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# 1.0 TESTING, ADJUSTING, BALANCING AND COMMISIONING REQUIREMENTS

## 1.1 GENERAL

This section specifies the requirements for all testing, adjusting, balancing and commissioning (TABC) of mechanical works to be carried out under the contract. The objectives of TABC are;

i. To verify the delivered materials are as per approved specification and good physical condition.

ii. To verify the installation works are carried out in accordance to specification and good engineering practises.

iii. To verify the performance in terms of functionality, safety, maintainability and operational ability of the installed equipment/systems meet the specified design intention through series of tests and adjustments.

iv. To ensure all test results are systematically recorded and verified prior to system commissioning.

TABC works are divided into four stages as the following;

i. Pre Delivery stage.

ii. Delivery stage.

iii. Installation stage.

iv. Functional Performance Test stage.

Contractor shall submit Inspection and Testing Plan (ITP) of TABC works to be carried out in accordance to this specification for Superintending Officer (S.O) review and approval.

## 1.2 INSPECTION AND TESTING PLAN (ITP)

ITP shall consist of;

i. List of all TABC Requirement

All TABC works with specific scope and boundaries shall be clearly stated at every stage of TABC works.

ii. TABC Work Schedules

TABC work schedules shall be integrated into main project schedules.

iii. Method Statements

TABC method statements shall consists of TABC procedures, responsibilities, necessary tools, measuring equipment and accuracy, consumables and acceptance criteria. Type of test required is listed in Schedule of Inspection and Testing.

Method statements and acceptance criteria for all equipment installation stage inspection and functional performance testing shall be endorsed by manufacturer or manufacturer's valid representative.

Acceptance criteria shall be stated as per Schedule of Design Requirements, technical specification or any applicable standards.

ITP shall be updated for any changes and resubmitted to the S.O/S.O's representative for approval.

Prior to the commencement of the TABC works as per approved ITP, contractor shall issue Request for Inspection and Testing (RFIT) to the S.O. During the TABC, contractor shall have his supervising foremen and mechanics available to aid the testing and to perform any adjustments as directed. The TABC works shall be carried out under the direction of experienced personnel and witnessed by S.O or S.O's representatives. No subsequent installation works shall proceed without S.O's approval of the test result.

Depending on the specific demands of individual installation, S.O's Representative may require additional or substitute testing works in regard to any elements in the installation other than those indicated in this specification.

***Table 1: Sample of Inspection and Testing Plan***

| Stage | Inspection / Test Name | Scope and Boundaries | Responsibility | Method Statement | Test Form No | Expected Date |
|---|---|---|---|---|---|---|
| Pre-Delivery Stage | Switchboard Test (if applicable) | Switch Board / Control Panel | Manufacturer | MS-ITP-PDI-02 | TF-02 | Feb-17 |
| Delivery Stage | Equipment verification and physical Inspection | VRF outdoor and indoor Unit | Contractor | MS-ITP-PDI-03 | TF-03 | Mar-17 |
| Installation Stage | Leak test | Pipe & equipment | Contractor | MS-ITP-PDI-04 | TF-04 | Mar-17 |
| | Support and hanger Inspection | Equipment, piping | Contractor | MS-ITP-PDI-05 | TF-06 | Jun-17 |
| | Charging gas | pipe | Contractor | MS-ITP-PDI-05 | TF-07 | Jun-17 |
| | Cable continuity and insulation test | Cable & wiring | Contractor | MS-ITP-PDI-05 | TF-08 | Jun-17 |
| | Gradient Pipe Test | Drain pipe | Contractor | MS-ITP-PDI-05 | TF-09 | Jun-17 |
| | Visual Inspection | VRF Unit , equipment and piping | Contractor | MS-ITP-PDI-05 | TF-09 | Jun-17 |
| Functional Performance Stage | VRF unit | Performance, Pressure, Control system, Running Amp, Temperature, Power input, Vibration, noise | Contractor | MS-ITP-PDI-05 | TF-10 | Jun-17 |

### 1.2.1 Pre Delivery Stage

Pre-delivery inspection and performance test shall be conducted if stated in the Schedule of Inspection and Testing requirements. These tests shall be witnessed by the government's representative if deemed necessary by the S.O. All travelling, food and accommodation cost of the government's representatives related to witnessed performance test shall be borne by the government.

A factory test shall be define as any test of equipment required as stated in the contract, conducted at manufacturer's plant or at an independent and accredited test facility approved by the S.O.

Performance test method statement, test standard and acceptance criteria shall be submitted to S.O for approval prior to such testing. The manufacturer shall produce a signed test report to be submitted for S.O's approval. Manufacturer shall be responsible for any reworks and adjustment of the equipment if the test results fail to comply with the approved acceptance criteria.

#### 1.2.1.1 Switchboard Factory Test

Switchboard pre-delivery acceptance test shall be carried out before delivery to site. The main circuits and the auxiliary circuits shall be tested to verify dielectric properties with power-frequency test voltage of 2500Vac for 1 minute and insulation resistance under test voltage of 1000V. Switchboard testing shall include inspection and checking of wiring, electrical continuity, functionality of the protective circuits, connections and effectiveness of mechanical actuating elements and logic circuit interlock. Test Results or Certificate duly certified by Competent Person as in Electricity Regulations 1994 shall be issued for every switchboard supplied and installed.

Type testing for switchboard as per categorization shall be as per Table 2 below:

***Table 2: Switchboard Testing***

| Category | Current Rating | Registration and type of test report |
|---|---|---|
| I | I ≤ 600 A | Suruhanjaya Tenaga (S.T) |
| II | 600 A ≤ I ≤ 1200 A | Suruhanjaya Tenaga (S.T) & Partial Type Test in accordance with MS IEC 60439-1<br>(i) Short Circuit Test<br>(ii) Temperature Rise Test |
| III | I ≥ 1200 A | Suruhanjaya Tenaga & Full Type Test in accordance with MS IEC 60439-1 |

### 1.2.2 Delivery Stage

All incoming material and equipment to site shall be inspected to verify that delivered items are complying with contract specification, as per approved materials and good physical conditions. Materials delivered to site shall be free from defects and adequately protected against site conditions.

### 1.2.3 Installation Stage

List of inspection and testing works during installation as per Table 3;

***Table 3 : Test List In Installation Stage***

| Inspection / Test name | System/Component | Objectives |
|---|---|---|
| Visual Inspection | VRF Unit, equipment and piping | Verify that all equipment installation as per technical specifications |
| Refrigerant Leak Test | Refrigerant pipe & Equipment | Verify refrigerant and integrity of all pipe joints and fittings. |
| Refrigerant Charge Test | Refrigerant gas | Verify refrigerant gas, pressure & running amp |
| Purging/Flushing | Refrigerant pipe and drain pipe | Verify that all pipes are internally clean |
| Cable Continuity Test | Electrical Cabling | Verify cable continuity effectiveness |
| Pipe Gradient Test | Drain pipe | Verify condensate drain pipe gradient as per technical specifications. |

1.2.3.1 Visual Inspection

All installation shall be subjected to technical specifications and drawings.

1.2.3.2 Refrigerant Leak Test

During test, all brazing joints, bends, fitting and valves shall be visual checked for any leaks or deformations for the entire piping system. Expanded conditions of all piping shall be carefully studied and any necessary change in hangers, anchors or guide locations shall be made.

Use nitrogen gas or electronic leak detector for refrigerant gas leakage. All pipes, valves, fitting, etc. shall be tested to the minimum of 1.5 times the working pressure, whichever is greater for period of 2 hours.

Pressure and leak tests of refrigerant piping systems are normally carried out on completion of the system, before pipework is insulated.

1.2.3.3 Refrigerant Charge Test

Refrigerant charge test shall be as per manufacturer recommendation.

1.2.3.4 Purging/ Flushing

To eliminate the probability of such chocking and damage, the internal surfaces of the piping system network need to be flushed clean.

Components that can be potentially damaged/choked by particles or debris from the flushing process shall be isolated from the flushing circuit and cleaned individually.

1.2.3.5 Cable Continuity Test

Cable continuity test shall be performed on each power cable by ohmmeter method. Perform an acceptance test on cables, including terminations and joints, after cable system installation and before the cable system is placed into service. In accordance with ANSI/IEEE 400, by means of direct voltage (dc) and recorded in the testing form.

1.2.3.6 Pipe Gradient Test

The entire drain pipe carrying condensate water from equipment air conditioning shall be tested with water flow.

### 1.2.4 Functional Performance Test

List of functional performance test are as the following. All Functional Performance Test shall commence after all inspection and testing during installation stage has been completed.

1.2.4.1 Pre-Functional Performance Test

a. Accuracy Test

Before the commencement of the functional performance test, the contractor shall carry out field calibration check for the functional accuracy of measuring, regulating and similar equipment, forming part of installation including gauges, transducers, sensors, switches and meters.

All calibration certificates of all measuring facility shall be submitted to the S.O.

1.2.4.2 Variable Refrigerant Flow Unit (VRF)

***Table 4: VRF Inspection and Test***

| Inspection /Test name | Objectives |
|---|---|
| VRF General Inspection | Verify that equipment physical conditions are acceptable. |
| Volumetric Air Flow Test | Verify that air flow is as per design flow. |
| Refrigerant Piping Inspection | Verify insulation/ condensation and refrigeration leakage |
| VRF Refrigerant High/Low Pressure Protection Test | Verify VRF protection against refrigerant high/low pressure condition. |
| VRF Control Test | Verify that control system function as per manufacturer. |
| Noise Level Test | Verify noise level within permissible limit. |
| VRF Load Test | a) Verify VRF performance as per published performance data.<br>b) Verify VRF ability to perform at peak and various anticipated load within allowable VRF operating parameters. |

a. VRF General Inspection

VRF shall be visually inspected for any deviation from approved shop drawings, approved material and identification of any physical defects that may arise during installation works.

b. Volumetric Air Flow Test

Air flow measurement in ducts shall be measured by either pitot tube traverse average method or vane anemometer (depending on site conditions). Fresh air flow rate shall be measured via vane anemometer or pitot static tube (single point). All points for pitot tube insertion shall be prepared and reseal adequately after measurement.

c. Refrigerant Piping Inspection

Refrigerant piping installation shall be inspected for any traces of leakage, insulation and condensation.

d. VRF Refrigerant High/Low Pressure Protection Test

VRF ability to cut off in the event of excessively high refrigerant pressure and low refrigerant pressure. The test shall be carry out by manipulating high/low pressure switch setting and observe tripping of compressors.

e. VRF Control Test

Each VRF control system shall be tested against their design as detail out in Table 5.

***Table 5: VRF Control Test Requirements***

| Type of VRF Control | Description |
|---|---|
| Temperature Control | Adjust thermostat setting above and below controlled parameter value (e.g. return air or space air temperature) and observe response in compressor on/off. |
| Damper Shut Off | For motorised fresh air damper application, ensure damper is closed when VRF is shut off. |
| Fire Mode Test | Test interlocking between smoke detector and VRF trip (control panel). Aerosol spray shall be used to activate smoke detectors and observe tripping of VRF. |

f. Noise Level Test

Noise level measurement shall be carried out via Sound Level Meter Type 2 / Class 2 General Purpose Grade for field use ± 1.0 dB. All measurement points are at a height of 1.5m from the floor at every enclosed space/zone. Measurement shall be made when VRF is on and another one when in off condition (background noise level).

g. VRF Load Test

After completion of VRF control test, VRF load test shall then be carried out by continuing to operate the VRF system for 3 consecutive days at design operating hours with active sequencing control and all duty indoor units switched on. Actual field performance data shall be compared with published VRF performance data from the manufacturer.

All VRF operating parameters shall be logged at 10 minutes interval which include data as per Table 6, and VRF capacity turn-down ratio (ratio of minimum recorded load and rated capacity) shall be tabulated.

Full load capacity of VRF system may not be achieved due to non-availability of cooling load of the actual building. Recorded VRF system load shall be corrected to include effect of

human, lighting and weather related load at design conditions in order to demonstrate VRF system ability to serve peak and partial cooling load as per design.

All VRF and switchboard operating parameters shall then be analysed by manufacturer and parameters that are beyond VRF recommended operating range shall be identified and rectified.

***Table 6: VRF Operating Variables***

| No | Data | Type of Measurements |
|---|---|---|
| 1 | Electrical power input of VRF system | Logged data for VRF. One-off measurement is allowed for constant load motors. |
| 2 | Outdoor air dry/wet bulb temperature | Logged data from data logger. |
| 3 | Condenser saturated temperature/pressure. | |
| 4 | Compressor %FLA or running current. | |
| 5 | Compressor discharge temperature. | |

1.2.4.3 Switchboard and Power Supply

List of Switchboard and power supply inspection and test name are listed in Table 7. Detail method statement for testing shall be submitted conforming to the test requirements in this specification. Only competent as in Electricity Regulations 1994 shall conduct the switchboard testing.

***Table 7: Switchboard and Power Supply Inspection and Test Requirements***

| Inspection / Test name | Description |
|---|---|
| Switchboard General Inspection | • Verify physical switchboard components are as per specification.<br>• Check for tripping setting and system trip<br>• Check for wiring, motor insulation and record data.<br>• Check for cable terminal tightness.<br>• Check for equipment and panel grounding connection.<br>• Check for any sign for cable heating. Cable temperature shall be measured and verify against IEEE standards for temperature rise during full load.<br>• Check for voltmeter, and ammeter function and accuracy record running voltage and ampere.<br>• Check for control circuit function as intended.<br>• Check for contractors, relays, ACB, MCCB, MCB, type, size and ratings as per specification. |
| Power Supply Test | • Verify that power supply parameters are within permissible range, safety protections are in place and physical condition of switch board and cabling works are acceptable as per specification and approved shop drawings.<br>• Verify rotation of equipment/phase sequencing according to manufacturer recommendation<br>• Verify phase protection relay installation and function. |
| Overcurrent and Earth Fault Protection | • Circuit breaker and Earth Fault Protection calibration and discrimination shall be conducted and coordinated between electrical contactors.<br>• Circuit breaker and Earth Fault Protection shall be tested against simulated leakage current.<br>• IDMT tripping delay shall be selected/programmed suitable for equipment starting overloading preventing nuisance tripping during starting. |

1.2.4.4 Air Distribution

List of air distribution system inspection and test name are listed in Table 8:

***Table 8: Air Distribution System Inspection and Test Name***

| Inspection / Test name | Objectives |
|---|---|
| Room Condition Test | Verify temperature, humidity and air velocity is within specification. |
| Pressurisation Test | Verify operating space differential pressure is within specification. |
| Duct Condensation Inspection | Verify insulation performance to prevent duct condensation. |

a. Room Condition Test

Space temperature and relative humidity shall be recorded either by temperature and humidity data logger or spot measurements using sling psychrometer as per S.O instruction. Time of measurement shall coincide with VRF test period.

Temperature and humidity data logger shall be used to measure temperature and humidity at these locations;

- Location where occupants are known to spend most of their time.
- Furthest zone and high heat load area.
- Main return duct
- Critical areas such as OT room, ICU/CCU/NICU room, Medical Record, High Dependency Ward (HDW), Isolation Room, Central Sterile Supply Department (CSSD), Laboratory, Medical store, Server room as decided by S.O.

For all other areas, spot measurements using sling psychrometer shall be used during anticipated peak and minimum cooling load period as per S.O instructions. Air velocity in spaces shall be measured using hot wire anemometer.

Building operation and weather conditions during testing such as outdoor air temperature and humidity, internal load factors i.e. population, lighting and equipments data shall be recorded.

Room condition test report shall be submitted consisting of the descriptive statistic of the measured data i.e. mean, max, min, range, frequency bin analysis, their respective location and building operation and weather conditions data during testing.

b. Pressurisation Test

In zone where differential pressure requirements are specified, pressurisation test shall be performed via pressure differential meter and verified by smoke test.

c. Duct Condensation Inspection

Visual check shall be carried out to determine any traces of condensation on duct surfaces. Any traces of condensation shall be reported.

1.2.4.5 Infiltration Test

Any path for infiltration of outside air or untreated air to the air conditioned space shall be identified visually and reported.

1.2.4.6 Wall Insulation and Sprayed PU Foam Insulation Effectiveness Test

Visual check on trace of condensation at all wall or slab surfaces shall be carried out and reported.

1.2.4.7 Mechanical Ventilation Test

List of mechanical ventilation system inspection and test name are listed in Table 9.

***Table 9: Mechanical Ventilation System Inspection and Test Name***

| Inspection /Test name | Objectives |
|---|---|
| Fan General Inspection | Verify that equipment physical conditions are acceptable. |
| Fan Volumetric Air Flow Test | Verify that air flow is as per design flow. |
| Fan Control Test | Verify that control system function as per design control strategies. |
| Noise Level Test | Verify noise level within permissible limit. |

a. Fan General inspection

Fan shall be visually inspected for any deviation from approved shop drawings, approved material and identification of any physical defects that may arise during installation works.

b. Fan Volumetric Air Flow test

Air flow measurement in ducts shall be measured by either pitot tube traverse average method or vane anemometer (depending on site conditions). All points for pitot tube insertion shall be prepared and reseal adequately after measurement. For ductless fan, vane anemometer shall be used.

c. Fan Control test

Fan control test shall be carried out as per Table 9:

***Table 10: Fan Control Test List***

| Type of Fan Control | Method |
|---|---|
| Temperature Control | Adjust thermostat setting above and below controlled parameter value and observe response in fan operation. Temperature reading of the served space shall be recorded via temperature data logger for 24 hrs fan operation. |
| Schedule operation | Adjust timer schedule and observe response in fan operation. |
| $CO_2$ Control | Adjust $CO_2$ sensor set point above and below controlled design value and observe response in fan operation. $CO_2$ reading of the served space shall be recorded via $CO_2$ meter (one off measurement). |

d. Noise Level Test

Noise level measurement shall be carried out via Sound Level Meter Type 2 / Class 2 General Purpose Grade for field use ± 1.0 dB. All measurement points are at a height of 1.5m from the floor at every enclosed space/zone. Measurement shall be made when fan is on and another one when in off condition (background noise level).

## 1.3 COMMISSIONING

Commissioning includes achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria.

All completed test forms and test summary shall be submitted to S.O's representative for final review and approval. Having satisfied that all appropriate tests have been conducted and the performance of the installation meet the design objectives; S.O's representative will issue or recommends to the S.O for the issuance of Certificate of Practical Completion (CPC).

### 1.3.1 Handing Over Documents

After issuance of Certificate of Practical Completion, contractor shall submit all related project handing over documents as the following;

a) Test Report complete with fully verified Inspection checklist and Test Forms.
b) Defects List
c) Operation and Maintenance Manual which includes
    a. *Standard/ Manual Operating Procedures*
    b. *Preventive Maintenance Schedule and Manual*
    c. *Equipment/Product Engineering Data.*
    d. *Operation set point (temperature, relative humidity, pressure etc)*
    e. *Switchboard overload setting and set points*
    f. *Control valve setting*
    g. *Contractor and manufacturer contact details*
    h. *Circuit Diagrams*
    i. *Inventory List*
d) As-Built drawings
e) Schedule of System Familiarization Program to end users.

### 1.3.2 System Familiarisation Program

In-class and practical System Familiarisation Program shall be conducted to the personnel nominated by S.O within one (1) month of issuance of Certificate of Practical Completion.

Program shall focus on:

- Overview of design concept and objectives
- Operation instruction & competency requirement
- Maintenance procedures
- Critical operating parameters monitoring and
- Emergency response & safety procedures.
- Environmental protection procedures.

Contractor shall submit program modules and materials to S.O for approval prior to commencement of training. Particulars of trainee shall be recorded and send to S.O for records.

# 2.0 POST OCCUPANCY EVALUATION

Post Occupancy Evaluation shall be performed by the contractor one (1) month before the end of defect liability period.

Space temperature and relative humidity shall be measured at all respective temperature zone. Temperature, relative humidity and air speed shall be within specification. Any adjustment to the system are required if the data deviate from the specification.

A survey shall be carried out to evaluate user experiences with the air conditioning and ventilation system from comfort, operation ability or any other related problems. Survey form as in Table 11 shall be used. All survey form shall be submitted to S.O for references.

***Table 11: Post Occupancy Evaluation Form***

| | | | |
|---|---|---|---|
| Block | | | |
| Floor | | | |
| Space | | | |
| VRF no | | | |
| Room Conditions | | | |
| *Parameters* | *Measured value* | | *Comment* |
| *Dry Bulb Temperature* | | *$^{o}C$* | |
| *Relative Humidity* | | *%* | |
| User Survey | | | |
| 1) Any difficulty in operating the system? If Yes, please state the details. | | | |
| | | | |
| 2) Any specific problem system? If Yes, please state the details. | | | |
| | | | |

# 3.0 TESTING INSTRUMENTS & ACCESSORIES

All permanent sensors and gauges use for measurement of temperature, pressure and flow shall be factory calibrated and all calibration certificates shall be submitted to S.O prior to testing works.

The contractor shall provide all necessary testing, calibrating instruments and labour required for the testing, adjusting, balancing and commissioning of the air-conditioning and mechanical ventilation system installed under the contract.

The Contractor shall also allow for any necessary replacement of parts in order to achieve the conditions specified in the drawings and specification. Provisional sum for that purpose is provided in Schedule of Price.

Testing instruments specification shall be but not limited to as per Table 12:

***Table 12 : Testing Instruments***

| Measurement | Type | Accuracy |
|---|---|---|
| Dry bulb and humidity (logging) | Temperature and Relative Humidity data logger | *Temperature measurement accuracy: ±0.5 °C (0°C<T<30°C) and 1.5% of reading at 30°C<T<70°C). Humidity measurement accuracy: ±2%RH (from 15°C to 25°C)* |
| Dry bulb and humidity (One off) | Sling Psychrometer | *± 0.5°C* |
| Duct thickness | Vernier caliper | *± 0.01 mm* |
| Ampere | Clampmeter (instantaneous) | *2.0% ± 5 digits (45-65Hz)* |
| Voltage | Clampmeter (instantaneous) | *1.5% ± 5 digits* |
| Combined power, ampere, voltage, power factor and Energy | Power/Energy logger (continuous) | *Active Power: ±(1.2% of reading + 0.005% of range) (For PF≥0.99); ±(1.2% of reading + 7 x (1-PF) + 0.005% of range) (from 0.6 PF to 0.98PF)* |
| Noise (Full spectrum) | Sound Level Meter Class 1 | *Class 1 as per IEC 61672-1:2002* |
| Noise (Average) | Sound Level Meter Class 2 | *Class 1 as per IEC 61672-1:2002* |
| Vibration | Vibration Analyser | *± 5% of reading (from 0.01 g to 50 g); where "g" in meter per second square.* |
| Surface temperature | Infrared thermometer | *Display accuracy ±1.0°C* |