	667.3	163.0	1.39	0.16	1.18	0.5	1.07	0.0
S.D	84.4	0.0	1.31	0.11	0.53	3.7	0.43	3.4
Real RMSE	0.19	True SD	1.29	Separation	6.68	Person Reliability		0.98
Item	163 Input		163 Measured		Infit		Outfit	
Mean	373.4	158.0	0.00	0.13	1.00	-0.3	1.07	-0.1
S.D	100.2	0.0	0.53	0.02	0.39	2.6	0.82	2.5
Real RMSE	0.13	True SD	0.52	Separation	4.02	Item Reliability		0.94

Table 7 shows the values of item and person reliability and separation index obtained for each construct in the instrument. This finding showed that the constructs were accepted as the item reliability values for technical skills (0.94), non-technical skills (0.93), and core personality (0.94) were higher than 0.8. Meanwhile, the item separation index for technical skills (3.93), non-technical skills (3.70), and core personality (3.81) as well as the items in the instrument were categorised into four (4) groups of item ability. It was also discovered that the values of person reliability and separation index obtained for technical skills (0.98 & 7.47), non-technical skills (0.91 & 3.19) and core personality (0.85 & 2.38) constructs were greater than 0.80 and 2, respectively.

Table 7
Item and person reliability and separation index for each construct in instrument

No	Constructs	Items	Item		Person	
			Reliability	Separation index	Reliability	Separation index
1	Technical Skill	115	0.94	3.93	0.98	7.47
2	Non-technical Skill	30	0.93	3.70	0.91	3.19
3	Core Personality	18	0.94	3.81	0.85	2.38

3.2 Item Polarity

All items in technical skill construct (Table 8) showed positive polarity at Point measure Correlation, meaning that the items were parallel with the measured constructs. No items were dropped based on polarity requirement as the items moved in one direction with the constructs.

Table 8
Polarity of technical skill construct for instrument testing

ENTRY NUMBER	TOTAL SCORE	COUNT	MEASURE	MODEL S.E	PT-MEASURE CORR.	PT-MEASURE EXP.	ITEM
1	717	158	-0.23	0.17	0.47	0.53	SHE1
16	652	158	-0.18	0.15	0.54	0.64	HT5
7	684	158	0.42	0.16	0.49	0.59	SHE7
BETTER FITTING OMITTED				+			
112	632	158	0.48	0.13	0.68	0.65	IE1
6	709	158	-1.31	0.16	0.58	0.54	SHE6
27	679	158	0.64	0.16	0.67	0.60	MV4
42	670	158	-0.42	0.15	0.70	0.61	RTPU5

Similarly, all items in non-technical skill (Table 9) and core personality (Table 10) constructs also showed positive polarity. Therefore, no items in both constructs were dropped based on polarity requirement.

Table 9
Polarity of non-technical skill construct

ENTRY NUMBER	TOTAL SCORE	COUNT	MEASURE	MODEL S.E	PT-MEASURE CORR.	PT-MEASURE EXP.	ITEM
11	581	158	0.97	0.13	0.66	0.76	ESS6
16	633	158	0.90	0.13	0.67	0.71	ESS11
18	646	158	-0.44	0.14	0.64	0.70	IR2
27	570	158	2.04	0.14	0.71	0.76	IR11
9	664	158	0.11	0.16	0.63	0.68	ESS4
7	698	158	-0.65	0.16	0.69	0.63	ESS2
14	698	158	-0.65	0.16	0.69	0.63	ESS9
21	698	158	-0.65	0.16	0.69	0.63	IR5
22	698	158	-0.65	0.16	0.69	0.63	IR6

Table 10
Polarity of core personality construct

ENTRY NUMBER	TOTAL SCORE	COUNT	MEASURE	MODEL S.E	PT-MEASURE CORR.	PT-MEASURE EXP.	ITEM
13	612	158	0.64	0.14	0.69	0.77	SC3
10	698	158	-1.05	0.16	0.64	0.68	PQ6
7	632	158	-0.27	0.14	0.73	0.76	PQ3
6	674	158	-0.27	0.16	0.71	0.72	PQ2
18	632	158	0.86	0.14	0.79	0.76	M3
2	702	158	-0.69	0.16	0.72	0.69	PS2
17	702	158	-0.69	0.16	0.72	0.69	M2
16	708	158	-0.79	0.17	0.73	0.68	M1

3.3 Fit Statistics

The value of infit MNSQ and outfit MNSQ for polytomous data should be in the range of 0.6 to 1.4 [33]. Table 11 shows the values of infit MNSQ and outfit MNSQ for each item in the technical skill construct. The analysis found that 115 items were in the range of 0.6 to 1.4. Therefore, no items in technical skill construct were dropped from the list of the questionnaire.

Table 11
Item fit for technical skill constructs

ENTRY NUMBER	TOTAL SCORE	COUNT	MEASURE	MODEL S.E	INFIT MNSQ	ZSTD	OUTFIT MNSQ	ZSTD	ITEM
1	717	158	-0.23	0.17	1.16	1.3	1.37	1.9	SHE1
16	652	158	-0.18	0.15	1.37	3.0	1.37	3.0	HT5
7	684	158	0.42	0.16	1.33	2.8	1.34	2.6	SHE7
18	684	158	0.42	0.16	1.33	2.8	1.34	2.6	TE2
86	624	158	0.52	0.13	1.22	1.9	1.34	2.6	PD5
BETTER FITTING OMITTED				+		+		+	
112	632	158	0.48	0.13	0.79	-1.9	0.98	-0.2	IE1
13	674	158	0.46	0.15	0.89	-1.0	0.79	-1.8	HT2
29	674	158	0.46	0.15	0.89	-1.0	0.79	-1.8	MV6
6	709	158	-1.31	0.16	0.75	-1.8	0.75	-1.6	SHE6
27	679	158	0.64	0.16	0.72	-2.8	0.68	-3.0	MV4
42	670	158	-0.42	0.15	0.69	-12.9	0.67	-3.1	RTPU5

Table 12 shows the values of infit MNSQ and outfit MNSQ for each item in non-technical skill construct and revealed that 30 items were in the range of 0.6 to 1.4. Therefore, no items in the non-technical skill construct were dropped from the list of the questionnaire.

Table 12
Item fit for non-technical skill constructs

ENTRY NUMBER	TOTAL SCORE	COUNT	MEASURE	MODEL S.E	INFIT MNSQ	ZSTD	OUTFIT MNSQ	ZSTD	ITEM
11	581	158	0.97	0.13	1.37	2.5	1.37	2.8	ESS6
16	633	158	0.90	0.13	1.21	1.7	1.27	2.0	ESS11
18	646	158	-0.44	0.14	1.27	2.2	1.20	1.6	IR2
27	570	158	2.04	0.14	1.25	2.1	1.27	2.2	IR11
14	698	158	-0.65	0.16	0.68	-2.3	0.64	-2.3	ESS9
21	698	158	-0.65	0.16	0.68	-2.3	0.64	-2.3	IR5
22	698	158	-0.65	0.16	0.68	-2.3	0.64	-2.3	IR6

In addition, all items in the core personality construct, as tabulated in Table 13, were dropped from the list of the questionnaire. Eighteen (18) items in the core personality constructs have the values of infit MNSQ and outfit MNSQ in the range of 0.6 to 1.4.

Table 13
Item fit for core personality constructs

ENTRY NUMBER	TOTAL SCORE	COUNT	MEASURE	MODEL S.E	INFIT MNSQ	ZSTD	OUTFIT MNSQ	ZSTD	ITEM
13	612	158	0.64	0.14	1.26	2.2	1.35	2.6	SC3
10	698	158	-1.05	0.16	1.03	0.3	1.34	1.7	PQ6
7	632	158	-0.27	0.14	1.15	1.2	1.21	1.5	PQ3
6	674	158	-0.27	0.16	1.03	0.3	1.19	1.4	PQ2

2	702	158	-0.69	0.16	0.82	-1.5	0.75	-1.3	PS2
17	702	158	-0.69	0.16	0.82	-1.5	0.75	-1.3	M2
16	708	158	-0.79	0.17	0.74	-2.1	0.66	-1.7	M1

3.4 Standardized Residual Correlation

In terms of the largest standardized residual correlation, Table 14 shows none of the items in the instrument has a correlation value above 0.7, therefore they items did not overlap with other items, and the items did not have the same characteristics with each other.

Table 14
Standardized residual correlations for instrument testing

Corr. Value	Item	
0.69	ACSU2	ACSU3
0.68	EC11	EC12
0.67	EC1	EC2
0.66	RS4	RS6
0.66	EC2	EC3
0.66	BF3	IR13
0.65	IE1	IE2
0.65	WP3	WP4
0.64	WACC2	WACC4
0.62	EEA1	EEA2

Based on Table 15, the validity and reliability report for instrument showed that no items should be dropped from the list of the questionnaire of study.

Table 15
Summary of finalized items for instrument

No.	Construct	Total Original Item	Dropped Item	Total Dropped Item	Total Maintained Item
1	Technical Skill	115	None	-	115
2	Non-technical Skill	30	None	-	30
3	Core Personality	18	None	-	18
		163		-	163

4. Discussions

Technical executors of HVAC maintenance in the O&G industry must be knowledgeable in hazardous area classifications, explosion-proof HVAC systems, and specific criteria for HVAC maintenance. With such knowledge, technical executors are better equipped to traverse the complexity of the O&G industry and meet system maintenance requirements within the established regulatory framework. This is supported by [29], where the need for competent employees continues to be perceived and is crucial in the O&G industry. The findings for technical competency are in line with the iceberg theory, where technical skills refer to the visible competency comprising knowledge, skills, abilities, and other attributes [30,31]. Based on item polarity, the technical skills, non-technical skills, and core personality constructs show positive polarity. Thus, the items were parallel with the measured constructs. Based on fit statistics, items in the HVAC instrument have infit MNSQ and outfit MNSQ values in the range of 0.6 to 1.4. In terms of the standardized residual correlation, none of the items has a correlation value above 0.7, hence no items were detected to overlap with other items,

and the items did not have the same characteristics as each other. The analysis result in this research proves that the competency instrument for HVAC maintenance technical executors in the O&G industry in Malaysia consists of 19 competencies with 115 sub-competencies in technical skill, three competencies with 30 sub-competencies in non-technical skill and four competencies with 18 sub-competencies in core personality. Technical skills concentrated on the HVAC system as well as O&G safety culture and explosion-proof understanding. The safety culture is essential as factors are exacerbated in the oil and gas business by hazardous conditions, highly flammable conditions, confined areas, heights, and frequent use of heavy equipment by personnel [32,37]. Regularly, workers in the O&G industry are vulnerable to potentially dangerous situations involving flammable and explosive conditions [33]. Non-technical skills are related to safety behaviour in the O&G industry [34]. IR4.0 and the accompanying digital changes are having an impact on the job landscape. When viewed in the broader context of research on resilience, personality is a master psychological mechanism that organizes mental subsystems, such as motivations, ideas, and self-control [35]. There is a good opportunity that is linked to the relative importance of objective and subjective professional accomplishment criteria [36]. Theoretically, the knowledge extended by the competencies instruments development for HVAC maintenance technical executors in the O&G industry is scarce. This study has contributed to HVAC maintenance technical executors in the O&G industry, TVET instructors, policymakers, HVAC maintenance organizations, and other relevant parties in future research. This study serves both theoretical and practical purposes, hence overcoming existing competency issues in the field of HVAC maintenance in the O&G industry.

5. Conclusions

The novelty of this competency instrument in the context of HVAC maintenance in the O&G industry is among the first empirically developed. These competency instruments were pertinent to academic and professional communities based on perspectives from the industry. For practical purposes, the HVAC competency instruments may assist the employees in their career advancement to be competent. Furthermore, these competency instruments represented the professional technical executors in the O&G industry. The developed HVAC instrument can also be extended to maintenance organizations to identify the lack of competency among their employees and further improve through specific training. The HVAC competency instrument developed is cooperative in measuring the competencies of the exiting executor team and allows management and planning of future employee development interventions, particularly in the training and development area. The HVAC competency instrument may serve as a valuable adjunct to interview sessions during the recruitment process, as it possesses the capability to identify individuals possessing the requisite qualifications as HVAC technical practitioners within the O&G industry.

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