Round Robin Testing Report

Asia EDGE Initiative Air-Conditioning Efficiency Project

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Energy demand in Southeast Asia has increased by more than 80% since 2000, driven by rapid economic growth. Higher appliance efficiency can increase energy security by reducing reliability on energy imports. Energy efficiency policies for room air conditioners (ACs) are particularly important as ACs are a major source of household energy demand and also contribute to peak load demand on hot summer days. The market for room ACs in Southeast Asian countries is expected to grow by at least 10% annually over the next 5 years. Managing demand through energy efficiency is a cost-effective way to limit the need for new power plants while supporting economic development and improved standards of living in rapidly expanding economies.

Testing is a fundamental element in efficiency policy programs helping the government and other stakeholders verify product performance and remove non-compliant products from the market. Requiring product testing by an accredited third-party laboratory prior to market entry prevents non-compliant products from entering the market. Furthermore, testing the products that are already on the market informs monitoring, verification, and enforcement activities under national compliance programs. Test data can provide a snapshot of the performance of air conditioners and other appliances on the market, and can be used to inform enforcement actions to rectify non-compliance.

This project has been implemented under the Asia EDGE Initiative Air Conditioning Efficiency Project, which supports the Lower Mekong partner countries in the implementation of sustainable energy policies to increase energy security. The project builds on the ASEAN Standardization Harmonization Initiative for Energy Efficiency (SHINE) program, which has been adopted by all ten ASEAN energy ministers, and is funded by the United States Department of State via a grant to CLASP.

In Vietnam, to support energy efficiency policy implementation and capacity building of local test facilities, CLASP implemented a structured inter-laboratory comparison exercise using a round robin testing (RRT) methodology. The proficiency testing exercise can help participating laboratories (PLs) to produce more accurate, consistent and reproducible test results for air conditioners. The RRT exercise assessed the laboratories involved in testing activities to strengthen their capacity for energy efficiency policy compliance and enforcement in Vietnam. Following the RRT exercise, the three PLs were provided with detailed reports evaluating their use of the test procedures and any recommendations for improvement.

CLASP implemented the RRT project in collaboration with Centro de Ensayos, Innovación y Servicios (CEIS), which is an independent testing laboratory based in Madrid, Spain, and local partners. A testing expert from CEIS provided technical expertise for RRT planning and design, implementation and reporting. Two local partners, the International Institute for Energy Conservation (IIEC) and an independent institutional advisor, supported coordination on the ground including the procurement and transport of testing samples between the laboratories.

CLASP also collaborated with the Vietnamese Ministry of Science and Technology's Directorate for Standards, Metrology and Quality, as well as with the Ministry of Industry and Trade, and the Bureau of Accreditation, to select the following three laboratories to participate in the RRT exercise:

- *Laboratory for testing energy efficiency, Testing and Verification Center for Industry (TVCI),* part of Vinacomin's Institute of Energy and Mining Mechanical Engineering

- *Quality Assurance and Testing Centre (QUATEST 3)*, under the Directorate for Standards, Metrology and Quality
- *Midea Energy Efficiency Testing Laboratory*, property of Midea Consumer Electric (Vietnam) Co., Ltd

All three laboratories are accredited under ISO 17025:2005 – *General Requirement for the Competence of Testing and Calibration Laboratories* standard requirements and TCVN 6576:2013 - *Non-ducted air conditioners and heat pumps - Testing and rating for performance* to determine AC cooling capacity and efficiency. The TVCI and QUATEST 3 laboratories use a calorimeter room method and Midea laboratory uses an air enthalpy method.

The test results were reported as per the following requirements:

- *TCVN 7830:2015 "Non-ducted air conditioners - Energy efficiency,"* which describes the MEPS for the defined levels of efficiency based on the CSPF.

- *TCVN 6576:2013 (ISO 5151:2010) "Non-ducted air conditioners and heat pumps – Testing and rating for performance,"* which describes the test procedures to determine cooling capacities and energy efficiencies.

- *TCVN 10273-1:2013 (ISO 16358-1:2013) "Air-cooled air conditioners and air-to-air heat pumps. – Testing and calculating methods for seasonal performance factors – Part 1: Cooling seasonal performance factor,"* which describes the test conditions and specifies the calculation method to obtain the CSPF.

Statistical analysis was performed as per:

- *ISO 13528:2015 "Statistical methods for use in proficiency testing by inter-laboratory comparison,"* which describes the calculation algorithms for the data treatment.

Three identical single split Mitsubishi Electric MSZ-HL35VA models were selected, and tested in full and half load conditions by three participating laboratories during the months of July and August 2019. The project team spent two days at each participating laboratory to provide guidance, conduct facility audits and witness testing of one sample – unit under test (UUT). Following the RRT exercise, each laboratory sent the testing data and test reports to the project team for analysis. The data and findings are coded to maintain confidentiality. This report summarizes the RRT exercise findings and recommendations to improve existing testing capacity in Vietnam.

Facility audits were conducted as per ISO 17025:2005 clause 5 - Technical Requirements, focusing on key requirements that can have an impact on the reliability of test results. Key recommendations that are broadly applicable to the facilities include:

- Laboratories should have a plan to periodically calibrate all measurement equipment that impacts the test results. All calibrated instruments should have traceability to SI units.
- After instrument calibration, the laboratory should assess whether its accuracy is in line with specifications and measurement standard requirements. Acceptance criteria are required for the calibration results.

- Based on calibration data, the laboratories should ensure that estimated measurement equipment uncertainties do not exceed the measurement standard and/or internal laboratory requirements. If there are any deviations, the laboratories should adjust the measurement equipment scaling factor and keep records of any adjustments made.

The **witness testing** activity evaluated sample set up for testing, refrigerant unloading and loading, and testing for both full and half load cooling capacities as per the RRT plan. Each participating laboratory was required to recharge the UUT with refrigerant before proceeding with testing. Key findings and recommendations include:

- The technicians should check installation manuals prior to setting up the unit as there can be special set-up requirements including additional refrigerant loading or specific piping length, vacuum, refrigerant loading and unloading procedures.

- If the refrigerant has to be released rather than recovered for future use or recycling, it should be done outdoors to prevent any safety hazard.

- PLs may be able to improve their productivity by increasing the number of tests completed per day or reducing test duration. PLs could optimize their procedures by beginning acclimatization of the laboratory environment in advance of testing to bring the room to thermal equilibrium as per standard requirements.

- The selection of the test sequence for a UUT can have an influence on the time it takes the calorimeter to reach steady state operating conditions. Starting with testing at half load cooling capacity, during which latent capacity is generally zero, can save some testing time.

- If PLs adopted two 9-hour work shifts for the two test steps, two complete cooling capacity tests could be performed every workday, thereby increasing the productivity of the facility.

The RRT test results were evaluated against reference values. This RRT exercise had a small number of participating laboratories, so the conclusions from statistical analysis are not statistically robust. The analysis results, however, offer insight into the performance of the laboratories, explanations for potential deviations in the results, and recommendations to address them. Two main statistical parameters, the reproducibility limit and the Z-score were used for this RRT.

Performance of the three laboratories is considered satisfactory for most of the measured parameters, because the RRT results for these parameters showed only small variations from the assigned values. A small bias was detected in the results of one laboratory, as they were concentrated on one end of the interval. However, this bias was not significant considering the measurement uncertainty of the test methods. The measured capacities of the UUT to lower the temperature (sensible capacity) and remove the moisture from the air (latent capacity) showed the most significant variations for the full load cooling capacity tests. These deviations may be caused by the UUT operational procedures during the test or inaccuracies in some measurement instruments. However, these deviations do not impact the main measured parameters: total cooling capacities, Energy Efficiency Ratio, Cooling Seasonal Performance Factor, and energy efficiency levels. All participating laboratories are encouraged to investigate whether deviations in the sensors are causing the bias identified in this RRT.

The RRT exercise also showed that there is an opportunity to increase the efficiency requirements for ACs in Vietnam to differentiate highly efficient products and support the market for more efficient technologies. Per TCVN 7830:2015 the minimum CSPF value for a 5-star AC unit is 4.20. The unit that was tested in this RRT exercise had a lowest calculated CSPF of 4.68 and is considered a 5-star product. However, more efficient products are available on Vietnam’s and other markets that have EER_{ful} above 4, and EER_{haf} above 6.

This RRT report supports regional harmonization and compliance efforts. Indonesia, Malaysia, the Philippines, Thailand, and Vietnam already have efficiency policies for ACs in place, and have or are in process of harmonizing their performance and testing standards as agreed under ASEAN SHINE. Cambodia, Lao PDR, and Myanmar are in the process of adopting the harmonized test method for ACs and developing their national policies. Adequate testing capacity and competent test facilities support regional compliance efforts under the initiative especially as the ASEAN Center for Energy is currently developing a regional mutual recognition agreement (MRA) for energy efficiency and a product registry. Under the MRA, countries without domestic testing capacity could outsource their testing to laboratories in neighboring countries, which can be more cost-effective than building a facility that would be under-utilized. The RRT exercise and analysis provide evidence of the competence of the three participating test laboratories.

1 Round Robin Testing Introduction and Overview

1.1 Background

Energy demand in Southeast Asia has increased by more than 80% since 2000, driven by rapid economic growth. With energy imports increasing in many countries, governments in the region are looking for ways to reduce their exposure to geopolitical and environmental risks by implementing more secure and sustainable energy policies, according to the International Energy Agency's Southeast Asia Energy Outlook 2019.

Higher appliance efficiency can increase energy security and economic development. Energy efficiency policies for room air conditioners (ACs) are particularly important as ACs are a major source of household energy demand and also contribute to peak load demand on hot summer days. The market for room ACs in Southeast Asian countries is expected to grow by at least 10% annually over the next 5 years. Managing demand through energy efficiency is a cost-effective way to limit the need for new power plants while supporting economic development and improved standards of living in rapidly expanding economies.

This project was implemented under the Asia EDGE Initiative Air Conditioning Efficiency Project, to support the Lower Mekong partner countries in the implementation of sustainable energy policies and increase energy security. The project builds on the ASEAN Standardization Harmonization Initiative for Energy Efficiency (SHINE) program, which has been adopted by all ten ASEAN energy ministers.

In Vietnam, the project has supported energy efficiency policy implementation and enforcement, including capacity building of local test facilities. To achieve this CLASP implemented a structured inter-laboratory comparison (ILC) exercise using a Round Robin Testing (RRT) methodology that can help laboratories produce more accurate, consistent and reproducible test results.

The RRT supports regional harmonization efforts under ASEAN SHINE initiative. Indonesia, Malaysia, the Philippines, Thailand, and Vietnam already have efficiency policy programs for ACs in place, and are harmonizing their performance and testing standards as agreed under ASEAN SHINE. Meanwhile Cambodia, Lao PDR, and Myanmar are in the process of adopting the harmonized test method for ACs and developing their efficiency policy programs.

Adequate testing capacity and competent testing facilities support regional compliance efforts under the initiative especially as the ASEAN Center for Energy is in process of developing a regional mutual recognition agreement (MRA) for energy efficiency and a product registry. Under the MRA the countries without national testing capacities could outsource their testing needs to laboratories in neighboring countries, which can be more cost effective than building a potentially under-utilized facility. By evaluating the laboratories in Vietnam, this RRT exercise provides evidence of their competence and accuracy.

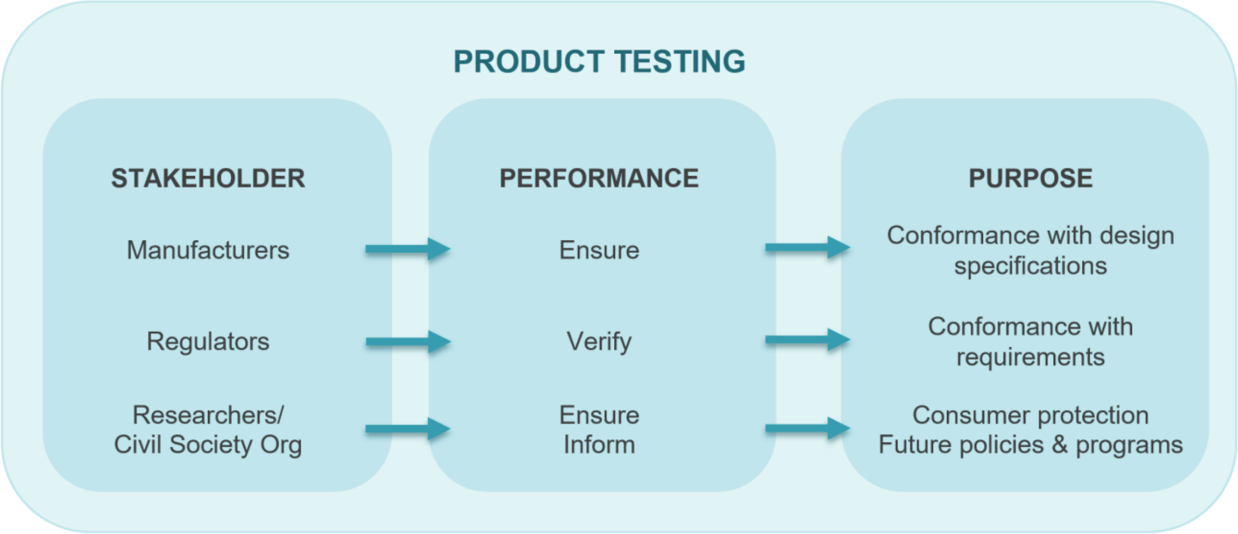
Additionally, the findings and recommendations of this report have broad applicability and can be considered by any laboratory in the region seeking to improve its capabilities and better align its testing processes with the requirements listed in ISO 17025.

This project is funded by the United States Department of State via a grant to CLASP.

1.2 The Role of Testing in Compliance Programs

Testing is a fundamental element in efficiency policy programs, and in transforming markets to more efficient and higher quality products. Tests help governments and other stakeholders verify product performance. Figure 1 summarizes the role and purpose of testing for different stakeholders. Product manufacturers may conduct testing throughout the product development cycle to ensure conformance with design specifications; regulators may require that products be tested at third-party laboratories to ensure conformance with local regulatory requirements; civil society organizations and researchers may conduct testing of new products and technologies to identify market trends, ensure consumer protection, or inform future policies and programs.

Figure 1. Product testing role and purpose.

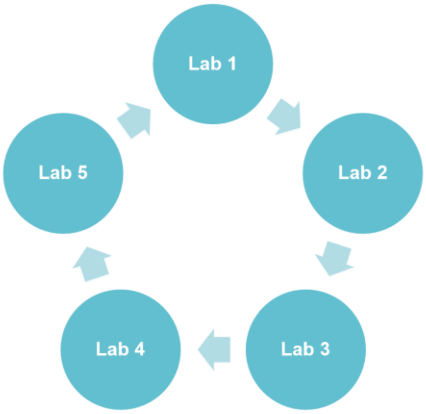


Standardized test methodologies facilitate accurate and reliable assessments of product performance and quality. Following a set of standard metrics, using proper testing facilities and assuring compliance with testing requirements are necessary for establishing and maintaining a meaningful compliance program.

1.3 Proficiency Testing using a Round Robin Testing Approach

Proficiency testing (PT) is used to assess a laboratory's technical capabilities to conduct certain tests and assess their continuing performance. Inter-laboratory comparison such as RRT is commonly used to implement proficiency testing. The round robin testing approach is shown in Figure 2.

Figure 2. Round robin testing approach.



For the RRT, the samples are selected and circulated around participating laboratories so the laboratories test the same samples. Their measurement results are then compared to a reference value, which is usually an average obtained from the participating laboratories[1]. Generally, the organizer determines the measurement parameters and test standard.

1.4 Purpose & Objectives of Round Robin Testing Exercise

The aim of this RRT exercise was to assess the laboratories involved in testing activities and strengthen their capacity for minimum energy performance standard (MEPS) compliance and enforcement in Vietnam.

The objectives of the RRT activity were to:

- Assess and evaluate performance of participating laboratories (PLs) for specific measurements
- Identify procedural and other gaps at individual laboratories and recommend actions for improvement
- Identify inter-laboratory variation in the test results to highlight potentially problematic test procedures

Following the RRT activity, the three PLs were provided with detailed reports on their use of the test procedures and any recommendations for improvement.

1.5 Project Organization & Execution

CLASP lead the RRT project, collaborating with various partners in its implementation. CLASP engaged with Centro de Ensayos, Innovación y Servicios (CEIS), an independent testing laboratory[2]

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[1] The test results may be also compared with those of a reference laboratory that has tested the same samples.

[2] CEIS works in the field of products certification and market control both nationally and internationally. CEIS also provides a wide range of services such as training, quality system assessment, and assessment of providers.

based in Madrid, Spain, to design and implement the RRT exercise. A testing expert (Expert) from CEIS provided technical expertise for RRT planning and design, implementation and reporting. Two local partners, the International Institute for Energy Conservation (IIEC) and an independent institutional advisor, supported coordination on the ground including the procurement and transport of testing samples between the laboratories.

The project team also collaborated with the Vietnamese Ministry of Science and Technology's Directorate for Standards, Metrology and Quality, as well as with the Ministry of Industry and Trade and the Bureau of Accreditation to select the following three laboratories to participate in the RRT exercise:

- *Laboratory for testing energy efficiency, Testing and Verification Center for Industry (TVCI),* part of Vinacomin's Institute of Energy and Mining Mechanical Engineering
- *Quality Assurance and Testing Centre (QUATEST 3)*, under the Directorate for Standards, Metrology and Quality
- *Midea Energy Efficiency Testing Laboratory*, property of Midea Consumer Electric (Vietnam) Co., Ltd

The three laboratories agreed to participate in the RRT activity to obtain expert insight into the strengths and weaknesses of their AC testing implementation. In this report, the individual results of the three participating laboratories are attributed to PL1, PL2 or PL3, and the correspondence of the individual laboratories to these designations is not provided to preserve their confidentiality.

All three laboratories are accredited under ISO 17025:2005 – *General Requirement for the Competence of Testing and Calibration Laboratories* standard requirements and TCVN 6576:2013 - *Non-ducted air conditioners and heat pumps - Testing and rating for performance* to determine AC cooling capacity and efficiency. The TVCI and QUATEST 3 laboratories use a calorimeter room method and Midea laboratory uses an air enthalpy method.

As a first step, the project team gathered information on the laboratories' capacities, competencies and resources through a survey. Collected information included staff technical skills and competence; accommodation and environmental conditions; test and calibration methods and method validation; equipment measurement traceability; handling of test and calibration items; and availability to participate in RRT activity.

The Expert developed the RRT plan drawing on his testing expertise, knowledge of ISO 17025, Vietnam's standards, and information provided by the laboratories. The RRT plan was shared with the laboratories prior to the activity.

Three test samples were selected based on analysis of the PLs' capabilities and a market study of room air conditioners conducted by CLASP. The selected units under test (UUTs) were air-to-air single split units of the same manufacturer and the same model (Table 1. Specifications for three test samples.Table 1, Figure 3), which ensured the test samples were as similar as possible. The full load cooling capacity of the selected samples at T1 conditions was within the range of 3kW to 6kW as per TCVN 6576:2013.

The inverter technology created an additional challenge for the RRT exercise. In addition to conducting sample testing strictly according to the standard, participating laboratories followed a specific set of instructions to operate the sample under designated cooling load conditions.

Table 1. Specifications for three test samples.

Test Facility	S1	S2	S3
Manufacturer	MITSUBISHI Electric Aircon. Systems Asia LTD		
Brand name	Mitsubishi Electric		
OU Model	MSZ-HL35VA		
OU Serial number	7002800 T	7001984 T	7002205 T
IU Model	MUZ-HL35VA		
IU Serial number	7002316 T	7002280T	7002388 T
Rated Voltage	220VAC		
Rated frequency	50 Hz		
Refrigerant type	R410A		
Factory default refrigerant load	0.720 kg		

Figure 3. Selected model and its energy efficiency information.

NHÃN NĂNG LƯỢNG

NHIỀU SAO HƠN - TIẾT KIỆM HƠN

HÃNG SẢN XUẤT: MITSUBISHI ELECTRIC
XUẤT XỨ: THÁI LAN
MÃ SẢN PHẨM: MSZ-HL35VA/MUZ-HL35VA
CÔNG SUẤT: 3,3 kW (11.260 BTU/h)
TIÊU CHUẨN VIỆT NAM: TCVN 7830:2012
HIỆU SUẤT NĂNG LƯỢNG (CSPF): 5,24
SỐ CHỨNG NHẬN: No. 0814094

BỘ CÔNG THƯƠNG
CHƯƠNG TRÌNH MỤC TIÊU QUỐC GIA VỀ SỬ DỤNG NĂNG LƯỢNG TIẾT KIỆM VÀ HIỆU QUẢ

A model with an inverter-type compressor was selected because this technology is most prevalent in Vietnam and globally, replacing traditional and less efficient fixed-speed air conditioners.

CLASP coordinated with local partners for the procurement and transport of test samples between the laboratories. The testing samples were repackaged in the original packaging and then placed in wooden boxes (Figure 4) to ensure safe transport and prevent any damage to them. CLASP worked with the three participating laboratories to develop a schedule for the RRT exercise.

Figure 4. Testing samples prepared for transport.

The project team traveled to Hanoi and Ho Chi Minh City, Vietnam (Figure 5) to provide guidance to the laboratories, conduct facility audits and witness testing in each participating laboratory. Laboratory staff hosted project team for two days at each facility to complete an audit and witness the testing of one AC sample.

Following is the laboratory visitation schedule:

- July 17-18, 2019 – TVCI laboratory, Hanoi, Vietnam
- July 22-23, 2019 – QUATEST 3 laboratory, Ho Chi Minh City, Vietnam
- July 24-25, 2019 – Midea laboratory, Ho Chi Minh City, Vietnam

The roles and responsibilities of the PLs were:

- Test the samples following the protocol outlined in the RRT plan and according to relevant standards
- Allow the RRT coordinator and other CLASP designated personnel to witness the testing of the UUT samples
- Respond to questions raised during the tests or afterwards related to the RRT exercise
- Report data to the RRT coordinator in a timely fashion
- Provide the PL’s own test report, CSPF calculation and energy calculation according to TCVN 6576:2013, TCVN 10273-1:2013, and TCVN 7830:2015
- Package and ship the samples to the next laboratory according to the RRT plan so each laboratory tests all three samples

Figure 5. The location of participating laboratories[3].

The PLs were subject to the following standards for this exercise:

- *TCVN 7830:2015 Non-ducted air conditioners - Energy efficiency* describes the MEPS for the defined levels of efficiency based on the CSPF
- *TCVN 6576:2013 (ISO 5151:2010) Non-ducted air conditioners and heat pumps – Testing and rating for performance* describes the test procedures to determine cooling capacities and energy efficiencies
- *TCVN 10273-1:2013 (ISO 16358-1:2013) Air-cooled air conditioners and air-to-air heat pumps. – Testing and calculating methods for seasonal performance factors – Part 1: Cooling seasonal performance factor* describes the test conditions and specifies the calculation method to obtain the CSPF

Following the RRT exercise, the test expert gathered the test data and reports from each laboratory to evaluate the results and compare them against assigned values. This report includes the summarized findings as well as recommendations to improve the existing capacity in Vietnam to produce more accurate, consistent, and reproducible tests for air conditioners.

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[3] Map source: http://www.vietnam-guide.com/maps/

2 Evaluation of Testing Facilities

2.1 Description of Evaluation Process

The evaluation process was conducted as per ISO 17025:2005 clause 5 - Technical Requirements. In particular, the laboratories were evaluated for compliance with the following sub-clauses of the standard:

- 5.2 Personnel
- 5.3 Accommodation and environmental conditions
- 5.4 Test and calibration methods and method validation
- 5.5 Equipment
- 5.6 Measurement traceability
- 5.8 Handling of test and calibration items
- 5.9 Assuring the quality of test and calibration results
- 5.10 Reporting the results

Due to time constraints, the RRT coordinator mainly focused on key requirements, which are the most relevant aspects that can have an impact on the reliability of the test results provided by the laboratory in the future. These are:

- Personnel competency observed during the witness testing activity and review of the training records
- Comparison of test procedure and testing equipment at the laboratory with the TCVN 6576:2013 standard requirements
- Calibration of measurement instruments and measurement traceability
- Assuring the quality of test results through internal quality management and round robin testing exercise.

The following sections discuss the observations made in reference to ISO 17025:2005 sub-clause 5 and assess the most important deviations[4].

2.2 Audit: Findings & Recommendations

2.2.1 Personnel

At each participating laboratory, one test technician had received training from the test equipment manufacturer. The test technicians showed a good knowledge of the equipment, its usage for testing and basic maintenance. In all laboratories, more than one technician was qualified (allowed) to test appliances or was in training with an experienced test technician.

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[4] Each PL has received separate confidential audit report summarizing the findings and recommendations for their facility.

The complexity of the facilities suggests that newly hired technicians will require training on the facility and test procedures, to be conducted by previously qualified staff.

ISO 17025:2005 sub-clause 5.2.5 requirement: *“The laboratory shall maintain records of the relevant authorization(s), competence, educational and professional qualifications, training, skills and experience of all technical personnel, including contracted personnel. This information shall be readily available and shall include the date on which authorization and/or competence is confirmed.”*

Deviation: There were no records of technician training on the test equipment.

Recommendation: The laboratories should keep records of tests conducted by the technician in training, evaluation of the trainer, and authorization for technician in training to conduct testing once training is complete.

2.2.2 Accommodation & Environmental Conditions

The control rooms in the laboratories were conditioned using an air conditioning unit. Signal conditioning systems, tachometers, wattmeter(s) and computer were located in these rooms. No temperature record was available for evaluating environmental conditions in these control rooms.

ISO 17025:2005 sub-clause 5.3.2 requirement: “*The laboratory shall monitor, control and record environmental conditions as required by the relevant specifications, methods and procedures where they influence the quality of the results*.”

Deviation: Some PLs did not evaluate the impact of the environmental conditions on the measurement equipment.

Recommendation: All measurement equipment is required to operate within a specific temperature range to guarantee its measurement accuracy. The laboratory must evaluate the impact of the environmental conditions on all measurement instruments located in the control rooms. Normally, at least a thermometer should be available in the control room to confirm compliance with air temperature requirements.

2.2.3 Test & Calibration Method & Method Validation

Some evaluated laboratories had no procedures or templates for estimating the measurement uncertainties for the energy efficiency ratio (EER) and the cooling seasonal performance factor (CSPF).

Estimation of uncertainty of measurement - **ISO 17025:2005 sub-clause 5.4.6.2 requirement**: “*Testing laboratories shall have and shall apply procedures for estimating uncertainty of measurement.”*

Deviation: The laboratories did not have a procedure to calculate the uncertainty for the CSPF as per TCVN 10273-1:2013 and the EER as per TCVN 6576:2013.
Related deviation is discussed in section *2.2.8 Reporting Results*.

Recommendation: The laboratories are required to have a procedure for estimating the measurement uncertainties and producing uncertainty estimates for test results.

2.2.4 Equipment

Testing laboratories have comprehensive descriptions of their facilities on file provided by the testing equipment manufacturer.

ISO 17025:2005 sub-clause 5.5.2 requirement: "*Equipment and its software used for testing, calibration and sampling shall be capable of achieving the accuracy required and shall comply with specifications relevant to the tests and/or calibrations concerned. Calibration programs shall be established for key quantities or values of the instruments where these properties have a significant effect on the results. Before being placed into service, equipment (including that used for sampling) shall be calibrated or checked to establish that it meets the laboratory's specification requirements and complies with the relevant standard specification.*"

Deviation: Some laboratories did not check the test facility requirements outlined in Annex A.1 and/or Annex C.3 of TCVN 6576:2013 testing standard.

Recommendation: The RRT coordinator had no major concerns in regards to PLs' abilities to meet key TCVN 6576:2013 standard requirements, but each laboratory should ensure compliance with mandatory requirements for air velocities in the test rooms and distances between the UUT and the wall. The calibration plans at some laboratories did not include all measurement instruments that impact the test results.

Deviation: Not all measurement instruments that have an important impact on the results are included in the calibration plans.

Recommendation: The laboratories should regularly calibrate all instruments that have an impact on the test results.

ISO 17025:2005 sub-clause 5.5.8 requirement: *"Whenever practicable, all equipment under control of the laboratory and requiring calibration shall be labelled, coded or otherwise identified to indicate the status of calibration, including the date when last calibrated and the date or expiration criteria when calibration is due."*

Deviation: Test equipment labels did not include calibration information, or it was not up to date.

Recommendation: All instruments shall have a calibration label clearly stating the instrument identification code, last calibration date, status of the instrument according to calibration results and next calibration date or calibration period.

2.2.5 Measurement Traceability

Some PLs did not have defined acceptance criteria for the measurement instruments for comparing against calibration results. Some laboratories lacked evidence that technicians took steps, based on the calibration reports, to evaluate whether the instruments were measuring as expected.

ISO 17025:2005 sub-clause 5.5.2 requirement: *“Equipment and its software used for testing, calibration and sampling shall be capable of achieving the accuracy required and shall comply with specifications relevant to the tests and/or calibrations concerned.”*

ISO 17025:2005 sub-clause 5.5.5 requirement: *“Records shall be maintained of each item of equipment and its software significant to the tests. The records shall include at least the following:*

> <…>
> *c) Checks that equipment complies with specification (see 5.5.2)*
> *f) dates, results and copies of reports and certificates of all calibrations, adjustments, acceptance criteria, and the due date of next calibration.*
> *<…>”*

<u>Deviation:</u> In some PLs, there was a lack of evidence that the laboratory has defined acceptance criteria for all the measurement instruments for comparing against calibration results.

<u>Recommendations:</u> After each instrument calibration, the laboratory shall assess whether the instrument’s accuracy is in line with specifications and measurement standard requirements. Acceptance criteria are required for the calibration results. TCVN 6576:2013 defines criteria for the allowed measurement uncertainties for the main parameters measured.

Based on the calibration results, it is common to adjust the instruments and/or modify scaling functions for the measured data as an input to the recording and calculating software. This is the only way to guarantee the test equipment measures as intended. . All laboratories shall keep records of all performed adjustments to measurement equipment. Uncertainty results from the calibrations should be used to estimate the uncertainty for the measured cooling capacities.

ISO 17025:2005 sub-clause 5.6.2.1.1 requirement: *“For calibration laboratories, the programme for calibration of equipment shall be designed and operated so as to ensure that calibrations and measurements made by the laboratory are traceable to the International System of Units (SI).”*

ISO 17025:2005 sub-clause 5.6.2.2.1 requirement: *“For testing laboratories, the requirements given in 5.6.2.1.1 apply for measuring and test equipment with measuring functions used, unless it has been established that the associated contribution from the calibration contributes little to the total uncertainty of the test result. When this situation arises, the laboratory shall ensure that the equipment used can provide the uncertainty of measurement needed.”*

Some laboratories had not calibrated critical measurement equipment.

<u>Deviation 1:</u> Some instruments were not included in the calibration plan, and there was no evidence they had been calibrated periodically (see also section 2.2.4).

<u>Deviation 2:</u> Some laboratories do not perform calibration on a specific measurement instrument, but rather conduct indirect checks to assess the operational state of the un-calibrated instrument. These indirect checks may lead to a conclusion that the measurement instrument is operating as expected, but such check cannot guarantee actual accuracy of the measurement instrument nor traceability to SI units.

Recommendation: All measurement equipment that has a significant impact on the test results must be calibrated periodically. This calibration must be traceable to SI units.

2.2.6 Handling of Test & Calibration Items

ISO 17025:2005 sub-clause 5.8.1 requirement: *"The laboratory shall have procedures for the transportation, receipt, handling, protection, storage, retention and/or disposal of test and/or calibration items including all provisions necessary to protect the integrity of the test and calibration item, and to protect the interest of the laboratory and the customer."*

ISO 17025:2005 sub-clause 5.8.4 requirement: *"The laboratory shall have procedures and appropriate facilities for avoiding deterioration, loss or damage to the test or calibration item during storage."*

One of the PLs had a reference sample (RS) that had been used for quality follow-up tests. The RS was stored in a room with other test samples. It was unboxed and exposed to ambient dust. During the audit, the RS had an electrical failure due to wrong voltage supply and was awaiting repair.

Deviation: The way the laboratory has stored RS cannot guarantee its integrity nor prevent it from deteriorating.

Recommendation: As the RS is intended for long-term, periodic testing, protecting it from environmental impacts and using an appropriate handling procedure are necessary to guarantee its long-term stability. Any damage to the coils or long-term exposure to dust may affect the capacity and efficiency of the RS and, thus, affect the validity and conclusions from quality follow-up test results.

2.2.7 Assuring the Quality of Test & Calibration Results

ISO 17025:2005 sub-clause 5.9.1 requirement: *"The laboratory shall have quality control procedures for monitoring the validity of tests and calibrations undertaken. <….> This monitoring shall be planned and reviewed <…>."*

ISO 17025:2005 sub-clause 5.9.2 requirement: *"Quality control data shall be analyzed and, where they are found to be outside pre-defined criteria, planned action shall be taken to correct the problem and to prevent incorrect results from being reported."*

All PLs have participated in some crosscheck activities such as testing a reference test sample between two laboratories. One PL had no evidence that they have procedures to ensure that the results of those activities are reviewed and appropriately addressed.

Deviation: One PL did not have quality control procedures in place to analyze the results of crosscheck tests.

Recommendation: Laboratories must have a procedure as per ISO 17025 sub-clause 5.9.1. There should be a plan for monitoring activities, which should include guidance for reviewing results against acceptance criteria and an action plan to address any deviations.

2.2.8 Reporting Results

ISO 17025:2005 sub-clause 5.10.1 General:
<…>
In the case of tests or calibrations performed for internal customers, or in case of a written agreement with the customer, the results may be reported in a simplified way. Any information listed in 5.10.2 to 5.10.4 which is not reported to the customer shall be readily available in the laboratory which carried out the tests and/or calibrations.
<…>

5.10.3.1 In addition to the requirements listed in 5.10.2, test reports shall, where necessary for the interpretation of the test results, include the following:
<..>

> *c) where applicable, a statement on the estimated uncertainty of measurement; information on uncertainty is needed in the test reports when it is relevant to the validity or application of the test results, when a customer's instruction so requires, or when the uncertainty affects compliance to a specification limit;*
> <..>

Deviation: As discussed in section *2.2.3 Test & Calibration Method & Method Validation*, some PLs did not have procedures nor templates to calculate uncertainties for main measured parameters. The PLs that had such procedures performed these calculations only when requested by the customer.

Recommendation: It is not mandated to include the uncertainties in the test report, but laboratories must calculate them for all cooling capacity tests and have them readily available. Apart from being a requirement under ISO 17025, uncertainty measurements provide useful information to evaluate the continuous performance of testing facilities. For example, when low-capacity equipment is tested, the uncertainty increases significantly. Knowing this may prevent testing beyond the laboratory's reasonable cooling capacity limits.

2.3 Witness Testing: Findings & Recommendations

This chapter summarizes the observations and deviations from witness as per the schedule in Appendix A.

The model tested was a Mitsubishi split-type air conditioning unit:

- Indoor unit model: MSZ HL35VA 7002280T
- Outdoor unit model: MUZ-HL35VA 7001984T

See Table 1 for more details on the UUTs and Figure 6 for unit set up.

The witness testing activity evaluated refrigerant unloading and loading, and testing for both full- and half-load cooling capacities as described in the RRT plan. Each participating laboratory was required to recharge the UUT with refrigerant[5] once, before proceeding with testing.

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[5] Each laboratory used the same type of refrigerant provided by the same refrigerant manufacturer.

Figure 6. Indoor and outdoor unit set up at one of participating laboratories.

2.3.1 Activity: Refrigerant Unloading

Before proceeding with the test set-up of the UUTs, the technicians at some PLs removed the refrigerant from the UUT by putting one end of the manifold flexible pipe into a water bucket. They then used the same manifold flexible pipe to vacuum the appliance and load refrigerant into it. In one case, the technician released the refrigerant in the laboratory, inside the “outdoor test room.”

Comment: Putting the pipe into water and using it afterwards to load refrigerant into the unit poses a risk of water or humidity getting into the UUT during the refrigerant loading process. R410A is highly hygroscopic and even a little humidity in the refrigerant circuit will negatively affect the product performance and/or lifetime. The unit runs for only a few hours during the test so no impact on the test results would be anticipated, but following that procedure on a customer unit can lead to reduced appliance service time.

Safety risk: The refrigerant should never be released in enclosed spaces. Releasing the refrigerant underwater only prevents the release of oil into the ambient air, but the refrigerant is still released into the atmosphere. Also inhaling refrigerant can be harmful to humans and poses a suffocation risk.

Technicians should always consider local regulations before releasing any refrigerant to the ambient air. The refrigerant R410A has global warming potential (GWP) of 2088 and 0 ozone depletion (ODP). It is commonly classified as a medium range GWP refrigerant.

Recommendation: The PLs should use a dedicated manifold for refrigerant pumping operations. If the refrigerant has to be released rather than recovered for future use or recycling, it is advised to always do it outdoors to prevent any safety hazard. Refrigerant release must be always performed slowly, allowing the refrigerant to completely evaporate before releasing from the manifold. This will limit the amount of oil that is dragged by the refrigerant during a pump-out operation.

2.3.2 Activity: Refrigerant Loading

The PLs loaded the refrigerant in all UUTs under test – the refrigerant weighting and loading are shown in Figure 7 .

Figure 7. Refrigerant weighting and loading at one of participating laboratories.

The UUTs default factory refrigerant load was 720g. During this exercise, some laboratories failed to complete accurately refrigerant loading into the UUTs, because they did not load the required full amount.

The estimated deviation in refrigerant loading during witness testing was 10-20g. The RRT coordinator did not correct the deviations at that, presuming no impact in the final test results due to this inaccurate procedure. In this RRT, the UUT's installation manual required an additional refrigerant load of 20g for each meter of interconnecting piping beyond 7 meters between the outdoor and indoor unit. All UUTs were installed using 5m refrigerant pipe, so the UUTs were assumed to run with an excess of 40g[6] of refrigerant when properly charged with the factory default value of 720g. Each PL had an estimated error for the refrigerant load below 40g.

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[6] When charged at 720g, the unit is supposed to have enough refrigerant for piping length of up to 7m. Because 20g/meter for piping exceeding 7m is required, it was assumed that UUT is able to normally run with 680g of refrigerant when the piping length is 5m ((7m -5m)*20g/m = 40g; 720 – 40 = 680 g).

Even though the laboratories had explanation in their testing procedure for accurately loading the refrigerant into the UUTs, all PLs left some weighted refrigerant (in liquid phase) in the manifold and manifold's hoses after the completion of refrigerant load.

Recommendation: The PLs should review their refrigerant loading procedures. Making changes to the refrigerant loading process as discussed above can improve the accuracy of loaded refrigerant.

2.3.3 Activity: UUT Start-up Operation

Some laboratories do not specify preconditioning of test rooms to allow the rooms to reach the test conditions before starting a test. In these cases, the technician turned on the UUT while the laboratory was not operating and not controlling the air temperature (air handling units were not operating). This resulted in temperatures in the calorimeter rooms to be actual ambient conditions and not the ones required for the test. Ambient conditions, which are supposed to be 27ºC for indoor and 35ºC for outdoor rooms, were between 28ºC and 30ºC for both indoor and outdoor rooms when the technician switched on the UUT for testing.

Recommendation 1: Some UUTs require the ambient conditions to be close to test point ambient conditions before starting the test. These specific temperature conditions are outlined by the manufacturer as well as in test standard to properly run the test, and should be established before beginning the test.

Recommendation 2: Although not addressed by any standard, it is commonly known that in the balanced calorimeter room method, it takes from 2 to 6 hours for the room walls to reach thermal equilibrium once the air temperature is fixed. The thermal equilibrium of the walls is one of the aspects affecting the time it takes to complete a test. Preconditioning could save several hours every day by avoiding wait time for the calorimeter room walls to reach thermal equilibrium, during which the measurements should not be recorded.

2.3.4 Activity: UUT set-up

In all PLs, the technicians installed the UUTs following their laboratory standard procedure.

TCVN 6576:2013 sub-clause A.2.1 requires the technician to install the UUT following the manufacturer's instructions.

Deviation: None of the technicians who installed the UUTs checked the manufacturer installation manuals prior to unit set up.

Recommendation: The technician should always check the installation manuals prior to setting up the unit. Although not common for room ACs, there can be special set-up requirements such as additional refrigerant loading or specific piping length, vacuum, refrigerant loading and unloading procedures, piping insulation details, or required tilt for the correct installation of indoor unit(s).

The test procedure of some PLs was not fully in line with the test standard regarding UUT set-up requirements.

TCVN 6576:2013 sub-clause A.1.2 requirement: *This sub-clause requires the distance between the UUT air inlet on the outdoor side to be at least 1m between the UUT and any other room surface.*

Deviation: At some PLs, the distance between the UUT air inlet and the wall on the outdoor side was less than 1 meter.

Recommendation: Technicians should keep one-meter free space between the outdoor UUT coil and back room wall (the separating partition between indoor and outdoor test rooms).

Additionally, some parts of the air-sampling device were close to the UUT coil, which might affect coil performance. Common practice is to keep air-sampling devices 10-25 cm from the AC's coil.

Technicians should ensure that the UUT set-up complies with requirements regarding the interconnecting piping length that must be exposed to outdoor air temperature conditions.

TCVN 6576:2013 sub-clause A.2.5 requirement: *"<…> Not less than 40% of the interconnecting tubing shall be exposed to the outdoor conditions <…>"*

Deviation: In some laboratories, the technicians did not check the piping length exposed to outdoor ambient temperature conditions.

Recommendation: It is recommended to mark the interconnecting pipes at 40% length from one end so that compliance with the requirement can be easily verified by visual inspection.

2.4 Test reports

No significant findings were reported here regarding minimum contents of the test reports. Individual findings were reported in each laboratories' report.

3 Statistical Analysis and Evaluation of Results

3.1 Introduction

The participating laboratories assessed the EER, CSPF and efficiency levels for UUTs. This section of the report summarizes the statistical analysis and results of the PLs for the parameters shown in Table 2.

Table 2. Parameters that PLs reported testing data for and the reference standards.

Parameter	Symbol	Standard reference	Test/ calculation method
Full-load cooling capacity	$\phi_{ful}(35)$	TCVN 10273-1	TCVN 6576:2013
Full-load power input	$P_{ful}(35)$		
Full-load energy efficiency ratio	EER_{ful}		
Half-load cooling capacity	$\phi_{haf}(35)$		
Half-load power input	$P_{haf}(35)$		
Half-load energy efficiency ratio	EER_{haf}		
Cooling seasonal performance factor	CSPF		
Latent capacity at full-load conditions	$\phi_{sc,LC1}$	TCVN 6576:2013	
Sensible cooling capacity at full-load conditions	$\phi_{d,LC1}$		
Sensible cooling capacity at half-load conditions	$\phi_{sc,LC2}$		
Latent capacity at half-load conditions	$\phi_{d,LC2}$		
Efficiency Level	-	TCVN:7830	TCVN:7830

Note, the tests were performed in T1 conditions (35^0C).

The test results were reported as per the following requirements:

- *TCVN 7830:2015 "Non-ducted air conditioners - Energy efficiency"* describes the MEPS for the defined levels of efficiency based on the CSPF.
- *TCVN 6576:2013 (ISO 5151:2010) "Non-ducted air conditioners and heat pumps – Testing and rating for performance"* describes the test procedures to determine cooling capacities and energy efficiencies.
- *TCVN 10273-1:2013 (ISO 16358-1:2013) "Air-cooled air conditioners and air-to-air heat pumps. – Testing and calculating methods for seasonal performance factors – Part 1: Cooling*

seasonal performance factor” describes the test conditions and specifies the calculation method to obtain the CSPF.

Statistical analysis was performed as per:

- *ISO 13528:2015 “Statistical methods for use in proficiency testing by inter-laboratory comparison”* describes the calculation algorithms for the data treatment.

In this analysis, the statistical parameters were calculated to assess the RRT exercise and the performance of each PL. For each measured parameter listed in Table 2, the following statistical parameters were calculated:

- An assigned value to serve as a reference value
- Repeatability and standard deviation of reproducibility assess the precision of the exercise
- The standardized Z-scores to assess the performance of the PLs.

3.2 Statistical Analysis

Data from the RRT exercise were analyzed according to ISO 13528:2015 *“Statistical methods for use in proficiency testing by inter-laboratory comparison,”* standard, but the small number of participants limited the statistical significance of the results. This effect is even more pronounced, because the participating laboratories used two different test methods (air enthalpy and calorimeter) for this exercise. The direct comparison of the results from testing by two different methods is not possible. Thus, the RRT coordinator relied significantly on his expertise in test methods, test procedures and the deviations from them to draw conclusions about the test results in this exercise.

3.3 RRT Data Collection & Analysis

3.3.1 Data Collection & Analysis, & Result Evaluation Method

Data were collected using the reporting templates (see Appendix B) shared with each PL prior to RRT exercise. The only data considered for this analysis was the data collected from PLs through these templates and the estimated results (explained further in this section), in cases when data was not provided. These estimated results were required for symmetrical data analysis, and evaluate requirements as per ISO 17025:2005 and TVCN 6576:2013 general quality issues.

Each PL performed the tests on the three UUTs as shown in Table *3*.

Table 3. The tests performed by each PL and the coding scheme.

Participating Laboratory	Test number	Test conditions	Sample Code		
			S1	S2	S3
PL1	R1	LC1	Full load	Full load	Full load
PL1	R1	LC2	Half load	Half load	Half load
PL1	R2	LC1	Full load	Full load	Full load
PL1	R2	LC2	Half load	Half load	Half load
PL2	R1	LC1	Full load	Full load	Full load
PL2	R1	LC2	Half load	Half load	Half load
PL2	R2	LC1	Full load	* Full load	Full load
PL2	R2	LC2	Half load	Half load	Half load
PL3	R1	LC1	Full load	Full load	Full load
PL3	R1	LC2	Half load	Half load	Half load
PL3	R2	LC1	* Full load	* Full load	* Full load
PL3	R2	LC2	* Half load	* Half load	* Half load

- *PL1, PL2 and PL3 refers to the participating laboratories*
- *S1, S2 and S3 refers to the samples*
- *R1 and R2 refers to the test numbers*
- *LC1 is full-load test condition; LC2 is half-load test condition is LC2*

Test results marked * in Table 3 were not submitted:

- PL2 experienced a power supply loss during testing and was unable to supply the results of test S2-LC1-R2.
- PL3 completed one set of tests. The values from R2 replicas were not submitted.

Seven test results were missing. Calculation algorithms in ISO 13528 are designed with the assumption that all input symmetrical data is available, so estimated values were used to complete these calculations.

To note, several different options were considered to address the asymmetrical dataset, including to exclude R2 tests from all participants. This option was discarded due to the already-limited number of tests from each participant and to avoid further reducing the statistical significance of the exercise. Instead, estimated values were calculated to approximate the results expected from other measurements (marked * in Table 3), which do not usually have a significant impact on the average value of data submitted by the PLs.

After collecting testing data and generating estimated values, statistical analysis was performed as per guidance in the ISO 13528:2015. The statistical analysis was done for each main measured parameter using the algorithms described below.

Algorithm A[7]*:*

This algorithm yields robust[8] values of the average assigned value *x** and standard deviation s* of the data to which it is applied.

The robust estimates *x** and *s** may be derived by an iterative calculation, i.e. by updating the values of *x** and *s** several times using the modified data from each iteration, until the respective values converge. The convergence may be assumed when there is no change from one iteration to the next in the third significant figure of the robust standard deviation *s** and of the equivalent figure in the robust average of the assigned value *x**.

Algorithm A was reproduced from ISO 13528:2015 sub-clause C.3.1

Algorithm S:

This algorithm yields robust value of repeatability (standard deviation S_r) if there are repetitions.
It is used in combination with *s** from algorithm A to calculate the final value of S_R that is then used to calculate the Z-scores and the reproducibility limit (R). It was reproduced from ISO 5725-5[9].

Finally, as complementary analysis, R was calculated as shown in section 3.3.3.

3.3.2 Determining Assigned Values

Two different methods were considered to assign reference values for the main measured parameters as per the RRT protocol (Table 2):

- **Method 1**: The assigned value is obtained from the test results of all PLs by calculating a robust mean as per ISO 13528:2015 standard requirements. The uncertainty for the assigned value can be estimated by the statistical analysis and the in-depth knowledge of uncertainties of the test methods.

- **Method 2**: Use a reference value provided by the UUT manufacturer as assigned value instead of agreed robust mean.

The method to assign the reference values for main measured parameters was determined after the testing data was collected and reviewed. The first method was selected based on analysis of the cooling full- and half-load test results because the deviation between laboratories' results was in line with the reproducibility of the test methods. So the assigned reference values for the parameters in

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[7] The algorithms A and S are not single equations - each have several equations with instructions describing a calculation process to enable calculate *x* and s*.* Refer to indicated standards for equations and instructions.

[8] *Robustness* is a property of the estimation algorithm not of the estimates it produces, so it is not strictly correct to name *robust* the averages and standard deviations calculated by such an algorithm. However, to avoid the use of excessively cumbersome terminology, the terms "robust average" and "robust standard deviation" should be understood in this document to mean estimates of the population mean or of the population standard deviation calculated using a robust algorithm.

[9] ISO 5725-5:1998 - Accuracy (trueness and precision) of measurement methods and results — Part 5: Alternative methods for the determination of the precision of a standard measurement method

Table 2 were determined by calculating the robust mean from the test results and estimated test results, in accordance with the RRT protocol and following the guidance in ISO 13528:2015.

The second option was rejected, because there were no significant deviations between the PLs results and product data from the UUT manufacturer, and because not all required test results could be compared against declared values from the UUT manufacturer. Available data from the UUT manufacturer were the total cooling capacity and EER at full load, the CSPF value and the efficiency level declared as per TCVN 10273-1:2013. The half load values for cooling capacity and the EER were not available.

Note that a classical statistical approach would have yielded similar results for the assigned values, because there were no significant deviations between the PLs results. The classical screening by Cochran or Grubbs tests to identify outliers would have resulted in no outliers for the main measured parameters. The average value and the robust mean value were relatively close in most test results. This normally means that the data sets fit with a Gaussian distribution with low spread on the test results.

3.3.3 Estimating Repeatability & Reproducibility

Repeatability (r) usually refers to tests done under repeatable conditions, namely:

- the same UUT is tested several times
- the same laboratory and test instruments are used in every test
- the same test technician performs all tests

Repeatability is a limit, below which (with a probability of 95%) is the absolute value of the difference between two test results obtained under repeatability conditions. It is calculated from the repeatability conditions as follows:

$$\textit{Repeatability limit (or value): } r = 2.8 * S_r$$

where S_r - the standard deviation of repeatability

Repeatability tests are normally performed consecutively or short timeline. For the purpose of this RRT exercise, all tests done on the same model of UUT by the same PL meet the repeatability conditions. Thus, the real repeatability of each PL when it tests under same defined repeatability conditions would be better than the estimated figures in this report. The reason is that in this report, repeatability may have dispersed test result of the three UUTs of the same model due to mass production variability, set-up conditions and refrigerant load.

Reproducibility (R) usually refers to tests done under reproducible conditions, namely:

- the same UUT is tested several times
- a different laboratory and/or different test technician participates in the test, and/or different set of instruments is used

Reproducibility is the limit, below which (with a probability of 95%) is the absolute difference between two test results obtained under reproducibility conditions. It is calculated from the reproducibility conditions as follows:

$$\text{Reproducibility limit (or value): } R = 2.8 * S_R$$

where S_R - the standard deviation of reproducibility

For each main measured parameter in Table 2, S_R and S_r were determined using robust methods of analysis (*Algorithms A and S for the* S_R *and algorithm S for the* S_r) as per ISO 13528:2015 standard. S_r and S_R are also referred to as precision parameters. They enable estimation of the precision of the RRT exercise based on the Gaussian statistical model (normal Gaussian distribution). Both parameters were used to determine the precision of the assigned values.
The variability of each PL and the degree of global dispersion observed between PLs were considered for this analysis.

If a PL test result exceeds the estimated R-value, it can indicate that PL results have significant bias. *R* is a good indicator of bias or error in the results from a PL, as is the z-score index (explained in section 3.3.4).

3.3.4 Performance Evaluation

The performance of PLs was evaluated by calculating a Z-score for each measured parameter listed in Table 2. The Z-score[10] was determined using the following equation:

$$Z\text{-score} = (X_{lab} - VA) / S_R \qquad (1)$$

where

X_{lab} - each PL result calculated as the average of all test results for each parameter evaluated
VA - assigned reference value - determined as the robust mean of the set of PLs' test results calculated according to ISO 13528
S_R - estimate of the standard deviation of the RRT results calculated according to ISO 13528 standard

Results with a value:

$|Z| \leq 2$ are ***satisfactory***

$2 < |Z| \leq 3$ are ***questionable*** or *provide a warning signal*[11]

$|Z| > 3$ are ***unsatisfactory*** or *provide an action signal*[12]

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[10] For z-score calculation, test results were not screened nor eliminated, because VA and S_R were calculated using robust statistics, so screening is not required for this analysis.

[11] Z-score between 2 and 3 indicates that the laboratory should consider checking their measurement procedures and/or measurement equipment.

[12] Z-score above 3 indicates the laboratory should perform further investigations and check their measurement procedures and/or measurement equipment.

IMPORTANT NOTE: These z-scores are provided for reference only and are not statistically significant due to the small number of laboratories involved in the RRT exercise. With less than eight participants, the statistical conclusions are not significant.

Annex D of the ISO 13528:2015 standard states that when there is a limited number of participants, the performance evaluation criteria should be based on external criteria such as expert judgement. Thus, different approaches can reasonably be used for the Z-score calculation.

When S_R is calculated from a greater number of qualified testing laboratories, the S_R is considered a good estimator for the typical combined uncertainty (*u*) of the measurement results. Due to limited number of participants in this RRT, the S_R may not be in line with *u* for some parameters. If the S_R is lower than *u*, there is a great risk that the Z-score will give inaccurate warning or action signals even for accurate test results. On the other hand, when the S_R is greater than *u,* questionable or unsatisfactory results may be erroneously recognized as satisfactory based on the z-score.

The uncertainty of the test method for the main measured parameters (u_{method}) is well known, and it is calculated and declared by the PLs. The calculation of *u is* based on the ISO TS/16491 technical specification.

After performing statistical analysis of the test results for all main measured parameters, additional analysis was done for parameters with questionable or unsatisfactory z-scores. When the estimated uncertainty for the assigned value is below the known uncertainty for the test method, an alternative calculation for the Z-score in equation (1) was performed by making $S_R = u_{method}$. In such cases, the maximum deviation between any test result and the assigned value would usually be below the estimated expanded uncertainty of measurement for the test method (U_{method}). The expanded uncertainty of measurement (U_{method}) is provided for a confidence level by multiplying u_{method} by a factor *k* - for 95% confidence level, k = 2, and $U_{method} = 2u_{method}$.

The alternative equation for the Z-score becomes:

$$Z\text{-score} = 2\,(X_{lab} - VA) / U_{method} = (X_{lab} - VA) / u_{method} \qquad (2)$$

where

X_{lab} - each PL result calculated as the average of all test results for each parameter evaluated
VA - assigned reference value - determined as the robust mean of the set of PLs' test results calculated according to ISO 13528
u_{method} – estimated uncertainty of the measurement result
U_{method} - estimated expanded uncertainty of measurement

3.3.5 Statistical Parameters

The statistical parameters calculated for each main measured parameter listed in Table 2 were:

- Assigned value (VA)
- Standard deviation of reproducibility (S_R)
- Reproducibility limit (R)
- Relative standard deviation of reproducibility (% RSD):

$$\%RSD = \frac{S_R}{VA} \cdot 100$$

To evaluate each PL performance, the Z-score was calculated for each main measured parameter. Analysis results are presented in the next section.

3.4 Evaluation of Results

3.4.1 Analysis of Anomalous Values

Values for statistical parameters were determined in accordance with the protocol established in ISO 13528. It was not necessary to screen for outliers or anomalous values in the results provided by PLs, because robust algorithms were used for data analysis. The robust algorithms force convergence of biased results in an iterative process, but do not exclude them from the calculations.

3.4.2 Presentation of Results

Results, including the main statistical parameters and z-scores for each PL, are discussed in the following sections. Each section includes graphical representation of the test results and a table that includes summarized statistical parameters including the Z-scores for every participant. Detailed results are included in Appendix C.

The maximum deviation of test result from the assigned value was calculated as $|\mathrm{X\,lab} - \mathrm{VA}|$, where VA is the assigned value. The deviation was expressed in watts and as a percentage, and compared to the reproducibility limit, R. When the maximum deviation of a test result against the assigned value was very close to or greater than R, it indicated bias in the result. Bias is also reflected in a Z-score greater than 2 as discussed in the following sections.

3.4.3 Full load Cooling capacity, Power input and Energy Efficiency Ratio

Participating laboratories results for full load cooling capacity, power input and energy efficiency ratio are presented in Figure 8, Figure 9, Figure 10, and Table 4. Additional data are provided in Appendix C.

The EER_{ful} is defined as

$$EER_{ful} = {}^{\emptyset_{ful}(35)}\!\big/_{P_{ful}(35)}$$

where

$\phi_{ful}(35)$ - full load cooling capacity (W)

$P_{ful}(35)$ – full load power input (W)

Figure 8. Participating laboratories' results for full load cooling capacity - $\phi_{ful}(35)$.

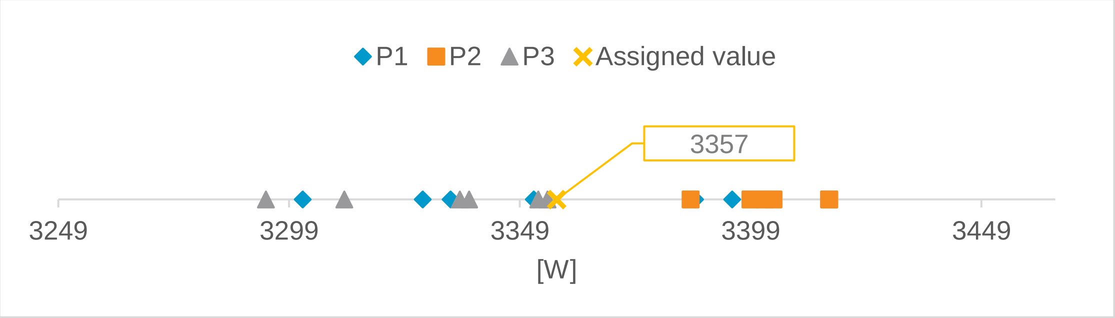


Figure 9. Participating laboratories' results for full-load power input - $P_{ful}(35)$.

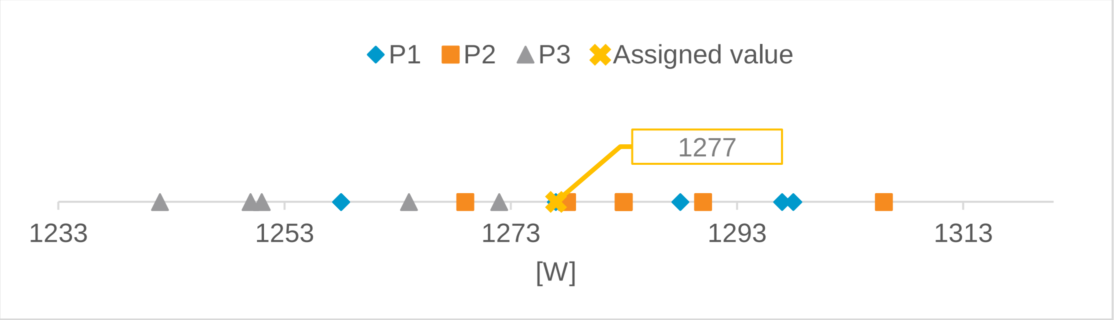


Figure 10. Participating laboratories' results for full-load energy efficiency ratio - $EER_{ful}(35)$.

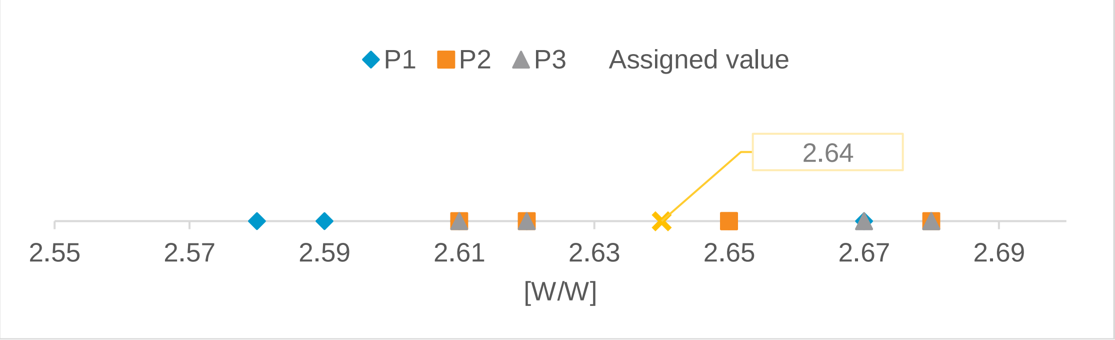


Table 4. Main statistical parameters for full load measured parameters.

Parameter symbol	Max deviation	Max deviation (%)	±2S_R	R	Z-scores		
					P1	P2	P3
$\phi_{ful}(35)$	63 W	1.9	88 W	108 W	-0.19	1.20	-0.67
$P_{ful}(35)$	35 W	2.3	32 W	44 W	0.14	0.50	-1.19
EER_{ful}	0.06	2.3	0.06	0.1	-0.60	0.06	0.40

The assigned value for $\phi_{ful}(35)$, - a robust mean of 3.36kW (Figure 8), - is consistent with the data received form the UUT manufacturer, which is equal to 3.3kW. The maximum difference between a test result and the assigned value for $\phi_{ful}(35)$ is 62.8W, which represents a deviation of 1.9% (Table 4). The relative reproducibility limit (%RSD) is 3.2% and the declared measurement uncertainties are close to the same value, thus, the deviation of 1.9% is a good result. All full load cooling capacity test results are closer to assigned value when compared with R.

For full load power input, the maximum deviation between a test result and the assigned value is 35.2 W, which represents a deviation of 2.8% (Table 4). Two P3 virtual test results (Figure 9) are slightly outside the interval (mean ± $2\,S_R$: 1246 W to 1309 W), but the difference between them and assigned value is still below R.

All PLs used the same precision instruments to measure full load power input with accuracies greater than 0.25%, so accurate measurement results for this measurement was assumed. Therefore, the deviations in the reported test results for power input may be a real difference in UUTs' energy consumption including mass production tolerances, refrigerant load and actual operating conditions of the UUTs. Actual operating conditions are related to the ambient temperatures and atmospheric pressure and vary due to testing facility location and to measurement uncertainties of the temperature sensors.

In Table 4, the maximum deviation between a test result and the assigned value for EER is 0.06, which represents a deviation of 2.3% and is less than R of 0.1.

Evaluated Z-scores for all PLs are below 2 (Table 4) indicating a good performance level for the three measurements.

3.4.4 Half load Cooling capacity, Power input and Energy Efficiency Ratio

Participating laboratories results for half load cooling capacity, power input and energy efficiency ration are presented in Figure 11, Figure 12, Figure 13, and Table 5. Additional data are provided in Appendix C.

The EER_{haf} is defined as

$$EER_{haf} = {\emptyset_{haf}(35)}/{P_{haf}(35)}$$

where

$\phi_{haf}(35)$ - full load cooling capacity (W)

$P_{haf}(35)$ – full load power input (W)

Figure 11. Participating laboratories' results for half load cooling capacity - $\phi_{haf}(35)$.

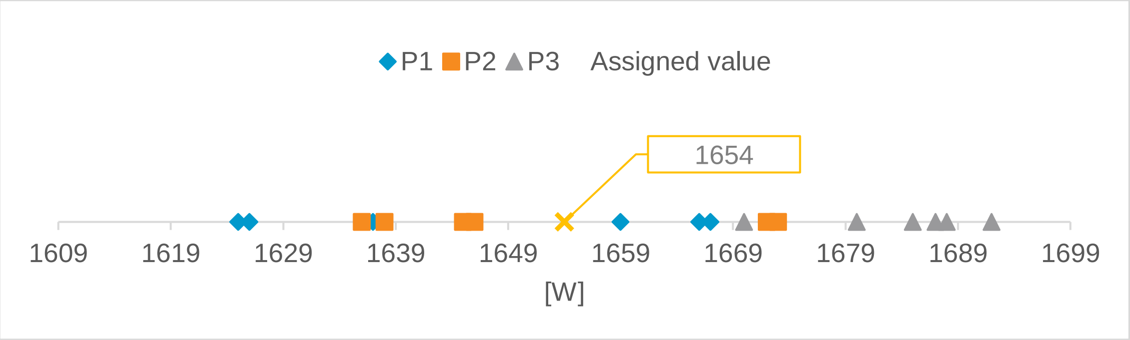


Figure 12. Participating laboratories' results for half load power input - $P_{haf}(35)$.

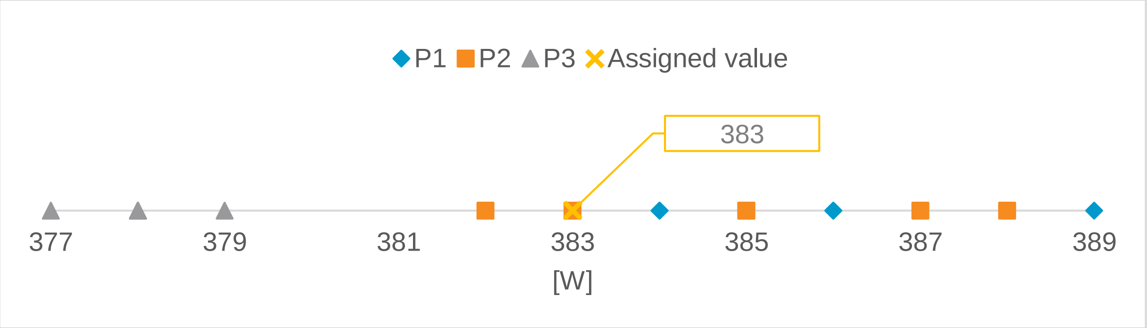


Figure 13. Participating laboratories' results for half load energy efficiency ratio – $EER_{haf}(35)$.

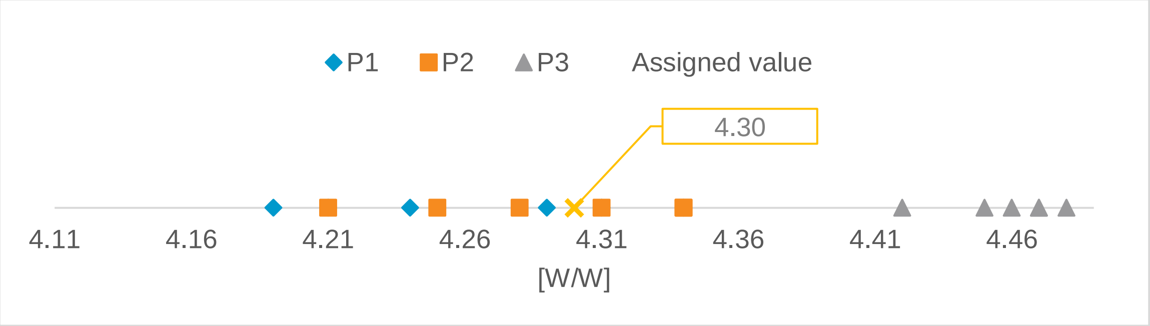


Table 5. Main statistical parameters for half load measured parameters.

Parameter symbol	Max deviation	Max deviation (%)	$\pm 2S_R$	R	Z-scores		
					P1	P2	P3
$\phi_{haf}(35)$	38 W	2.3 %	32 W	45 W	-0.44	-0.14	1.87
$P_{haf}(35)$	6 W	1.7%	12 W	16 W	0.48	0.42	-0.79
EER_{haf}	0.18	4.1%	0.1	0.19	-0.44	-0.16	2.26 (1.75*)

For a half load cooling capacity, the maximum deviation between a test result and the assigned value is 38.4 W, which represents a deviation of 2.3% (Table 5). Some P3 results are outside the interval mean ± $2\ S_R$ (1622 W to 1686 W), but the maximum difference between them and the assigned value still below R. Because P3 results are concentrated on one interval end, they have a small bias. Also, Z-score for P3 is below, but close to 2 (Table 5), which may indicate a small bias. All laboratories show satisfactory performance based on Z-scores.

Table 5 shows that the maximum deviation for the half load power input, $P_{haf}(35)$, is 6.4 W or 1.7%, and all the results are closer to the assigned value when compared with R of 16 W.

When $P_{haf}(35)$ is measured with calibrated watt meters, the measurement is typically very accurate. All PLs use the same precision class instruments, with accuracies greater than 0.25% to measure power input. Thus, deviations shown in the figures can be assumed as real differences in the energy consumption of the UUTs. Therefore, the deviations in the reported test results for power input may be a real difference in UUTs' energy consumption including mass production tolerances, refrigerant load and actual operating conditions of the UUTs. Actual operating conditions are affected by ambient temperatures and atmospheric pressure, and vary due to testing facility location and to measurement uncertainties of the temperature sensors. All participants show a good performance level according to Z-score evaluation.

For the half load energy efficiency ratio (EER_{haf}), the maximum deviation between a test result and the assigned value is 0.18 or 4.1%. The reproducibility limit is 4.5% and the estimated expanded measurement uncertainty of the EER is 4.1%. Some P3 results are outside the interval (mean ± $2\ S_R$: 4.17 to 4.44) as shown in Figure 13, but the difference between them and assigned value is still less than reproducibility limit (R).

Similarly to $\phi_{\text{haf}}(35)$, P3 test results for EER_{haf} may be seen to have some bias as well because all of them are slightly above the other PLs' results (Figure 13Figure).[13] The main reason is that $\phi_{\text{haf}}(35)$ test results reported by P3 are slightly higher and $P_{haf}(35)$ test results are slightly lower compared to the other PLs' results. These, in turn, cause greater bias in EER_{haf} results.

P3 did not provide estimated uncertainty for EER_{haf}, but it is safe to assume that the uncertainty was slightly higher than the estimated uncertainty of 3.9% for $\phi_{\text{haf}}(35)$, because $P_{haf}(35)$ had low uncertainty. Based on the experience with similar laboratories and the test method, the assumption can be made that the uncertainty for EER_{haf} for P3 should be around 4.1%, if calculated.

The estimated Z-score of 2.26 is slightly above two, which indicates that the results are *questionable* posing a *warning signal*. As explained in section 3.3.4, when the RRT exercise has low number of participants (less than 9), one should be careful drawing conclusions from the statistical analysis, because they might be not well founded.

The Z-score* for all three laboratories was calculated using the alternative equation (2), presented in section 3.3.4. The uncertainty of 4.1% was used for the estimating Z-score* and the standard deviation of reproducibility was calculated as follows:

$$S_R \approx \frac{U(EER_{haf})}{2} = u(EER_{haf}) = 2.05\%$$

---

[13] Because of low number of PLs, the bias can be seen both ways – either P3 has bias in its test results or P1 and P2 having bias in their results. Thus, following explanations and reasoning may be interpreted both ways.

The PL1 and PL2 had the same scores while PL3 score using alternative equation was estimated at 1.75* (Table 5), which is below 2.

P3 laboratory reported additional test data, which was referenced to assess the Z-score deviation indicating that other than capacity or energy measurements factors could have caused it. Without other reliable findings to support the deviation, it is recommended to observe testing in low capacity range (below 2kW) during future RRT or quality follow up tests, and to check the ambient sensors (dry bulb outdoor, dry bulb and wet bulb indoor). An unknown deviation in one of the outdoor or indoor ambient test rooms' sensors (even if it is within the allowed uncertainty measurement limits for the individual measurements defined in the TCVN 6576:2013) could lead to deviations in the measured cooling capacity.

3.4.5 Cooling seasonal performance factor and Energy efficiency level

Participating laboratories results for cooling seasonal performance factor (CSPF) and energy efficiency (EE) level are presented in Figure 14 and Table 6. Additional data are provided in Appendix C.

Figure 14. Participating laboratories' results for cooling seasonal performance factor – CSPF.

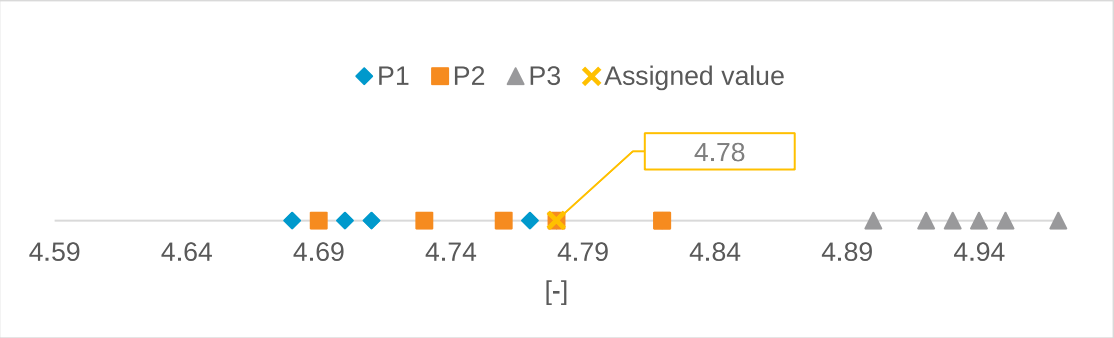


Table 6. Main statistical parameters for CSPF and energy efficiency level.

Parameter symbol	Max deviation	Max deviation (%)	$\pm 2S_R$	R	Z-scores		
					P1	**P2**	**P3**
CSPF	0.19	3.9%	0.1	0.19	-0.59 (-0.19*)	-0.23 (-0.08*)	2.30 (0.75*)
EE	0	0	0	0	0	0	0

For the CSPF, the maximum deviation between assigned value and test results is 0.19 or 3.9%. Similarly to previous analyses, some P3 results are outside the interval (mean $\pm 2 S_R$: 4.65 to 4.92) as shown in Figure 14, but the differences between them and assigned value are below or equal to R. The P3 results for CSPF showed bias, which was expected as the CSPF was calculated using reported full load cooling capacity and power input, and half load cooling capacity and power input results with half load test results showing bias.

P3 did not report the estimated uncertainty for the CSPF. The RRT coordinator estimated it from the provided test data, which was around 8.5% for k=2 and 95% confidence level.

The estimated Z-score for PL3 was 2.30, which was greater than two indicating a *warning signal*. Because of small number of laboratories participating in this RRT, the conclusions based on these deviations could not be made. Additionally, the maximum deviation of a test results from assigned value is 0.19, which is the same as R (Table 6), and the maximum deviation of 3.9% is below the estimated uncertainty for the CSPF, which is 8.5%. This does not allow to conclude that there is a measurement problem in PL3. Because most of the test results are close, even small deviations (compared to the measurement uncertainty) may give a *warning* or even an *action signal*.
Alternative Z-scores*, shown in Table 6, were calculated using equation (2) and a standard deviation for the reproducibility of 4.25%.[14] Alternative Z-score* calculation approach showed that all PLs had a good performance level as per Z-score classification.

The laboratories estimated the energy efficiency level for tested samples following the instructions in the Vietnamese standard. All three PLs listed five as energy efficiency level for all three UUTs, thus, no statistical analysis was performed for EE level. The laboratories performed correctly the analysis for EE level.

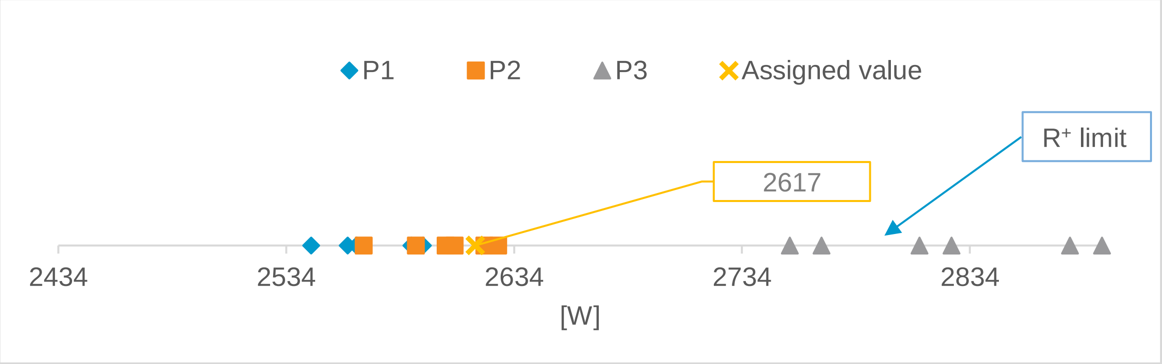
3.4.6 Sensible and Latent cooling capacities at full load

Sensible cooling capacity ($\phi_{sc,LC1}$) and latent cooling capacity ($\phi_{d,LC1}$) were closely related and simultaneously analyzed to better understand the possible deviations. They can be defined and are related as follows:

$$\phi_{sc,LC1} = \phi_{ful}(35) - \phi_{d,LC1}$$

$$\phi_{d,LC1} = \phi_{ful}(35) - \phi_{sc,LC1}$$

Figure 15. Participating laboratories' results for sensible cooling capacity at full load - $\phi_{sc,LC1}$.



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[14] Uncertainty for CSPF equals to 8.5% for k=2, 95% confidence level.

Figure 16. Participating laboratories' results for latent cooling capacity at full load - $\phi_{d,LC1}$.

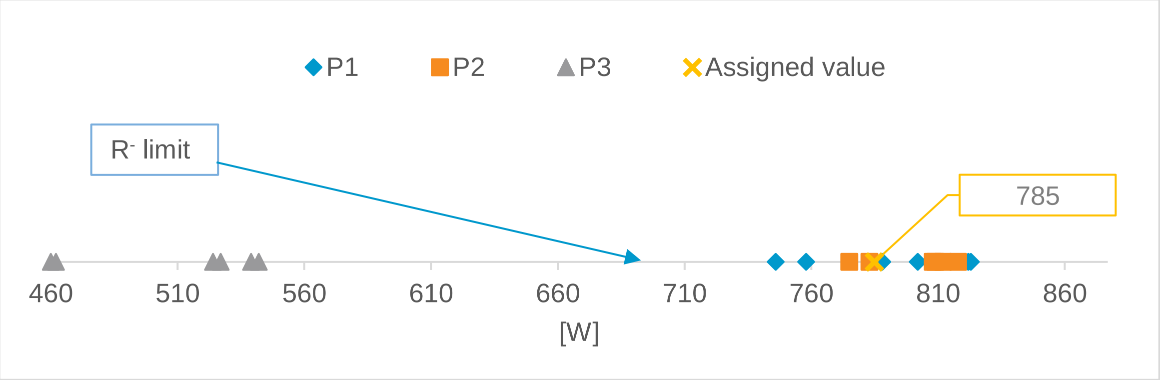

Table 7. Main statistical parameters for sensible and latent cooling capacities at full load.

Parameter symbol	Assigned Value	Max deviation (W)	Max deviation (%)	$\pm 2S_R$	R	Z-scores		
						P1	P2	P3
$\phi_{sc,LC1}$	2617	275	10.5	130	183	-0.72	-0.21	3.14
$\phi_{d,LC1}$	785	325	41.4	66	184	0.14	0.47	-8.43

For $\phi_{sc,LC1}$ the maximum deviation between the assigned value and test results is 275 W or 10.5%, and for $\phi_{d,LC1}$ - 325 W or 41.4% (Table 7). Ideally, maximum deviations should be the same and not similar (in watts) as in this case. This is because the assigned values for these parameters are not averaged values, but robust means.

Z-score for P3 is 3.14 for the sensible capacity and -8.43 - for the latent capacity. Because these parameters are related, the deviation in one parameter causes a deviation in the other. Z-score result that is above 3 means that a test result is *unsatisfactory*.

Because there were no significant deviations in the full load cooling capacity results, the above deviations may be due to the actual operating conditions of the UUT or inaccuracies in some measurement instruments[15]. Measurement uncertainty or bias error in the following instruments[16] could explain the observed deviations:

- For the air enthalpy method:
  - Outdoor dry bulb temperature sensor
  - Indoor dry bulb and wet bulb temperature sensors to measure both, entering and leaving, air temperature conditions

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[15] These underlying deviations can be within the allowed measurement uncertainties for the different measured parameters stated in the TCVN 6576:2013 standard.

[16] Both test methods were analyzed here to guarantee confidentiality of the results in this report. Also, because of the reduced statistical significance of the data, any of the three PLs could be affected.

- For the balanced calorimeter room method:
    - Outdoor dry bulb temperature sensor
    - Indoor dry bulb and wet bulb temperature sensors
    - UUT condensate weighting scale

To note, for this RRT, the Z-score is only informative, because of low number of participants. The alternative Z-scores* were not calculated for sensible and latent cooling capacities, because of lack of reproducibility information of the test methods.

3.4.7 Sensible and Latent cooling capacities for Half load

As for full load, the sensible cooling capacity ($\phi_{sc,LC2}$) and latent cooling capacity ($\phi_{d,LC2}$) were simultaneously analyzed to better understand the possible deviations. They can be defined and are related as follows:

$$\phi_{sc,LC2} = \phi_{hal}(35) - \phi_{d,LC2}$$

$$\phi_{d\ ,LC2} = \phi_{hafl}(35) - \phi_{sc,LC2}$$

Figure 17. Participating laboratories' results for sensible cooling capacity at half load - $\phi_{sc\ ,LC2}$.

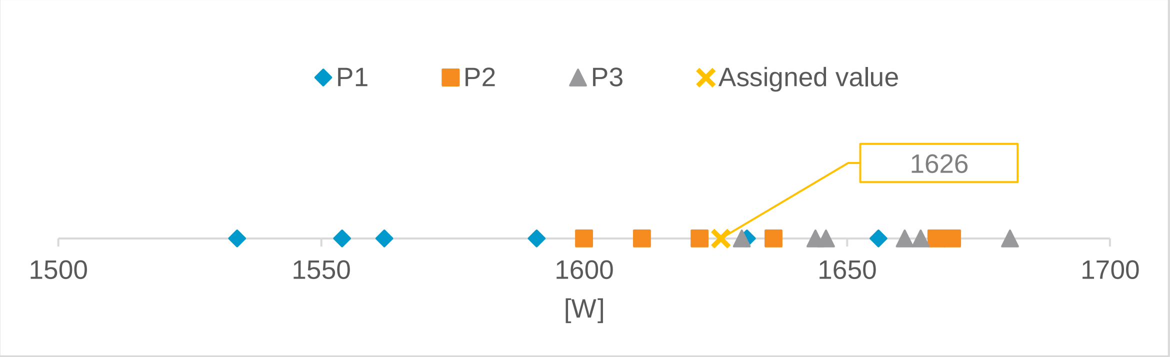

Figure 18. Participating laboratories' results for latent cooling capacity at half load - $\phi_{d\ ,LC2}$.

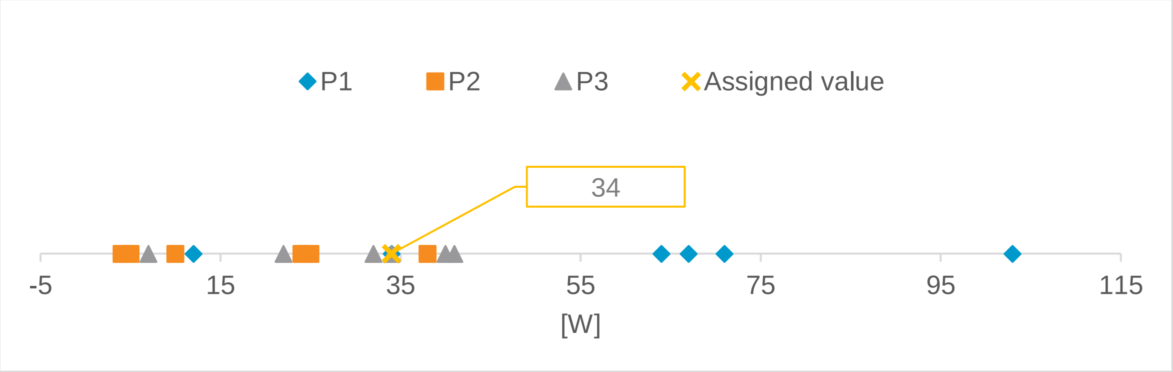

Table 8. Main statistical parameters for sensible and latent cooling capacities at half load.

Parameter symbol	Assigned Value	Max deviation (W)	Max deviation (%)	$\pm 2S_R$	R	Z-scores		
						P1	P2	P3
$\phi_{sc,LC2}$	1626	92	5.6%	90	126	-0.85	0.18	0.62
$\phi_{d,LC2}$	34	69	201%	50	71	0.96	-0.65	-0.19

For $\phi_{sc,LC2}$ the maximum deviation between the assigned value and test results is 92 W or 5.6%, and for $\phi_{d,LC2}$, - 69 W or 201.1% (Table 8). Z-scores for all PLs are below one, which shows good performance by all three PLs.

The maximum deviations for $\phi_{sc,LC2}$ and $\phi_{d,LC2}$ are much smaller compared to the full load analysis results. This may be due to the real dew point temperature in the indoor side of UUT and the evaporating temperature of the refrigerant inside the UUT indoor coil. When testing at full load capacity, the evaporating temperature of the refrigerant inside the indoor side of the UUT is usually below the indoor air dew point temperature. Thus, a certain percent of total cooling capacity is used to dehumidify the air by condensing water in the indoor UUT coil (latent cooling capacity). The latent capacity will be greater if there are larger differences between the air dew point temperature and refrigerant evaporating temperature. This occurs if evaporating temperature is lower than expected (behavior of the unit) and if the actual humidity of the air is above the set point. Even when using the calibrated measurement equipment to measure the dry bulb and wet bulb temperatures, deviations in these temperature sensors within the uncertainty limits (as per the TCVN 6576:2013 standard) can explain the differences between laboratories' latent and total cooling capacities.

When testing the inverter UUT at half load, the evaporating temperature of the refrigerant is usually greater than the indoor side air dew point temperature. Under such conditions, there will be normally no latent capacity provided by the unit. When the latent capacity is above zero, it may be because of low accuracy of the measurement instruments under such conditions. The observed deviations in this RRT are attributed to the detection limit when measuring latent capacity, because of significant uncertainty, when the real latent capacity is zero or very small.

The more accurate results for the half load sensible and latent capacities compared to full load, supports the explanation that deviations on $\phi_{sc,LC1}$ and $\phi_{d\ ,LC1}$ are likely due to the actual operating conditions of the UUT or small inaccuracies in some measurement instruments.

4 Conclusions and Recommendations

Conclusions from Data Analysis

This RRT exercise had a small number of participating laboratories, so the conclusions from statistical analysis are not statistically significant. The results, however, offer insight into the performance of the laboratories, explanations for any observed deviations from the expected results, and recommendations to address them. Two main statistical parameters, the reproducibility limit (R) and the Z-score, were used for this RRT to evaluate bias of the PLs.

Most of Z-scores for each PL fell within the “satisfactory” range, which indicates with a high degree of certainty that despite any specific procedural errors or deficiencies, the accuracy and reproducibility of the test results at PLs was high.

Performance of the three laboratories is considered satisfactory for all the assessed parameters. The most significant RRT exercise findings are related to the balance between sensible and latent capacities in the full load cooling capacity tests. The probable cause for these deviations may be due to the actual operating conditions of the UUT or inaccuracies in some measurement instruments. However, they do not impact the main measured parameters: total cooling capacities, EER, CSPF and energy efficiency level.

Qualitative insights based on analysis of the main measured parameters are as follows:

- All PLs showed satisfactory performance and no bias for full load cooling capacity - $\phi_{ful}(35)$, power input - $P_{ful}(35)$, Energy Efficiency Ratio - EER_{ful}, and half load power input $P_{hal}(35)$ based on calculated R and Z-scores.

- RRT activity results showed small variation in the results for the main parameters - $\phi_{ful}(35)$, $P_{ful}(35)$, EER_{ful}, $\phi_{haf}(35)$, $P_{hal}(35)$, EEE_{haf} and CSPF. This was confirmed by small S_R and %RSD as compared to the measurement uncertainties, despite the PLs using different test methods.

- PL3 showed more bias in tests under half load conditions than the other laboratories. Its test results for half load cooling capacity - $\phi_{haf}(35)$ showed some bias as they were concentrated on one end of the interval. However, this bias was not significant considering the measurement uncertainty of the test methods. The Z-Scores for all PLs showed a satisfactory performance. Similarly, PL3 results for Energy Efficiency Ratio $EEE_{,hal}$ showed some bias and the Z-score of 2.26 was greater than two, which indicates a questionable performance. The alternative Z-score* that was calculated using different criteria for calculating the S_R was estimated around 1.75, which shows satisfactory performance.

- PL3 showed some bias for cooling seasonal performance factor – CSPF and Z-score of 2.30 indicating “questionable” performance, but alternative Z-score* of 0.75 indicated satisfactory performance.

- PL3 showed bias for full load sensible cooling capacity - $\phi_{sc,LC1}$ and latent cooling capacity **-** $\boldsymbol{\phi_{d,LC1}}$. For $\phi_{sc,LC1}$, the maximum deviation of 10.5% was greater than the reproducibility limit of 7.0%. Similarly, for $\phi_{sc,LC2}$, the maximum deviation of 41.4% was much greater than the reproducibility limit of 11.7%. The Z-scores for both were 3.16 and -8.43, respectively, which are classified as “unsatisfactory” performance. Because there were no significant deviations in the full load cooling capacity results, these findings may be due to the actual operating conditions of the UUT or inaccuracies in some measurement instruments.

- The test results for sensible and latent cooling capacities for full and half load had greater variations. The maximum %RSD for other parameters was 1.5%, while the %RSD for the sensible and cooling capacities ranged from 2.5% up to 74%. This means there could be some bias error in specific measurement instruments due to innacuracies or to the actual operating conditions of the UUT.
- Test results for half load sensible cooling capacity - $\phi_{sc,LC2}$ showed satisfactory performance by all PLs, but latent cooling capacity - $\phi_{d,LC2}$ had the greatest data variation. This might be because the available measurement equipment does not accurately measure latent capacity when it is zero or very small.
- All laboratories estimated level five for the Energy Efficiency Level. No statistical conclusions are applicable for this parameter due to the absence of any variability.

Recommendations

This section summarizes key recommendations stemming from the RRT exercise.

Recommendations for equipment calibration

- Laboratories should have a plan to periodically calibrate all measurement equipment that can have an impact on test results. All calibrated instruments should have traceability to SI units.
- In calibration reporting, there should be full traceability between laboratory’s sensor readings, sensor identification, and the reference sensor readings. The calibrated range of the measurement equipment should match or exceed the range of the instrument.
- Based on calibration data, the laboratories should ensure that estimated measurement equipment uncertainties do not exceed the measurement standard and/or internal laboratory requirements. If there are any deviations, the laboratories should adjust the measurement equipment scaling factor and keep records of any adjustments made.

General recommendations

- The laboratories should verify procedures in the product manual before proceeding with the set-up of a new UUT.
- PLs usually perform up to 150 cooling capacity tests per year. All PLs use a two-step approach: the first step is to set-up the UUT inside the laboratory, and the second step is testing for cooling capacities. If PLs adopted two 9-hour work shifts for the two test steps, two

complete cooling capacity tests could be done every work day, thereby increasing the productivity of the facilities.

- PLs may be able to improve their productivity by increasing the number of tests completed per day or reducing test duration. The PLs typically perform one test per day (either full load or half load), with UUT set-up during the prior day. PLs could optimize their procedures by beginning acclimatization of the laboratory environment in advance of testing to bring the room to thermal equilibrium as per standard requirements. Bringing the walls of the test room to thermal equilibrium is required for accurate cooling capacity results, and, depending on the temperature difference between actual test conditions and the air temperatures required for the tests, reaching that state can take several hours.

- The selection of the tests sequence for a UUT can affect the time it takes the calorimeter to reach steady state operating conditions. Starting with first testing the UUT for the half load cooling capacity, during which usually latent capacity is zero, can save some testing time. If there is no water in the indoor side of the UUT (in the coil or in the drain pan) the laboratory will more quickly reach air humidity equilibrium.

- All PLs are encouraged to look into possible small deviations in some specific sensors as per 3.4.6 to better understand bias that was identified in this RRT for full load sensible cooling and latent cooling capacities.

- Based on observations, the PLs typically conduct tests on single package unit and single split unit (wall type) ACs. Other types of AC units that can be tested at the facilities include:
    - Single split console ACs
    - Suspended single split ceiling ACs
    - Multi split wall ACs
    - Multi split console ACs
    - Single split cassette ACs

  Using the balanced calorimeter room method, the above units could be tested with minor changes in test procedures and adding additional frames to set-up these UUTs. For the air enthalpy method, there are additional requirements.

Policy recommendations

Per TCVN 7830:2015 Table 1, the efficiency level of ACs is classified from 1-star (lowest efficiency) to 5-stars (highest efficiency). The minimum CSPF value for 5-star unit is 4.20. The unit that was tested in this RRT exercise had a lowest CSPF value calculated as 4.68[17] and was considered a 5-star product.

More efficient products are available on Vietnam's and other markets that have EER_{ful} above 4, and EER_{haf} above 6. Therefore, there is an opportunity for policy makers to increase the efficiency requirements for each star rating level to differentiate highly efficient products and guide markets toward more efficient technologies.

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[17] The CSPF value is derived from the EER at full load and half load: EER_{ful}= 2.59 and EER_{hal} = 4.19, which is equal to 4.68.

Appendix A: Testing Schedule

WEEK 1	Monday 15-Jul	Day 1 -Tuesday 16-Jul	Day 2 - Wednesday 17-Jul	Day 3 - Thursday 18-Jul	Day 4 - Friday 19-Jul	Day 5 - Saturday 20-Jul	Day 6 - Sunday 21-Jul
SAMPLE 1: S1	S1 arrive at TVCI		**Testing at TVCI (S1), testing expert on site**	**Testing at TVCI (S1), testing expert on site**	S1 packaged & shipped to Midea	In transit - Hanoi & HCMC	In transit - Hanoi & HCMC
SAMPLE 2: S2	S2 arrive at TVCI & shipped to QUATEST 3	In transit - Hanoi & HCMC	In transit - Hanoi & HCMC	In transit - Hanoi & HCMC	S2 arrive at QUATEST 3		
SAMPLE 3: S3	S3 arrive at TVCI & shipped to Midea	In transit - Hanoi & HCMC	In transit - Hanoi & HCMC	In transit - Hanoi & HCMC	S3 arrive at Midea		

WEEK 2	Monday - Day 7 22-Jul	Tuesday - Day 8 23-Jul	Wednesday - Day 9 24-Jul	Thursday - Day 10 25-Jul	Friday - Day 11 26-Jul	Saturday - Day 12 27-Jul	Sunday - Day 13 28-Jul
SAMPLE 1: S1	In transit between Hanoi and HCMC	S1 arrive at Midea	**Testing at Midea (S1), testing expert on site**	**Testing at Midea (S1), testing expert on site**	S1 packaged & shipped to QUATEST 3		
SAMPLE 2: S2	**Testing at QUATEST 3 (S2), testing expert on site**	**Testing at QUATEST 3 (S2), testing expert on site**	S2 packaged & shipped to Midea		**Testing at Midea (S2)**	**Testing at Midea (S2)**	
SAMPLE 3: S3	**Testing at Midea (S3)**	**Testing at Midea (S3)**	S3 packaged & shipped to QUATEST 3	**Testing at QUATEST 3 (S3)**	**Testing at QUATEST 3 (S3)**		

WEEK 3	Monday - Day 14 29-Jul	Tuesday - Day 15 30-Jul	Wednesday - Day 16 31-Jul	Thursday - Day 17 1-Aug	Friday - Day 18 2-Aug	Saturday - Day 19 3-Aug	Sunday - Day 20 4-Aug
SAMPLE 1: S1	**Testing at QUATEST 3 (S1)**	**Testing at QUATEST 3 (S1)**	S1 repacking. Wait for donation.				
SAMPLE 2: S2	S2 packaged & shipped to TVCI	In transit - Hanoi & HCMC	In transit - Hanoi & HCMC	In transit - Hanoi & HCMC	S2 arrive at TVCI		
SAMPLE 3: S3	S3 packaged and shipped to TVCI	In transit - Hanoi & HCMC	In transit - Hanoi & HCMC	In transit - Hanoi & HCMC	S3 arrive at TVCI		

WEEK 4	Monday - Day 21 5-Aug	Tuesday - Day 22 6-Aug	Wednesday - Day 23 7-Aug	Thursday - Day 24 8-Aug	Friday - Day 25 9-Aug
SAMPLE 1: S1					
SAMPLE 2: S2			**Testing at TVCI (S2)**	**Testing at TVCI (S2)**	S2 repacking. Wait for donation.
SAMPLE 3: S3	**Testing at TVCI (S3)**	**Testing at TVCI (S3)**	S3 repacking. Wait for donation.		

The testing dates for the participating laboratories are as follows:

TVCI laboratory:

- Sample 1 – S1: July 17-18
- Sample 3 – S3: August 5-6
- Sample 2 – S2: August 7-8

QUATEST 3 laboratory:

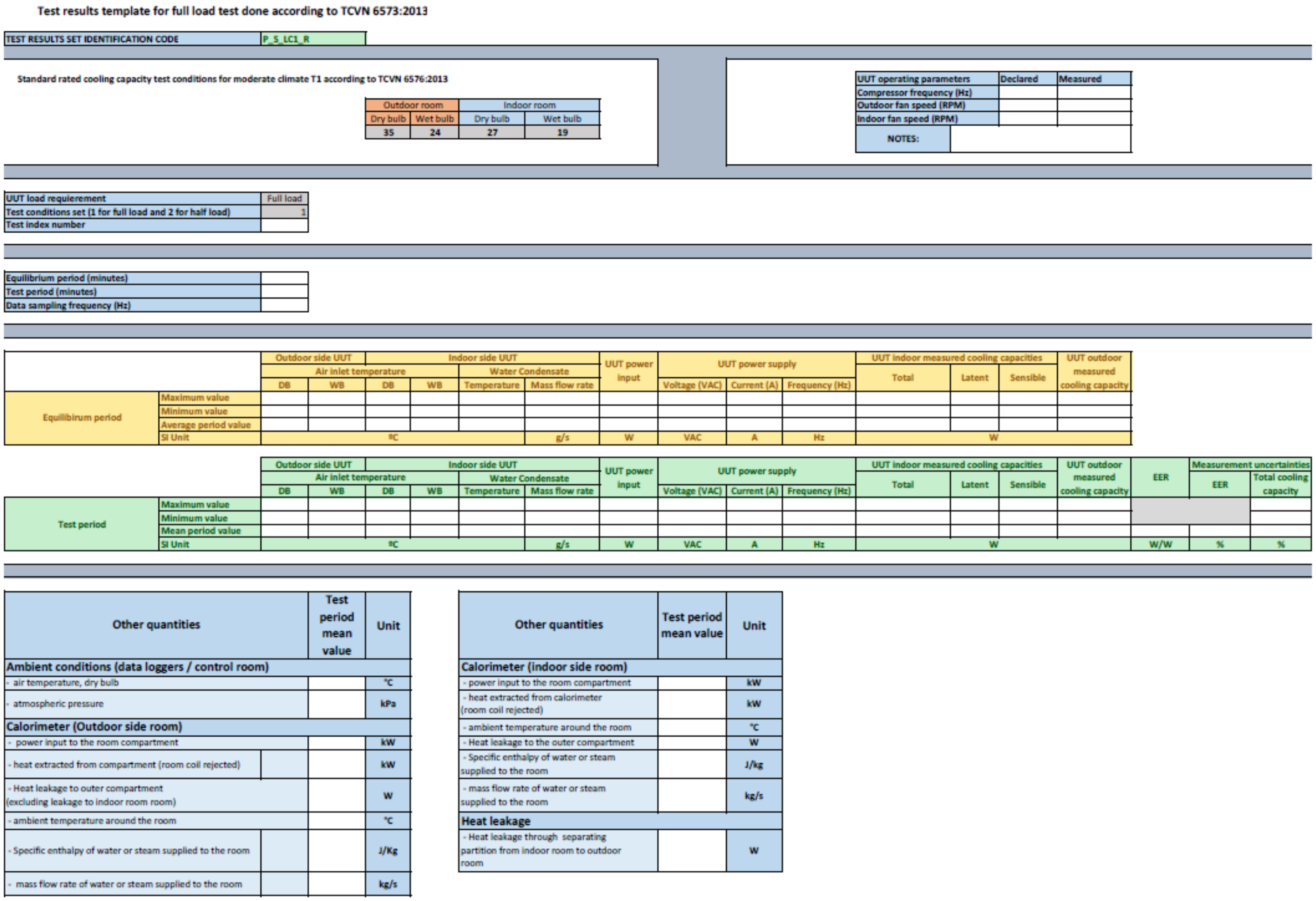
- Sample 2 – S2: July 22-23
- Sample 3 – S3: July 25-26
- Sample 1 – S1: July 29-30

Midea laboratory:

- Sample 3 – S3: July 22-23
- Sample 1 – S1: July 24-25
- Sample 2 – S2: July 26-27

Appendix B: Forms

Templates for this RRT exercise have been distributed in electronic excel form. Below forms are included for reference only.



Test results template for full load test done according to TCVN 6573:2013

TEST RESULTS SET IDENTIFICATION CODE	P_S_LC1_R

Standard rated cooling capacity test conditions for moderate climate T1 according to TCVN 6576:2013

Outdoor room		Indoor room	
Dry bulb	Wet bulb	Dry bulb	Wet bulb
35	24	27	19

UUT operating parameters	Declared	Measured
Compressor frequency (Hz)		
Outdoor fan speed (RPM)		
Indoor fan speed (RPM)		
NOTES:		

UUT load requierement	Full load
Test conditions set (1 for full load and 2 for half load)	1
Test index number	

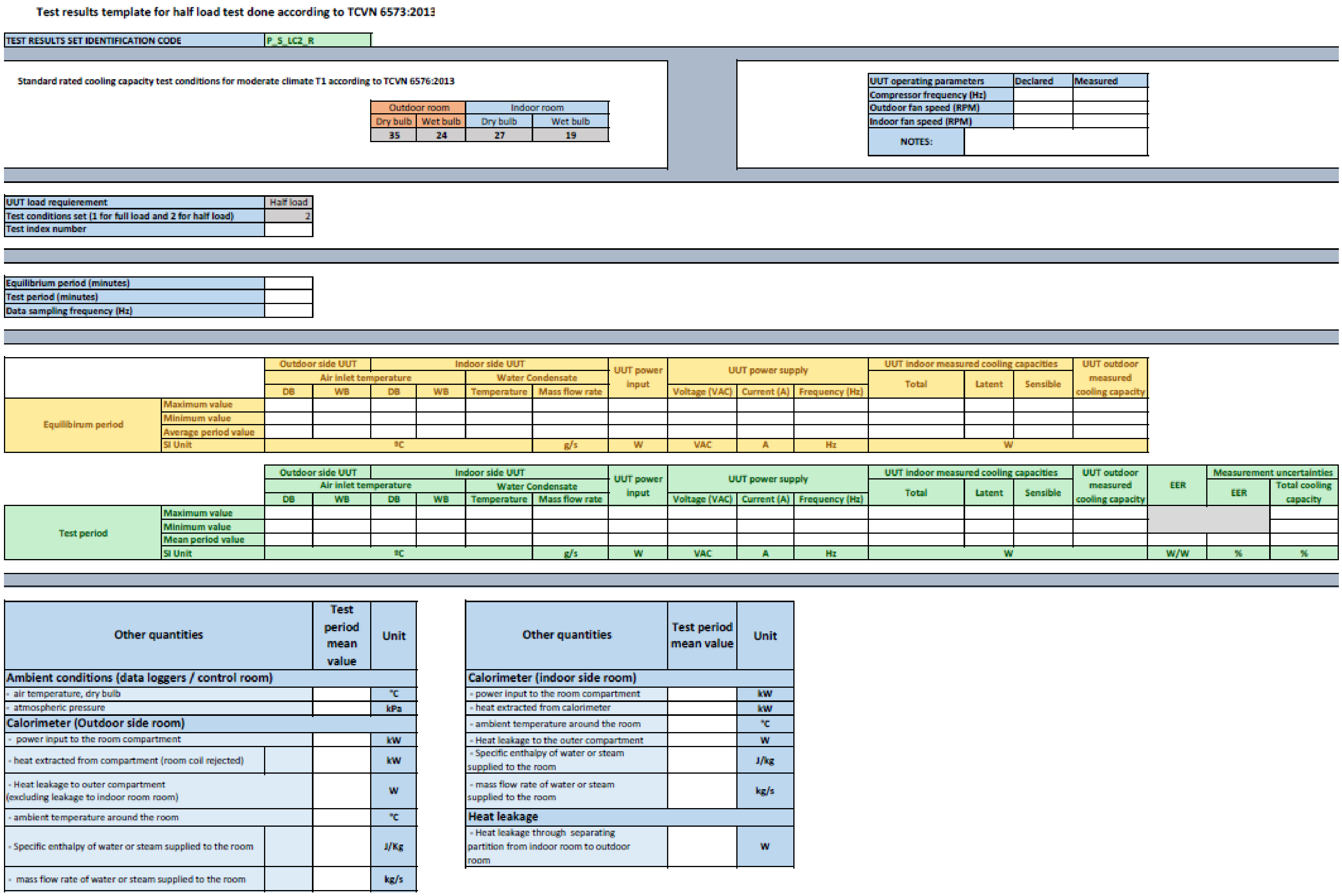
Equilibrium period (minutes)	
Test period (minutes)	
Data sampling frequency (Hz)	

		Outdoor side UUT		Indoor side UUT				UUT power input	UUT power supply			UUT indoor measured cooling capacities			UUT outdoor measured cooling capacity
		Air inlet temperature				Water Condensate						Total	Latent	Sensible	
		DB	WB	DB	WB	Temperature	Mass flow rate		Voltage (VAC)	Current (A)	Frequency (Hz)				
Equilibirum period	Maximum value														
	Minimum value														
	Average period value														
	SI Unit	ºC					g/s	W	VAC	A	Hz	W			

		Outdoor side UUT		Indoor side UUT				UUT power input	UUT power supply			UUT indoor measured cooling capacities			UUT outdoor measured cooling capacity	EER	Measurement uncertainties	
		Air inlet temperature				Water Condensate						Total	Latent	Sensible			EER	Total cooling capacity
		DB	WB	DB	WB	Temperature	Mass flow rate		Voltage (VAC)	Current (A)	Frequency (Hz)							
Test period	Maximum value																	
	Minimum value																	
	Mean period value																	
	SI Unit	ºC					g/s	W	VAC	A	Hz	W				W/W	%	%

Other quantities	Test period mean value	Unit
Ambient conditions (data loggers / control room)		
- air temperature, dry bulb		°C
- atmospheric pressure		kPa
Calorimeter (Outdoor side room)		
- power input to the room compartment		kW
- heat extracted from compartment (room coil rejected)		kW
- Heat leakage to outer compartment (excluding leakage to indoor room room)		W
- ambient temperature around the room		°C
- Specific enthalpy of water or steam supplied to the room		J/Kg
- mass flow rate of water or steam supplied to the room		kg/s

Other quantities	Test period mean value	Unit
Calorimeter (indoor side room)		
- power input to the room compartment		kW
- heat extracted from calorimeter (room coil rejected)		kW
- ambient temperature around the room		°C
- Heat leakage to the outer compartment		W
- Specific enthalpy of water or steam supplied to the room		J/kg
- mass flow rate of water or steam supplied to the room		kg/s
Heat leakage		
- Heat leakage through separating partition from indoor room to outdoor room		W



Test results template for half load test done according to TCVN 6573:2013

TEST RESULTS SET IDENTIFICATION CODE	P_S_LC2_R

Standard rated cooling capacity test conditions for moderate climate T1 according to TCVN 6576:2013

Outdoor room		Indoor room	
Dry bulb	Wet bulb	Dry bulb	Wet bulb
35	24	27	19

UUT operating parameters	Declared	Measured
Compressor frequency (Hz)		
Outdoor fan speed (RPM)		
Indoor fan speed (RPM)		
NOTES:		

UUT load requierement	Half load
Test conditions set (1 for full load and 2 for half load)	2
Test index number	

Equilibrium period (minutes)	
Test period (minutes)	
Data sampling frequency (Hz)	

		Outdoor side UUT		Indoor side UUT				UUT power input	UUT power supply			UUT indoor measured cooling capacities			UUT outdoor measured cooling capacity
		Air inlet temperature				Water Condensate						Total	Latent	Sensible	
		DB	WB	DB	WB	Temperature	Mass flow rate		Voltage (VAC)	Current (A)	Frequency (Hz)				
Equilibirum period	Maximum value														
	Minimum value														
	Average period value														
	SI Unit	°C					g/s	W	VAC	A	Hz	W			

		Outdoor side UUT		Indoor side UUT				UUT power input	UUT power supply			UUT indoor measured cooling capacities			UUT outdoor measured cooling capacity	EER	Measurement uncertainties	
		Air inlet temperature				Water Condensate						Total	Latent	Sensible			EER	Total cooling capacity
		DB	WB	DB	WB	Temperature	Mass flow rate		Voltage (VAC)	Current (A)	Frequency (Hz)							
Test period	Maximum value																	
	Minimum value																	
	Mean period value																	
	SI Unit	°C					g/s	W	VAC	A	Hz	W				W/W	%	%

Other quantities	Test period mean value	Unit
Ambient conditions (data loggers / control room)		
- air temperature, dry bulb		°C
- atmospheric pressure		kPa
Calorimeter (Outdoor side room)		
- power input to the room compartment		kW
- heat extracted from compartment (room coil rejected)		kW
- Heat leakage to outer compartment (excluding leakage to indoor room room)		W
- ambient temperature around the room		°C
- Specific enthalpy of water or steam supplied to the room		J/Kg
- mass flow rate of water or steam supplied to the room		kg/s

Other quantities	Test period mean value	Unit
Calorimeter (indoor side room)		
- power input to the room compartment		kW
- heat extracted from calorimeter		kW
- ambient temperature around the room		°C
- Heat leakage to the outer compartment		W
- Specific enthalpy of water or steam supplied to the room		J/kg
- mass flow rate of water or steam supplied to the room		kg/s
Heat leakage		
- Heat leakage through separating partition from indoor room to outdoor room		W

Fill in CSPF value calculated according to TCVN 10273-1:2013 from full load and half load results

	Unique Id or result*
Laboratory	0
Sample	0
Test index number	
Test conditions	1
Qfull [W]	0
Pfull [W]	0
Test index number	2
Qhalf [W]	0
Phalf [W]	0

Unique Test Id code for Qfull, Pfull is:	
P0_S0_LC1_R	
Unique test Id code for Qhalf, Phalf is:	
P0_S0_LC2_R	
Unique test Id code for CSPF is:	
P0_S0_LC1_LC2_R	
CSPF	

*This column is automatically filled from previous pages

Designated energy efficiency level from CSPF according to TCVN 7830:2015

LEVEL	

Appendix C: Detailed Results by Parameter

Full load Cooling Capacity - $\phi_{ful}(35)$

Participating laboratories testing and analyses results for full-load cooling capacity are presented in the tables below. The data in orange-highlighted cells is estimated.

$\phi_{ful}(35)$, LC1 (W)	S1		S2		S3	
	R1	R2	R1	R2	R1	R2
P1	3302	3334	3395	3387	3328	3352
P2	3386	3416	3399	3416	3404	3402
P3	3311	3294	3338	3355	3353	3336

Statistical Parameter	$\phi_{ful}(35)$, LC1
Assigned value	3357 W
Standard deviation of reproducibility (S_R)	39 W
Relative standard deviation reproducibility (%RSD)	1.2%
Interval mean ± 2 S_R	[3280 ; 3435]
Reproducibility limit (R)	108 W
Relative reproducibility limit	3.2%

Participating Laboratory	*Z-score*
P1	-0.19
P2	1.20
P3	-0.67

Full Load Power Input - $P_{ful}(35)$

Participating laboratories testing and analyses results for full-load power input are presented in the tables below. The data in orange-highlighted cells is estimated.

$P_{ful}(35)$, LC1 (W)	S1		S2		S3	
	R1	R2	R1	R2	R1	R2
P1	1277	1288	1297	1298	1258	1258
P2	1278	1290	1283	1306	1283	1269
P3	1264	1242	1250	1272	1251	1229

Statistical Parameter	$P_{ful}(35)$, LC1
Assigned value	1277 W
Standard deviation of reproducibility (S_R)	16 W
Relative standard deviation reproducibility (%RSD)	1.2%
Interval mean ± 2 S_R	[1246 ; 1309]
Reproducibility limit (R)	44 W
Relative reproducibility limit	3.5 %

Participating Laboratory	*Z-score*
P1	0.14
P2	0.50
P3	-1.19

Full Load Energy Efficiency Ratio - EER_{ful}

Participating laboratories testing and analyses results for full-load Energy Efficiency Ratio are presented in the tables below. The data in orange-highlighted cells is estimated.

EER_{ful}, LC1	S1		S2		S3	
	R1	R2	R1	R2	R1	R2
P1	2.58	2.59	2.62	2.61	2.65	2.67
P2	2.65	2.65	2.61	2.62	2.65	2.68
P3	2.62	2.61	2.67	2.68	2.68	2.67

Statistical Parameter	EER_{ful}, LC1
Assigned value	2.64
Standard deviation of reproducibility (S_R)	0.03
Relative standard deviation reproducibility (%RSD)	1.3%
Interval mean ± 2 S_R	[2.58 ; 2.70]
Reproducibility limit (R)	0.1
Relative reproducibility limit	3.7%

Participating Laboratory	*Z-score*
P1	-0.60
P2	0.06
P3	0.40

Half Load Cooling Capacity - $\phi_{haf}(35)$

Participating laboratories testing and analyses results for half load cooling capacity are presented in the tables below. The data in orange-highlighted cells is estimated.

$\phi_{haf}(35)$, LC2 (W)	S1		S2		S3	
	R1	R2	R1	R2	R1	R2
P1	1626	1625	1666	1659	1637	1667
P2	1646	1636	1672	1673	1645	1638
P3	1680	1670	1687	1688	1692	1685

Statistical Parameter	$\phi_{ful}(35)$, LC2
Assigned value	1654 W
Standard deviation of reproducibility (S_R)	16 W
Relative standard deviation reproducibility (%RSD)	1.0 %
Interval mean ± 2 S_R	[1622 ; 1686]
Reproducibility limit (R)	45
Relative reproducibility limit	2.7%

Participating Laboratory	*Z-score*
P1	-0.44
P2	-0.14
P3	1.87

Half Load Power Input - $P_{haf}(35)$

Participating laboratories testing and analyses results for half load power input are presented in the tables below. The data in orange-highlighted cells is estimated.

$P_{haf}(35)$, LC2 (W)	S1		S2		S3	
	R1	R2	R1	R2	R1	R2
P1	384	386	383	384	386	389
P2	387	388	385	385	382	383
P3	377	378	378	378	378	379

Statistical Parameter	$P_{haf}(35)$, LC2
Assigned value	383 W
Standard deviation of reproducibility (S_R)	6 W
Relative standard deviation reproducibility (%RSD)	1.5%
Interval mean ± 2 S_R	[371 ; 394] W
Reproducibility limit (R)	16 W
Relative reproducibility limit	4.2%

Participating Laboratory	*Z-score*
P1	0.48
P2	0.42
P3	-0.79

Half Load Energy Efficiency Ratio - EER_{haf}

Participating laboratories testing and analyses results for half load Energy Efficiency Ratio are presented in the tables below. The data in orange-highlighted cells is estimated.

EER_{haf}, LC2	S1		S2		S3	
	R1	R2	R1	R2	R1	R2
P1	4.21	4.19	4.34	4.31	4.24	4.29
P2	4.25	4.21	4.34	4.34	4.31	4.28
P3	4.46	4.42	4.47	4.47	4.48	4.45

Statistical Parameter	EER_{haf}, LC2
Assigned value	4.30
Standard deviation of reproducibility (S_R)	0.05
Relative standard deviation reproducibility (%RSD)	1.6 %
Interval mean ± 2 S_R	[4.17 ; 4.44]
Reproducibility limit (R)	0.19
Relative reproducibility limit	4.5%

Participating Laboratory	*Z-score*	*Alternative Z-score**
P1	-0.57	-0.44
P2	-0.20	-0.16
P3	2.26	1.75

Note: Alternative Z-score* was obtained using a standard deviation for the reproducibility of 4.25% (U(CSPF) = 8.5% for k=2, 95% confidence level).

Cooling Seasonal Performance Factor - CSPF

Participating laboratories dimensionless results are presented below[18].

Half load	S1		S2		S3	
	R1	R2	R1	R2	R1	R2
P1	4.70	4.68	4.82	4.78	4.71	4.77
P2	4.73	4.69	4.82	4.82	4.78	4.76
P3	4.93	4.90	4.95	4.94	4.97	4.92

Statistical Parameter	CSPF
Assigned value	4.78
Standard deviation of reproducibility (S_R)	0.05
Relative standard deviation reproducibility (%RSD)	1.4%
Interval mean ± 2 S_R	[4.65 ; 4.92]
Reproducibility limit (R)	0.19
Relative reproducibility limit	3.9%

Participating Laboratory	*Z-score*	*Alternative Z-score**
P1	-0.59	-0.19
P2	-0.23	-0.08
P3	2.30	0.75

Note: Alternative Z-score* was obtained using a standard deviation for the reproducibility of 4.25% (U(CSPF) = 8.5% for k=2, 95% confidence level).

Full load Sensible cooling capacity ($\phi_{sc,LC1}$) and Latent cooling capacity ($\phi_{d,LC1}$)

$\phi_{sc,LC1}$ (W)	S1		S2		S3	
	R1	R2	R1	R2	R1	R2
P1	2545	2589	2594	2565	2561	2565
P2	2568	2608	2591	2604	2621	2627
P3	2769	2755	2878	2892	2826	2812

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[18] Refer to TCVN 10273-1 for CSPF calculation algorithm.

$\phi_{d,LC2}$ (W)	S1		S2		S3	
	R1	**R2**	**R1**	**R2**	**R1**	**R2**
P1	758	746	802	823	822	788
P2	818	809	808	812	783	775
P3	542	539	460	462	527	524

Statistical Parameter	$\phi_{sc,LC1}$	$\phi_{d,LC1}$	$\phi_{ful(35)}$
Assigned value	2617 W	785 W	3357 W
Standard deviation of reproducibility (S_R)	65 W	33 W	39 W
Relative standard deviation reproducibility (%RSD)	2.5%	4.2%	1.15%
Interval mean ± 2 S_R	[2486 ; 2748]	[720 ; 851]	[3280 ; 3435]
Reproducibility limit (R)	183 W	92 W	108 W
Relative reproducibility limit	7.0%	11.7%	3.2%

Participating Laboratory	*Z-score*		
	$\phi_{sc,LC1}$	$\phi_{d,LC1}$	$\phi_{ful(35)}$
P1	-0.72	0.14	-0.19
P2	-0.21	0.47	1.20
P3	3.14	-8.43	-0.67

Half load Sensible cooling capacity ($\phi_{sc,LC2}$) and Latent cooling capacity ($\phi_{d,LC2}$)

$\phi_{sc,LC2}$ (W)	S1		S2		S3	
	R1	**R2**	**R1**	**R2**	**R1**	**R2**
P1	1562	1554	1631	1591	1534	1656
P2	1622	1611	1667	1670	1636	1600
P3	1646	1630	1664	1681	1661	1644

$\phi_{d,LC2}$ (W)	S1		S2		S3	
	R1	**R2**	**R1**	**R2**	**R1**	**R2**
P1	64	71	34	67	103	12
P2	24	25	5	4	10	38
P3	34	40	22	7	32	41

Statistical Parameter	$\phi_{sc,LC2}$	$\phi_{d,LC2}$	$\phi_{ful(35)}$
Assigned value	1626 W	34 W	1654 W
Standard deviation of reproducibility (S_R)	45 W	25 W	16 W
Relative standard deviation reproducibility (%RSD)	2.8%	74.1%	1.0 %
Interval mean ± 2 S_R	[1536 ; 1716]	[-17 ; 85]	[1622 ; 1686]
Reproducibility limit (R)	126 W	71 W	45 W
Relative reproducibility limit	7.8%	207.6%	2.7%

Participating Laboratory	*Z-score*		
	$\phi_{sc,LC2}$	$\phi_{d,LC2}$	$\phi_{ful(35)}$
P1	-0.85	0.96	-0.44
P2	0.18	-0.65	-0.14
P3	0.62	-0.19	1.87

Energy Efficiency Level

Full load	S1		S2		S3	
	R1	R2	R1	R2	R1	R2
P1	5	5	5	5	5	5
P2	5	5	5	5	5	5
P3	5	5	5	5	5	5