Commissioning Process Standard for HVAC Systems

ISHRAE Standard 10003-2020

ISHRAE®
Indian Society of Heating, Refrigerating and Air Conditioning Engineers

THIS PAGE IS INTENTIONALLY LEFT BLANK

Commissioning Process Standard for HVAC Systems

ISHRAE Standard 10003-2020

ISHRAE®

ISHRAE (the Indian Society of Heating Refrigeration and Air conditioning Engineers) is a society of HVAC&R professionals. The standard developed by ISHRAE Standards Development Organization (ISHRAE SDO) complies with the Accreditation criteria document of Quality Council of India (QCI). This standard was developed through consensus process by balanced stakeholders participation as Standards Technical Committee (STC) members and also taking in to consideration of the comments received from public wide circulation on ISHRAE website.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISHRAE shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISHRAE list of patent declarations received. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission.

Permission can be requested from ISHRAE at the address below or by writing to the e-mail mentioned below:

Contact us:
ISHRAE HQ
1103-1104, 11th Floor,
Chiranjiv Tower, 43, Nehru Place,
New Delhi-110019, India

Tel. : 011-4163 5655
011-2923 4925
Email : chair_scc@ishraehq.in
Website : www.ishrae.in

ISHRAE Commissioning Standard Committee

Name	Role	Stakeholder Group	Organization
K. Ramachandran	Chair (TG-Chair: Installation and commissioning)	Chair	Eskayem Consultants Pvt. Ltd.
Shankar Sapaliga	Co-Chair	Specifier	International Copper Association India
Dr. Jyotirmay Mathur	SCC-Chair	Academia	Malaviya National Institute of Technology
V. Manjunath	SCC-Co Chair	Testing	Underwriters Laboratories Inc.
Ajaj A. Kazi	STC Member	Specifier	Voltas Limited
Ashish Rakheja	STC Member	Specifier	AEON Integrated Buiding Design Consultants LLP
Kundan Singh Adhikari	Secretary - SDO	Secretary - SDO	ISHRAE
M. Selvarasu	STC Member	Specifier	LEAD Consultancy And Engineering Services (India) Private Limited
Maija Virta	STC Member	Specifier	Santrupti Engineers Private Limited
Prabhat Goel	STC Member	Specifier	In personal capacity
Ravi Prakash Kurkiya	STC Member	User	Green Rating for Integrated Habitat Assessment
Ravikumar P. Gondkar	STC Member	Specifier	LEAD Consultancy And Engineering Services (India) Private Limited
Rumi Engineer	STC Member	Specifier	Godrej & Boyce Mfg. Co. Ltd.
S.P. Garnaik	STC Member	Regulator	Energy Efficiency Services Limited
Sanjay Seth	STC Member	User	Green Rating for Integrated Habitat Assessment
Sandeep Dahiya	STC Member	Specifier	In personal capacity
Shankar Chatterjee	STC Member	Specifier	In personal capacity
Shiv Batra	STC Member	User	IBM India Pvt Ltd.
Dr. Shivraj Dhaka	STC Member	User	Indian Green Building Council (IGBC)
Suhaas Mathur	STC Member	User	GBCI

TABLE OF CONTENTS

TABLE OF CONTENTS...contd.

THIS PAGE IS INTENTIONALLY LEFT BLANK

FOREWORD

ASHRAE has long felt the need to establish a standard for the commissioning process of HVAC systems. Objective is to provide a structural methodology for implementing the process for systems as well as for individual components with a view to obtain a fully functional and properly balanced HVAC system with adequate documentation and trained operating and maintenance staff.

The process begins at inception of the project and continues for the life of the facility. It ensures through specified methodology that the design, construction, testing, documentation and training meets the Owners Project Requirements.

By adopting this process, the project owner can ensure compliance with quality parameters from the start of the project. By adhering to this standard, any need to modify the HVAC system post facility occupancy can be considerably eliminated.

It is strongly suggested that the commissioning authority be part of the HVAC project process. The commissioning authority shall represent the owner's needs from the inception stage to post occupancy and in fact, for the whole life of the project.

The commissioning authority can either be an employee of the owner or can be an independent professional. He / She should be experienced in facility operation and maintenance, as well as in design testing, balancing as well as in construction management and quality.

This standard is developed to help those who are implementing a quality based and cost effective process. Starting the commissioning process right at project inception will achieve maximum benefits.

Appendices are included to better understand each stage of the project. They are not mandatory but are to be used to develop guidelines and documents which may define owner's project needs as well as other stages described in the standard.

The commissioning process, commencing at project inception, is a valuable tool for the owner to control the project at each stage on a real time basis.

K. Ramachandran
Chair – Standard Technical Committee
STC – Commissioning Process Standard for HVAC Systems

THIS PAGE IS INTENTIONALLY LEFT BLANK

1.0 Purpose

The purpose of this standard is to specify the process to be followed for commissioning of Heating, Ventilating and Air Conditioning (HVAC) systems to meet Owner's Project Requirements (OPR) defined for performance and conformance to design intent approved by the owner. This standard provides input for continuous improvement in the commissioning process.

2.0 Scope

This standard defines the process of commissioning, lists the parameters to be measured, test methods, measuring and reporting method for all types of electrically driven HVAC systems to enable the project to be accepted and put to beneficial use by the project owner by conformance check as per agreed Owner's Project Requirement For new building or renovation. The standard is applicable for complete HVAC system or only selected part of the system or only selected equipment or only selected sub-assembly.

2.1 Out of Scope

This standard does not aim to define the system and equipment performance levels. Also, this standard does not define safety conformance requirements of the equipment and personnel. Wherever safety compliance requirements are defined by local or national regulatory authorities, conformance to those regulations shall be applicable.

HVAC systems based on vapour absorption chillers, evaporative cooling equipment and passive cooling systems are out of scope of this standard.

3.0 Definitions

3.1 Acceptance

A formal action taken by a person with appropriate authority to declare that aspect under consideration of the project meets defined requirements, thus permitting subsequent activities to proceed.

3.2 Accuracy

The closeness of agreement between a test result and the accepted reference value.

3.3 Back Check

A verification during the commissioning process that an agreed upon solution to a design comment has been addressed.

3.4 Balancing

The process of adjusting the flow rate of a fluid in a distribution system to achieve the design flow rate.

3.5 Basis of Design

This details the design team's approach to meet OPR and obtains owners approval for critical design decisions. It shall include HVAC requirements of each space consistent with the occupancy, activity to be carried out and desired quality of indoor air. It shall satisfy applicable technical and code requirements. Basis of design records the concepts, calculations, decisions and product selections to meet the owners project requirements (OPR) and to satisfy applicable regulatory requirements, standards and guidelines. This is a dynamic document and will be updated throughout the design and construction process.

Note: Also known as Design Criteria.

3.6 Benchmarking

The complete process containing an objective establishment step, a measurement step, a controlling step for the level of quality of the measurement results, and a comparison step. In case of this standard benchmarking has been referred to the comparison of energy usage of building under consideration to that of other similar building.

3.7 Building

A structure that has the provision of shelter for its occupants or contents as one of its main purposes, usually partially or totally enclosed and designed to stand permanently in one place. A roofed construction for which energy is used to condition the indoor climate.

3.8 Calibration

Comparing an instrument of unknown accuracy with a standard of known accuracy to detect or eliminate by adjustment any variation in the accuracy.

3.9 Commissionable system

A system designed and installed to specified requirements in such a manner as to enable commissioning to be carried out.

3.10 Commissioning

Advancement of an installation from a state of static completion to full working order meeting the specified requirements.

3.11 Commissioning authority

An owner appointed representative responsible for delivering the commissioning process activities. Commissioning authority (CxA) shall not be an employee of design and construction companies involved in the project under consideration.

3.12 Commissioning process

A quality focussed process for enhancing the delivery of a project. It is a process that defines the verification and conformance check method for all the HVAC equipment under the scope of this standard are installed, tested, operated and maintained to meet the OPR.

3.13 Commissioning process activities

The systematic activities performed for commissioning of the equipment to conform to requirements of OPR.

3.14 Commissioning process report

A written document that details activities completed as part of the commissioning process and significant findings from those activities.

Note: The report is continuously updated during the course of the project.

3.15 Commissioning check lists

A form used by commissioning agent to verify conformance of equipment and accessories through out process of commissioning including delivery of the equipment, installation accessories at site and installation of the equipment as defined by the equipment supplier to meet performance requirement defined in OPR. List of testing and inspection parameters to be verified to check the conformance of HVAC equipment to OPR.

3.16 Commissioning issue

Any non-conformance to the OPR requirement defined for the HVAC system.

3.17 Commissioning plan

The commissioning plan is a written document describing the commissioning activities and their schedule which ensures that the design, construction and operation meet the OPR. The commissioning plan shall include the scope of the process, resources required at each stage of the process as well as the agreed timelines for each stage.

3.18 Commissioning report – Final

A document that records the activities and results of the commissioning process and is developed from the commissioning plan.

3.19 Commissioning specifications

The contract documents that detail the objectives, scope and implementation of the commissioning process as developed in the commissioning plan.

3.20 Commissioning team

Individuals and agencies who through co-ordinated actions are responsible for implementing the commissioning process.

3.21 Construction phase

The construction phase involves installation, inspection, and testing of systems and assemblies to meet the Owner's project requirements.

3.22 Contract documents

The documents like design and construction contracts, price agreements, drawings, specifications and data sheets but not limited to, for effective execution of commissioning and to verify equipment meets performance requirement as defined in OPR.

3.23 Data logging

Monitoring and recording of parameters such as temperature, flow, current etc. (applicable to equipment) for a defined period and time interval using data recorders.

3.24 Deficiency

Any condition that may adversely affect the commissionability, operability or functionability of a system, equipment or component.

3.25 Design stage

The design stage involves the development of Basis of Design that meets the OPR and development of construction documents including drawings and designs.

3.26 Design check list

A form developed by the commissioning team to verify that elements of the design are in compliance with Owners Project Requirements.

3.27 Design professional

Architect or engineer of record for the project.

3.28 Energy performance

Calculated or measured amount of energy needed to meet the energy demand associated with typical use of the system.

3.29 Evaluation

Process by which performance of system or components thereof are measured and confirmed with respect to the criteria required in Owners Project Requirements.

3.30 Functional Performance testing

Testing performed to ensure that designated systems of the project meet the requirements as per OPR.

3.31 Installation verification

Observations or inspections that confirm the system or component has been installed in accordance with the contract documents and industry accepted best practices.

3.32 Issue resolution

A formal and ongoing record of concerns and their resolution.

3.33 Maintainability

A design component or construction process that will allow a system or components to be effectively maintained.

3.34 Monitoring

Observing, supervising, controlling or verifying the operations of a system.

3.35 Ongoing commissioning

A continuation of the commissioning process into post occupancy operation stage to continually improve the operation and performance of the facility.

3.36 Operation and Maintenance manual

Set of documents detailing the design, method of operation and maintenance requirements / procedures of the system.

3.37 Owner

A person or legal entity that will own the delivered facility.

3.38 Owner’s Project Requirements

A written document that details the requirements of a project and the expectations of how it will be used and operated.

Note: This is a dynamic document and will be updated throughout the design and construction process.

3.39 Performance test

The process of verifying that a material, product assembly or system meets defined performance criteria.

3.40 Precision

Ability of an instrument to produce repeatable readings of the same quantity under the same conditions.

3.41 Procedure

A defined approach that outlines the execution of a sequence of work or operation

3.42 Pre-design

The pre-design stage involves the preparation of the OPR. It also includes site analysis, construction cost analysis and budgeting to guide project management including the project schedule.

3.43 Range

The upper and lower limits of an instrument's ability to measure the value of a quantity.

3.44 Recommissioning

Application of the commissioning process requirements to a project that has once undergone the process.

3.45 Resolution - Measurement

Smallest change in a measured variable that an instrument can detect.

3.46 Resolution

Implementation of actions that correct a tested or observed deficiency.

3.47 Regulation

Process of adjusting any one or more parameters in a system to obtain specified values.

3.48 Retro commissioning

Commissioning process applied to existing buildings and systems.

3.49 Site observation reports

Reports of site inspections and observations made by the commissioning authority.

3.50 Systems manual

A system focused composite document that includes all information required for the owners to operate the system.

3.51 Test procedures

A written protocol that defines methods, personnel and expectations for tests conducted on components, systems and interfaces between systems.

3.52 Testing

Measurement and recording of system parameters to assess conformance with specifications.

3.53 Tolerance

Permissible range of variation acceptable from the design value of a measurable characteristic.

3.54 Training plan

A written document that detail expectations, schedule and deliverables of the commissioning process activities for the benefit of users.

3.55 Validation

The process by which work is verified as complete and is operating correctly.

3.56 Verification

Process by which specific documents, components, systems and interface among systems are confirmed to comply with the criteria discussed in owner's project requirements.

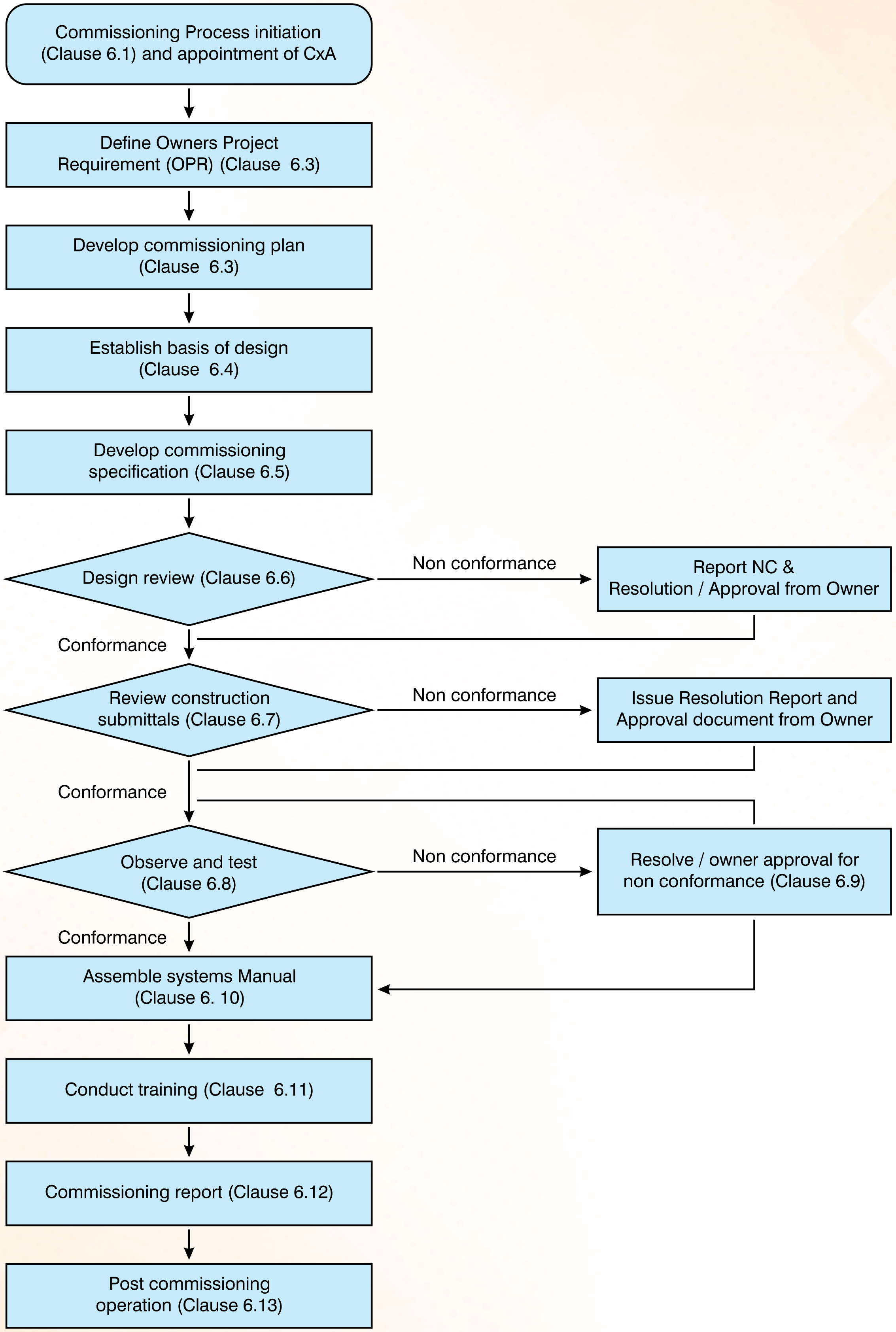
3.57 Continuous commissioning

Commissioning efforts executed after a project has been completed and accepted by the Owner.

4.0 Utilisation

4.1 Essential activities for applying the commissioning process are covered in this standard along with the sequence thereof. Deliverables and documentation at each stage of the process are established.

4.2 Following are the commissioning process activities.



4.3 Each step in the above process shall have an acceptance criterion which establishes completion and acceptance by owner / client.

Note: The commissioning authority shall verify the conformance to OPR only and shall not have authority to accept any revisions and project on behalf of the owner.

5.0 Management of Commissioning Process

5.1 Initiating the process

The owner shall be responsible for determining the scope of the commissioning plan, selecting the commissioning authority, incorporating them into project team and establishment of the commissioning budget. Owner shall direct the process, review and accept each step of the process.

Owner shall include the commissioning activities as well as the commissioning plan in the design and construction team's contracts.

5.2 Owner along with the commissioning team shall develop the Owner's Project Requirement (OPR) document. The OPR shall define the equipment, systems and assemblies covered in the scope of commissioning process. Any update to the OPR made during project life shall be approved by owner.

5.3 The commissioning plan as defined in clause 4.18 shall be developed and approved by the owner. Commissioning plan shall include the roles and responsibilities of each commissioning team member.

5.4 The Basis of Design document as defined in clause 4.5 shall be prepared and owner shall approve it.

5.5 Commissioning specifications shall be developed for all systems and assemblies being commissioned. These shall be incorporated in all relevant contract documents. Commissioning specifications shall include the list of equipment and systems to be evaluated with required check list formats and sample test forms.

5.6 Design Review shall be conducted to verify conformance of the various systems and assemblies in the design documents with the OPR. Design review shall be completed before issue of construction documents.

Note: Commissioning Design review is not a "Peer Review".

5.7 The HVAC system is installed, and put into operation during the Construction Phase of the project. During this phase, Project submittals shall be reviewed for conformance with OPR. Commissioning team shall be involved with the construction, start-up, testing and balancing of all the components and sub-assemblies of the HVAC system. The commissioning team shall review installation compliance with manufacturer's installation instructions. In addition to the components and sub-assemblies of the HVAC system, the commissioning team shall also check the conformance of aspects of Construction such as receiving and unloading of equipment, on-site storage, cleaning and closing of constructed duct work, pipe work etc as well as the stipulated indoor air quality procedures during construction phase. Passivation of installed pipes flushing and cleaning and pressure testing and leakage testing of duct work and pipe work shall also be witnessed by the commissioning team for conformance. During this stage, operation and maintenance team shall be trained as necessary.

Regular meetings of the commissioning team shall take place for co-ordinating the above activities and to identify and resolve any non-conformance.

Commissioning team shall maintain complete record of all commissioning submittals and reviews thereof and in case any of the submittals are not in conformance with the OPR shall obtain owner's approval before accepting the concerned equipment or system.

5.8 Observation and testing shall be carried out to comply with OPR and contract documents. For this, check lists, test procedures and report forms shall be developed before installation. Person responsible shall carryout test as per the test protocols. Repeat testing shall be carried out until all equipment, systems or assemblies confroms to the requirement. All check lists and test results shall be compiled into the final commissioning report. The reports shall be presented in the relevant format as specified in the annexures.

5.9 Any non-conformance identified during commissioning process shall be documented and all unresolved non-conformance shall be presented to owner and owner's acceptance shall be included in the issues resolution document which will be part of the commissioning report – final.

5.10 The systems manual shall provide all information needed to operate and maintain the buildings systems and assemblies and for training of personnel. The systems manual shall be updated during the commissioning process with respect to design, construction and operation. Owner shall approve the systems manual for use in building operations.

5.11 Operating and maintenance personnel shall be trained on the commissioned systems in accordance with a documented training plan as conformance with OPR and is accepted by the owner. Evaluation of the training imparted and documented feedback from participants shall be as per the OPR.

5.12 Commissioning Report - Final, summarizes the entire commissioning process for the benefit of the building owner and those who are entrusted with the responsibility of operating and maintaining the systems installed. The commissioning Report – Final, shall include all design and construction review reports and all unresolved issues along with a resolution. Commissioning Report – Final, shall be accepted and approved by the owner.

5.13 Post occupancy operation commissioning shall include all delayed and seasonal tests and warranty issues. This needs to be completed prior to warranty completion. All unresolved issues identified and listed during the commissioning process shall be resolved during this stage and in case any of the issues are remaining to be resolved it shall have the owner's acceptance duly recorded. Any additional training during the post occupancy period as included in the OPR document shall be completed in this stage. At the end of the post occupancy commissioning period documents such as the systems manual, unresolved issue statements, training documentation and commissioning report – final, shall all be updated and furnished to owner for his acceptance.

Annexure A (Normative)
Initiating the Commissioning Process

1.0 The purpose of this annexure is to assist the commissioning team in successfully using the commissioning process for various systems and assemblies that constitute the HVAC system for the building.

1.1 HVAC Systems range from simple unitary systems to complex and large systems employing water chilling units, pumps, water flow systems of closed hydronics for chilled water, open water distribution for condenser water, cold air distribution systems with fans, Air Handling Units, ducted air systems, several types of ventilation and exhaust systems employing large fans as well as electric drives with motors, starters, connecting cabling and wiring, control elements for control and monitoring of various parameters.

While equipment like window air conditioners, split air conditioners, cooling towers, pumps, fans, Air Handling Units etc. are well-engineered products tested and certified at the factory/origin, subsystems such as water and air distribution are engineered and assembled at the project site to meet specific design requirements.

1.2 Procedures, methods and documentation requirements in this annexure describe the application of the commissioning process for each project delivery phases from initiation through post commissioning operation phase.

1.3 This section of the annexure specifically deals with initiation of the commissioning process

1.4 The project owner shall specify the role and responsibility of each team member and the goals and objectives to be achieved. These shall be clearly defined in the OPR. These should be updated periodically since the objectives may change as the project progresses.

1.5 In case there are concerns which are unresolved between the project team, the owner shall intervene and provide direction to the team to resolve the concerns.

1.6 Commissioning activities need to be incorporated within the project delivery process and shall be part of the project scope, budget and time schedules.

1.7 Commissioning scope shall specify the system to be commissioned and the purpose of contracts the owner shall have entered with the following teams:

- Project Management Consultant (PMC)
- Architect/ Civil Engineer
- Mechanical Electrical and Plumbing consultant (MEP)
- Commissioning Authority (CA)
- Suppliers of equipment and systems.
- Installers/Contractors
- Facility Management Agency (FMA)

1.8 Owner shall ensure that the project budget is sufficient to support the commissioning activity and the construction schedule provides enough time to complete the commissioning activities.

Annexure B (Normative)
Owners Project Requirements (OPR)

1.0 OPR document shall define the functional requirements of the project and the expectations of the owner as regards the project's use and operation.

2.0 Project owner shall provide the inputs which goes into OPR and the commissioning authority shall assist the owner in identifying the facilities requirements.

3.0 OPR shall incorporate inputs from owner, design team, operation and maintenance teams and also from the project users. All targets shall be verifiable and measurable so that they can be used as benchmarks in the commissioning process. The owner shall be responsible for updating the OPR from time to time till the end of the commissioning process.

4.0 OPR shall include the following information specifically required for HVAC system.

1. HVAC system performance criteria

a) Primary purpose of the building

b) Space programme

c) Number of occupants and usage profiles.

d) Flexibility to change floor layouts and use of spaces or the building.

e) Training required for operating and maintaining the building.

2. Targets for IEQ

a) Thermal comfort

b) Indoor air quality

c) Lighting

d) Acoustics

e) User satisfaction

3. Health and safety

a) Security

b) Water quality

c) Emergency lighting

d) Fire and smoke management

e) Accessibility and maintainability

4. Data / Communications

a) Phone connectivity

b) Wireless network

c) Wireless Internet of Things data network.

5. Environmental performance

a) Energy performance index

b) Primary energy consumption

c) Energy supply – Current & Future

d) Water use and reduction potential

e) Lifetime greenhouse gas emissions.

f) Operational greenhouse gas emissions.

g) Waste management.

h) Targets for ongoing commissioning and continuous monitoring.

Note: The OPR can include any additional requirements not limiting to the above mentioned parameters.

5.0 OPR shall be part of the systems manual documentation. The document shall be updated as decisions are made through during design, construction, occupancy, and operations phases of the project.

6.0 OPR can be included as a part of tender documents issued to vendors with a clear stipulation that the document is only for information and shall not be used to interrupt contract requirements.

Annexure C (Normative)
Developing a Commissioning Plan

1.0 Commissioning plan details the processes required for successful commissioning. Based on the OPR the commissioning plan defines the scope and budget for the commissioning process.

2.0 The commissioning plan shall contain the following information:

2.1 Commissioning process overview.

2.2 Roles and responsibilities of commissioning team.

2.3 Documentation requirements.

2.4 Detailed description of commissioning process activities during pre-design phase, design phase construction phase, occupancy and operation phases.

2.5 Design document verification procedures.

2.6 Steps to take where process verification indicates any deviation from OPR.

2.7 Verification for compliance with OPR at all project phases.

3.0 During design, construction and operation phases, concern and resolution log shall be maintained. The log shall list all concerns which are at variance with the OPR and also how each of them have been resolved. All outstanding concerns shall be reviewed periodically.

4.0 Commissioning progress report shall be issued periodically and typically contains the following information.

4.1 Process activities completed till date of report.

4.2 Any changes in the process schedule.

4.3 New issues, outstanding issues and planned activities to resolve outstanding issues.

4.4 Process activities scheduled till next meeting.

Annexure D (Normative)
Establishing Basis of Design

1.0 Basis of design shall be a written document and shall clearly specify the designer's approach to the OPR. OPR will provide the information requirements and the format of the design document to the team. Design team shall formulate the basis of design and shall submit it to the owner for review and approval.

2.0 Basis of design document shall be updated to reflect any changes to the design criteria as the project moves forward along with the reasons for such changes.

3.0 Following contents shall constitute basis of design and which can be modified and used for each project based on discussions and agreement between the owner, commissioning team and the designer.

a) HVAC – Preliminary and Schematic Design
   i. Space Use
   ii. Redundancy
   iii. Diversity
   iv. Outdoor design criteria
   v. Indoor design conditions
   vi. Ventilation requirements
   vii. Zoning requirements
   viii. Occupancy
   ix. Permitted tolerances on indoor conditions
   x. Standards and Codes
   xi. Green Building and Energy Code compliances
   xii. Control systems

b) Integration with other Building Systems
   i. Lighting and power
   ii. Water management including cooling tower make up and heat recovery systems
   iii. Smoke management and Fire Safety
   iv. Renewable energy
   v. Sewage recycling and reuse
   vi. Any other systems as required by the OPR

c) Design Development
   i. Energy modeling reports
   ii. Ventilation calculations
   iii. Heating/ Cooling load estimates
   iv. Equipment data sheets
   v. Control schematics
   vi. Input / Output summary

d) System performance parameters
   i. Adaptability of mechanical systems
   ii. Maintainability
   iii. Service and inspection access
   iv. Reliability
   v. Service life
   vi. Replacement schedule
   vii. Efficiency targets

4.0 Commissioning team shall verify Basis of Design for HVAC system commissioning and conformance that they are in line with owner's project requirements. In terms of user comfort and energy efficiency, it is important to simulate building operation and typical spaces in the pre-design phase. This will ensure that the selected technical solutions fulfill the performance targets.

Note: Computational Fluid Dynamics simulations will be helpful to simulate comfort conditions and air movements within the building.

Annexure E (Normative)
Developing Commissioning Specifications

1.0 Commissioning specifications shall include the commissioning process activities performed during construction stage and upto the post occupancy commissioning.

2.0 Administrative procedures for the commissioning process and how the construction team interacts with the commissioning team shall form part of the specifications.

3.0 Testing requirements for equipment, sub-assemblies and systems as well the construction teams involvement in the commissioning related testing needs to be clearly defined.

4.0 The commissioning team shall verify the construction team activities starting with installation, testing, and training of operating and maintenance personnel and preparation of systems manual (clause 6.10) to confirm that they conform to the OPR.

5.0 In case manufacturers authorised personnel is required at the time of start–up, same shall be specified.

6.0 Inclusion of commissioning process requirement and commissioning standard to be included as part of tender document

Annexure F (Normative)
Design Review Report

1.0 This stage of the commissioning process involves review of design submissions. The commissioning team needs to ensure that the design submissions meet the OPR.

2.0 Design review shall include review of drawings as well as the specifications.

3.0 As a first step of the drawing review process the criteria on which the drawings will be reviewed shall be documented.

4.0 Drawings shall initially be reviewed on its general quality such as continuity, labelling, clarity, legibility etc.

5.0 Second stage review of the drawings shall verify placement of equipment, its accessibility, possibility for maintenance and replacement, height requirements, sectional and elevational details, service connections etc.

6.0 A final drawing review shall involve sustainability requirements, conditions maintained with respect to OPR, BOD etc.

7.0 Any non-conformance in drawing review shall be documented and communicated to the originator of the drawing as well as the owner.

8.0 Review of specifications shall involve verification that they pertain to the project and is clear and concise. Similar to drawing review any non-conformance shall be documented and communicated to the originator as well as to the owner.

9.0 Design review report shall contain:

a) List of documents reviewed (Title, issue date)

b) Issues, comments and variable with OPR if any.

c) Copy of drawings review.

d) Review on systems and assemblies.

e) Non-conformance report if any

Annexure G (Normative)
Review / Construction Submittals

1.0 In order to ensure that components procured fulfil the design requirements, contractor shall submit details of all major components to the commissioning authority who will check and confirm that they fulfil the operational requirements of the project. Commissioning authority shall provide the report to the owner as well as to the contractor. Commissioning authority shall also highlight any issues that may result in rework or change orders.

2.0 Following shall be reviewed:

2.1 Measurement of product data to specified standards.

2.2 Required safety requirements are fulfilled.

2.3 Where any changes are made technical performance of the system is not affected.

2.4 All selected components and materials which are selected have independent third party certification.

2.5 Products subject to energy and eco labelling meet the parameters specified.

2.6 All changes in components, materials and installation are updated in the documentation and non-conformance shall be reported.

Annexure H (Normative)
Installation and Inspection

1.0 This section of the standard specifically deals with inspection and testing of the systems / equipment for performance.

1.1 Observation helps to ensure that a particular component / material / sub assembly is received as it was specified, whether it was installed as specified in the OPR without damage and accessibility, maintainability and such other specified attributes are met.

1.2 Testing implies verification of the performance of the equipment or system and performance testing means altering some of the parameters to evaluate response of the system against expectations.

1.3 Testing shall cover physical properties of the system and assembly as well as performance parameters as well as logical or operational parameters.

1.4 Checklists are developed for testing which shall include criteria, process requirements and performance testing. Checklists shall not be considered to be exhaustive and shall be reviewed to ensure compliance with OPR and BOD.

1.5 Construction checklists shall be prepared for components and equipment that are delivered, installed and started up during construction. An individual checklist shall be prepared for each piece of component or piece of equipment. Similar construction checklists shall be prepared for systems and assemblies and for each test procedure, test data records shall be developed.

1.6 Test data records shall include the following:

A. Test number
B. Date and Time
C. System / Equipment identification.
D. Testing conditions
E. Expected performance
F. Observed performance
G. Test conclusion
H. Dated signature of person conducting test.

1.7 Test reports shall cover the following stages.

1. Delivery check lists
2. Pre installation checks
3. Installation check lists
4. Performance data.

1.8 Preparation for tests shall include the following:

1. Certifying that all systems and equipments are installed and are operating as per the requirements of contract documents.

2. Certifying that testing, adjusting and balancing procedures have been completed and pproved.
3. Systems and equipment shall be put in operation mode.
4. Safety cutouts, alarms and interlocks shall be verified.
5. Required measuring / logging instruments shall be installed.

1.9 Scope of testing shall include the following:

A. Equipment

- A.1 Unitary and Package Systems
- A.2 VRF Systems
- A.3 Chillers
- A.4 Cooling Towers
- A.5 Pumps
- A.6 Air Handling Units
- A.7 Ducting systems
- A.8 Variable Air Volume Systems
- A.9 Fans
- A.10 Hot Water generators
- A.11 Fan Coil Units
- A.12 Meters and gauges.

B. Sub Systems

- B.1 Refrigerant Piping
- B.2 Water piping
- B.3 Chilled water system
- B.4 Condenser water system
- B.5 Direct Expansion system
- B.6 Air Distribution System
- B.7 Hot Water system
- B.8 Basement Ventilation System
- B.9 Kitchen ventilation system
- B.10 Exhaust system
- B.11 Pressurisation System
- B.12 Control System (HVAC)

1.10 Scope of testing shall include measuring capacities and also effectiveness of operational and control functions. Whenever possible, tests shall be performed at design conditions. When required, simulated conditions may be produced using artificial load.

1.11 Sample test reports are given in attachments HA.1 to HA.12 in respect of equipment and HB1 to HB12 in respect of sub Systems.

Annexure H1 (Normative)
Test Measurements and Testing Instruments

1.0 The following is a non comprehensive listing of measurements which should be taken while testing of HVAC systems.

2.0 As regard to test measurement and testing instruments for Indoor Environment Quality (IEQ), please refer ISHRAE IEQ Standard:10001-2019.

2.1 The system / equipment under test shall be operated to determine proper functioning of all components as well as instruments. All measurements and readings are to be taken only after the system / equipment has been operated and steady state conditions are established. After establishing steady state, the measurements are taken for period of 30 minutes and shall be minimum 3 sets of readings taken during the test period at equally timed intervals.

All parameters shall be calculated from the average of measurement data obtained at the end of the test period.

3.0 The measurement instruments shall meet measurement accuracy requirements as below.

3.1 Dry bulb temperature (DBT) and wet bulb temperatures (WBT) ≤ ± 0.1°C and temperature differentials.

3.2 Pressure or pressure differential ≤ ± 2% of the numerical value of measured quantity.

3.3 Flow measurements ≤ ± 2% of the flow rate measured.

4.0 All test instruments shall be calibrated based on the schedule and procedure specified by the manufacturer and calibration records shall be maintained.

5.0 Test instrumentation

5.1 Air side measurements:

5.1.1 Rotating Vane Anemometer

The mechanical propeller or revolving vane anemometer consists of a light, wind-driven wheel connected through a gear train to a set of recording dials that read the linear feet (meters) of air passing through the wheel in a measured length of time. The instrument is made in various sizes, but 3, 4, and 5 in. (75, 100, and 125 mm) are the most common. Each instrument requires individual calibration. The required instrument accuracy of calibration is 1%–3% of scale (using a corrective chart).

Recommended uses:

a. Use to measure supply, return, and exhaust air quantities at registers and grilles.

b. Use to measure air quantities at the faces of return air dampers or openings, total air across the filter or coil face areas, etc.

c. Each reading from this instrument must be corrected by its calibration chart.

d. The air terminal manufacturer's specified Ak (effective area) factor for the terminal must be used in computing air quantities.

e. Total inlet area of the instrument must be in the measured airstream.

f. It is not suitable for measurement in ducts.

g. It is fragile and cannot be used in dusty or corrosive air.

h. Since the instrument has a turbine wheel of very low inertia, caution is advised as to reliability of readings in non-uniform, turbulent, or stratified airstreams. This is likely to occur downstream of dampers, face and bypass coils, or any device that causes turbulence in the airstream being measured.

i. The instrument is not direct reading and, therefore, must be timed manually.

j. At low velocities, the friction drag of the mechanism is considerable. In order to compensate for this, a gear is commonly used. For this reason, the correction is additive at the lower range and subtractive at the upper range, with the least correction in the middle of the range. Most of these instruments are not sensitive enough for use below 1.0 m/s (200 fpm), although ball-bearing models claim ranges down to 0.15 m/s (30 fpm).The useful range is from 1.0 to 10.0 m/s (200 to 2000 fpm).

5.1.2 Direct reading digital type- Vane anemometer

This instrument is the same as the mechanical type in most respects, except that it uses a powered electronic circuit to convert a pulse generated by the rotating vane into a small electric current to give a meter reading calibrated directly in air velocity units. Generally, these instruments have microprocessor software to compensate for any nonlinearity

Recommended Uses:

a. Use to measure supply, return, and exhaust air quantities at registers and grilles.

b. Use to measure air quantities at the faces of return air dampers or openings or of total air across the filter or coil face areas, etc.

Limitations:

a. The air terminal manufacturer's specified Ak factor (effective area) for the terminal must be used in computing air quantities.

b. The total inlet area of the instrument must be placed in the measured airstream.

c. It is not suitable for measurement in ducts.

d. It is fragile and cannot be used in dusty or corrosive air.

e. Since the instrument has a turbine wheel of very low inertia, caution is advised as to reliability of readings in non-uniform, turbulent, or stratified airstreams. This is likely to occur downstream of dampers, face and bypass coils, or any device that causes turbulence in the airstream being measured.

f. At low velocities, the friction drag of the mechanism is commonly used. For this reason, the correction is additive considerable. In order to compensate for this, a gear is at the lower range and subtractive at the upper range, with the least correction in the middle of the range. Most of these instruments are not sensitive enough for use below 1.0 m/s (200 fpm), although ball-bearing models claim ranges down to 0.15 m/s (30 fpm). The useful range is from 0.51 to 25.4 m/s (100 to 5000 fpm).

5.1.3 U tube Manometer/ Pitot Tube

The manometer is a simple and useful means of measuring partial vacuum and pressure, both for air and hydronic systems. In its simplest form, the manometer consists of a U-shaped glass tube partially filled with liquid. A difference in height of the two fluid columns denotes a difference in pressure in the two legs.

Recommended Uses:

a. Use to measure pressure changes through coils, heat exchangers, and orifices.

b. Use to measure pressure changes across water circulators.

c. Use to measuring gas pressures.

Limitations:

a. Manometer tubes shall be cleaned to ensure accuracy and shall be filled with the correct fluid.

b. Use collecting safety reservoirs on each side of a mercury manometer to prevent blowing out mercury into the water system, which can cause rapid deterioration of any copper it touches in the system.

5.1.4 Pitot Tube

Construction:

A Pitot static tube, used in conjunction with a manometer, provides a basic method of determining the air velocity within a duct. The typical Pitot static tube is of a double concentric tube construction, consisting of a 3.2 mm (1/8 inch). O.D. inner tube that is concentrically located inside a 7.9 mm (5/16 inch). O.D. outer tube. The outer static tube has eight equally spaced 1.02 mm (0.04 inch). diameter holes around the circumference of the outer tube, located 63.5 mm (2.5 inch) () back from the nose or open end of the Pitot tube tip. At the base end, or tube-connection end, the inner tube is open ended, as is the head. The outer tube has a side outlet tube connector perpendicular to the outer tube, directly parallel with and in the same direction as the head end of the Pitot static tube

Recommended Uses:

a. Use to measure airstream “total pressure” by connecting the inner tube outlet connector to one side of a manometer or draft gauge.

b. Use to measure airstream “static pressure” by connecting the outer tube side outlet connector to one side of a manometer or draft gauge.

c. Use to measure airstream “velocity pressure” by connecting both the inner and outer tube connectors to opposite sides of a manometer or draft gauge.

d. This instrument, when used with a manometer or micro manometer, is a reliable and rugged instrument. Its use is preferred over any other method for the field measurement of air velocity, system total air, outdoor air, return air quantities, fan static pressure, fan total pressure, and fan outlet velocity pressures, where such measured quantities may be required.

5.1.4. Flow Measurement hood/ matrix

Construction:

This is a conical or pyramid shaped hood used to collect all the airflow from a terminal and guide it over a flow-measuring system, which reads directly in cfm (L/s). The instrument can be a swinging vane anemometer, a differential-pressure air gauge (diaphragm type), a manometer, or a thermal anemometer. The balancing cone should be tailored for the particular job. The large end of the cone should be sized to fit over the complete air-terminal unit and should have a seal to eliminate air leakage. The cone should terminate in a straight section with factory-designed and calibrated pressure grids, straighteners, and instruments

Recommended Uses:

Use to proportion air distribution devices directly in L/s (cfm).

Limitations:

a. Shall not be used where discharge velocities exceed 10 m/s (2000 fpm)

b. It shall be recognized that the device generally redirects the normal pattern of air discharge and that it contributes an artificially imposed pressure drop in the branch of the air terminal being measured. These will result in a decrease in the delivered airflow of the outlet.

c. The air-terminal manufacturer should be contacted for details in using this instrument with the manufacturer's terminals.

d. The instrument must be calibrated for the method of use intended. For use with supply distribution devices, the instrument shall be calibrated in the supply mode. For use with return distribution devices, the instrument shall be calibrated in the return mode.

5.1.5 Digital Thermometer

Construction:

There are four basic types of electronic thermometers: thermocouple, thermistor, RTD (resistance temperature detector), and diode sensors. They consist of a portable, hand-held, battery-powered, digital thermometer connected by a short cable to a variety of interchangeable probes. The probes are designed for sensing the temperature of air or other gases, of liquids by immersion in liquids, or of the surfaces of solids by contact with a solid surface. Some instruments offsets introduced by mechanical shocks, ambient temperature variations, or component drift. Some instruments have F/C switching and 0.1/1.0 resolution switching. Response times are 1 to 10 s for liquids and solids, and 5 to 50s for gases. Instrument accuracy shall be ±0.3°C (±0.5°F) where the temperature is below 350°C (700°F) and ±0.8°C (±1.5°F) for temperatures of 350°C (700°F) and above. The lower range instruments shall be used for all measurements within their range.

Recommended Uses:

Suitable for all TAB temperature measurements, including air and other gases, liquids, and surfaces of pipes and other components with the appropriate probe. The manufacturers' directions must be followed regarding proper use of probe and maximum allowable temperature for the probe and/or thermometer. Equipment is available to measure from –230°C to 1230°C (–380°F to 2250°F). Common ranges used are –10°C to 120°C (+14°F to +248°F).

Limitations:

a. The power source – battery shall be charged or replaced for good operation level.

b. In piping applications, it should be remembered that the surface temperature of the pipe is not equal to the fluid temperature and that a relative comparison is more reliable than an absolute reliance on readings at a single circuit or terminal unit.

c. Measurement must be taken at least as long as the response time.

5.1.6 Sling Psychrometer

Construction:

The sling psychrometer consists of a matched pair of mercury-filled glass-tube thermometers, one of which has a cloth wick or sock around its bulb. The two thermometers are mounted side-by-side on a frame fitted with a handle by which the device can be whirled with a steady motion through the surrounding air. The whirling motion is periodically stopped to take readings of the wet-bulb and dry-bulb thermometers (in that order) until such time as consecutive readings become steady. Due to evaporation, the wet-bulb thermometer will indicate a lower temperature than the dry-bulb thermometer, and the difference is known as the wet-bulb depression. The required instrument test accuracy is ±0.5°C (±1°F)

Recommended Uses:

The sling psychrometer can be used in determining the psychrometric properties of conditioned spaces, return air, outdoor air, mixed air, and conditioned supply air. The readings taken from the sling psychrometer can be plotted on a standard psychometric chart air can be determined.

Limitations:

a. Accurate wet-bulb readings require an air velocity of between 5.0 and 7.5 m/s (1000 and 1500 fpm) across the wick, or a correction shall be made.

b. Distilled water only must be used and the wick should be replaced for every measurement.

c. For an instrument with 450 mm (18 inch) radius, it shall be whirled at a rate of at least two revolutions per second.

d. Evaporation must reach equilibrium to be accurate.

5.1.7 Humidity Measuring Devices

Construction:

In addition to the sling psychrometer, there are variety of instruments available to measure the moisture in air that can be more accurate and do not require the swinging of a manually wetted wick. These instruments include the following:

a. Battery-powered hygrometer

b. Powered dew-point indicator

c. Powered psychrometer with built in pump and fan

d. Digital psychrometer with built in reservoir and fan

Recommended Uses:

These instruments do not require hand swinging and, thus, may be more convenient to use. The hygrometers give direct, rapid RH readings, and the digital psychrometer gives dry-bulb and wet-bulb depression in about 30 seconds.

5.1.8 Electronic Differential Pressure Gauge /Meter

This instrument is a hand-held (or belt-worn) device that measures differential pressure and gives a digital readout directly in pressure or velocity. Some instruments are available with adapters and probes to measure flow and temperature. Typical ranges reach 0 to 25 kPa (0 to 100 inch water column) for low density fluids, and 0 to 0 to 600 kPa (200 ft water column) or 0 to 700 kPa (0 to 100 psi) for high density fluids. Temperatures can be measured from –48°C to 120°C (–55°F to 250°F).

Recommended Uses:

Use with a Pitot static tube, static probe, flow grid, orifice plate, or special balancing valve. Some instruments can also be combined with a flow measuring hood. Many instruments have memories, averaging capabilities, and printers.

Limitations:

a. These instruments are battery powered and require checking batteries and replacing or recharging them.

5.1.9 Electronic Tachometer

The stroboscope has a controlled high-speed electronic flashing light. The frequency of the flashing light is electronically controlled and adjustable. When the frequency of the flashing light is adjusted to equal the frequency of the rotating machine, the machine will appear to stand still. This unit need not be in contact with the machine when it is being used. The instrument accuracy is generally within 1.5% of the indicated value and within 1% if a magnetic pickup is used. The solid-state photoelectric tachometer is an optional instrument that is pointed at the device to be measured and the rpm is directly read on the dial face. A reflective paint or material must be spotted on the rotating device, which is actually counted electronically integrated over time to give an instantaneous rpm reading. The instruments usually have several ranges, and no electrical or physical contact with the device is necessary. Accuracy is within ±1% of the dial scale reading when properly calibrated.

Recommended Uses:

Use to measure rotational speeds when instrument contact with the rotating equipment is not feasible.

Limitations:

Care must be taken to avoid reading multiples of the actual rpm when using the stroboscope. Readings must be started at the lower end of the scale.

5.1.10 Clamp-On AC power meter (Wattmeter)

The clamp-on type power meter has trigger-operated, clamp-on transformer jaws like the voltammeter. The instrument will measure true rms voltage and current, in addition to power, in single-phase or balanced three-phase circuits. Compared with mean-value measurement, true rms measurement is especially valuable for distorted waves, such as noise and multiplexed signals Typical ranges are 20 to 600 V RMS, 2 to 200 A RMS, and 2 to 200 KW; or 20 to 600 V RMS, 0.2 to 20 A RMS, and 0.2 to 20 KW.

Recommended Uses:

The instrument will measure single-phase, split-phase, and three-phase power sources. Given the motor efficiency and power factor, power draw can be related to motor brake horsepower as related on a fan or pump curve and, thus, the operating point can be determined.

Limitations:

Caution is required, particularly when taking measurements under confined conditions. Readings below 10% of input range are not recommended. Batteries must be checked before use.

5.1.11 Digital Sound level meter

This is used to measure sound pressure level. The most basic sound level meters measure overall sound pressure level and have up to three weighted scales that provide limited filtering capability. The instrument is useful in assessing outdoor noise levels in certain situations and can provide limited information on the low-frequency content of overall noise levels.

5.1.12 Vibration analyser

Sound-level meters and computer-driven sound-measuring systems are the most useful instruments for measuring and evaluating vibration. Usually, they are fitted with accelerometers or vibration pickups for a full range of vibration measurement and analysis. Other instruments used for testing vibration in the field are described as follows.

Vibrometers measure vibration amplitude by means of a light beam projected on a graduated scale.

Vibrographs are mechanical instruments that measure both amplitude and frequency. They provide a chart recording amplitude, frequency, and actual wave form of vibration. They can be used for simple, accurate determination of the natural frequency of shafts, components, and systems by a bump test. Reed vibrometers, vibrometers, and vibrographs have largely been replaced by electronic meters that are more accurate and have become much more affordable.

Vibration meters are convenient modern electronic instruments that measure the vibration amplitude. They provide a single broadband (summation of all frequencies) number identifying the magnitude of the vibration level. Both analog and digital readouts are common.

Vibration analyzers are relatively expensive electronic instruments that measure amplitude and frequency, usually incorporating a variable filter.

Strobe lights are often used with many of the other instruments for analyzing and balancing rotating equipment.

Stethoscopes are available as mechanic's type (basically, a standard stethoscope with a probe attachment), relatively inexpensive models incorporating a tunable filter, and moderately priced powered types that electronically amplify sound and provide some type of meter and/or chart recording.

The choice of instruments depends on the test. Vibrometers and vibration meters can be used to measure vibration amplitude as an acceptance check. Because they cannot measure frequency, they cannot be used for analysis and primarily function as a go/no-go instrument. The best acceptance criteria consider both amplitude and frequency. Anyone seriously concerned with vibration testing should use an instrument that can determine frequency as well as amplitude, such as a vibrograph or vibration analyzer.

Vibration measurement instruments (both meters and analyzers) made specifically for measuring machinery vibration typically use moving coil velocity transducers, which are sizable and rugged These are typically limited to a lower frequency of 500 cycles per minute (cpm) [8.33 Hz] with normal calibration. If measuring very-low-speed machinery such as large fans, cooling towers, or compressors operating below this limit, use an adjustment factor provided by the instrument manufacturer or use an instrument with a lower low-frequency limit, which typically uses a smaller accelerometer as the vibration pickup transducer.

5.2 Water Side

5.2.1 Ultrasonic flow meter

This is a device that, by the use of acoustic signals, determines the flow directly in design units (gpm, L/s, etc.) The ultrasonic flow metering station will either be an integral part of the piping system or a strap-on meter. In either case, there is no intrusion into the pipe or liquid flow to generate a pressure drop. There are no moving parts in the flow to maintain or service. There are two distinct types of ultrasonic flowmeters: a transit-time device for HVAC or clear water measurement and a Doppler-effect device for flows containing a required volume of particulate in the liquid.

Recommended Uses:

Use to measure flow in full pipes. Excellent when low or zero pressure drop is a requirement. They are best fitted for larger pipes and most manufacturers' specifications are based on flows of 1 fps or greater.

Limitations:

a. Doppler Flowmeters: The liquid must contain particulate or gas bubbles.

b. Transit-time Flowmeters: The liquid must be acoustically transparent (i.e., of low particulate content, such as typical lake or river water, or cleaner).

c. Strap-on (Portable) Flowmeters: Pipe parameters (pipe diameter, wall thickness, and material of construction) must be known or determinable. The pipe must be acoustically transparent (concrete or lined pipe is not).

5.2.2 Mercury Thermometer

Description:

Mercury-filled glass-tube thermometers have a useful temperature range of –36°C to 510°C (–38°F to 950°F). They are available in a variety of temperature ranges, scale graduations, and lengths. The required instrument test accuracy minimum must be within a scale division mark.

Recommended Uses:

a. The complete-stem-immersion calibrated thermometer must be used with the stem completely immersed in the fluid in which the temperature is to be measured.

b. Thermometers calibrated for partial stem immersion are more commonly used. They are used in conjunction with thermometer test wells specifically designed to receive them. No emergent stem correction is required for the partial-stem-immersion type.

Limitations:

a. Radiation effects – When the temperature of the surrounding surfaces are substantially different from the measured fluid, there is a considerable radiation effect upon the thermometer reading if the thermometer is left unshielded or otherwise unprotected. Proper shielding or aspiration of the thermometer bulb and stem can minimize these radiation effects.

b. Time is required for the thermometer to reach the temperature of the fluid being measured.

c. Mercury may separate in the tube.

5.2.3 Calibrated Pressure Gauge

Test gauge shall be of a minimum “Grade A” quality and have Bourdon tube assemblies made of stainless steel, alloy steel, monel, or bronze, and a non-reflecting white face with black letter graduations conforming to ANSI/ASME Standard B40.1-1985, Gauges: Pressure Indicating Dial Type-Elastic Element.1 Test gauges are usually 3.5 to 6 in. (90 to 150 mm) in diameter with bottom or back connections. Many dials are available with pressure, vacuum, or compound ranges. Instrument minimum accuracy shall be within 1% of full scale.

Recommended Uses:

Use primarily for checking pump pressures, coil, chiller, and condenser pressure drops and pressure drops across orifice plates, venturis, and other flow-calibrated devices.”

Limitations:

a. Pressure ranges shall be such that the anticipated working pressure range is in the middle two-thirds of the scale range, and the gauge shall not be exposed to pressures greater than the maximum dial reading. Similarly, where there is exposure to vacuum, use a compound gauge.

b. Reduce or eliminate pressure pulsations by installing a snubber or needle valve in the water line.

c. Eliminate vibration by avoiding mounting on vibrating equipment or piping, wall mounting is preferred. Another alternative is to install pressure/temperature test ports that can be used with a portable stem probe and gauge (or thermometer) through an elastic, durable, self-sealing material. The test port shall be capped when not in use for additional sealing security.

5.2.4 Fluid System Digital Electronic Differential Pressure Meters

This instrument measures the differential pressure across an element in a system when flow is present. The digital reading can be in a pressure range of 0.3 to 50 ft wc (1 to 150 kPa). Some instruments provide a temperature probe for a range of 32°F to 248°F (0°C to 120°C), hoses with snap-on fittings, and automatic air purging. A computer is available for calculating the flow in a range of 0.2 to 4750 gpm (0.01 to 300 L/s) and computing the hand wheel setting of compatible valves by proportional balancing procedures. Maximum working pressures can be up to 300 psig (2060 kPa).

Recommended Uses:

Use to measure fluid flow, temperature, and differential pressure; for computing the setting of compatible valves by proportional balancing procedures.

Limitations:

The computing feature is limited to compatible valves.

6.0 Test Methods

6.1 Air volumetric Measurement

6.1.1 Digital Vane Anemometer

Procedures:

To obtain the air velocity from the readings of an air-velocity meter, refer to the test procedure section 7- of this standard.

Location of Instrument:

If the opening is covered with filters or grille, the instrument should touch the grille face and shall be 25 to 50 mm (1 to 2 inches) away for the filter section but should not be pushed in between its bars. For a free opening without a grille, guide wires should be stretched across the plane of the opening and the instrument held in such a manner that the airflow through the instrument is in the same direction as was used for calibration (usually from the back toward the dial face). An instrument should be held in place by means of a thin handle; the hands and body of the observer should be entirely outside the area of flow.

Correction Factor:

The correction factor is the factor by which the average velocity for the instrument is to be multiplied to obtain the true average velocity.

Average Velocity for Instrument

Average Velocity × Designated Area = True Flow Rate

Accuracy:

The rotating vane anemometer can be relied upon for air volume measurements with an accuracy +5% if the measurements are made at a free-open intake (with flange) or at a free-open discharge from a long duct. When the opening is covered with a grille or screen, the results are not as reliable, but an accuracy of 5% could be expected, both for flanged intakes and for discharge or supply openings that have an approach duct at least 2 diameters in length. The instrument factor is little affected by the area or the shape of the opening, by the instrument size, or by the air velocity above 500 fpm (2.5 m/s). For comparative measurements, the anemometer is highly accurate, within 2% or less.

6.1.2 Pitot Tube & U Tube Manometer (Duct Traverse method)

General:

It is assumed that an HVAC system will contain airways (ducts) suitable for flow measurement. Research and state-of-the-art practices allow the traversing of ducts as a field method for fan or system-performance measurement.

Flow rate is determined by using the area and the average velocity at a traverse plane, as in the following equation:

$Q = V \times A$

where

Q = flow rate in m^3/s (cfm)

A = cross sectional area at the traverse plane in m^2 (ft^2)

V = average velocity in m/s (fpm)

6.1.2.1 Flow in Ducts

Instruments:

The instruments recommended for use in measuring velocity pressure include a pitot static tube and electronic instruments of comparable accuracy. These are described in Section 5 - Test equipment description.

Location of traverse plane:

The qualifications for a pitot traverse plane that is considered suitable for the measurements used in determining flow rate are as follows

The angle of the flow stream in any specific location is indicated by the orientation of the nose of the pitot static tube that produces the maximum-velocity pressure reading. However, when making a duct traverse, the nose of the pitot tube is held parallel to the side walls of the duct and pointing into the airflow.

The cross-sectional shape of the duct in which the traverse plane is located should not be irregular. Proper distribution of traverse points and accurate determination of the area of the traverse plane are difficult to achieve when the airway in which the traverse plane is located does not conform closely to a regular shape (round, oval, or rectangular).

The cross-sectional shape and area of the duct should be uniform throughout the length of the duct in the vicinity of the traverse plane. In instances where the divergence or convergence of the duct is irregular or more than moderate in degree, significantly non uniform flow conditions may exist.

The traverse plane should be located to minimize the effects of leaks in the portion of the system that is located between the traverse plane and the fan.

A location in a long, straight run of duct of uniform cross section will usually provide acceptable conditions for the Pitot traverse plane. In locating the traverse plane close to a fan, as is often done to minimize the effect of leakage, flow conditions upstream of the fan are usually more suitable. In some installations, more than one traverse plane may be required in order to account for the total flow. Also, more than one traverse location per system may be used to substantiate the accuracy of the system performance.

In any installation in which a field test is anticipated, particularly when the requirement for a field test is an item in the specifications, provision should be included in the system for a suitable traverse plane location.

In any instance in which the fan is ducted on the outlet side and the traverse plane is to be located downstream from the fan, the traverse plane should be situated a sufficient distance downstream from the fan to allow the flow to diffuse to a more uniform velocity distribution and to allow the conversion of velocity pressure to static pressure. The information presented in figure below provides guidance for the location of the traverse plane in these cases (see Figures H1.1 and H1.2). The location of the traverse plane on the inlet side of the fan should be more than 0.5 equivalent diameters from the fan inlet. In any case in which the traverse plane must be located within an inlet box, the plane should be located a minimum of 0.3 m. (12 inch) downstream from the leaving edges of the damper blades and more than 0.5 equivalent diameters upstream from the edge of the inlet cone.

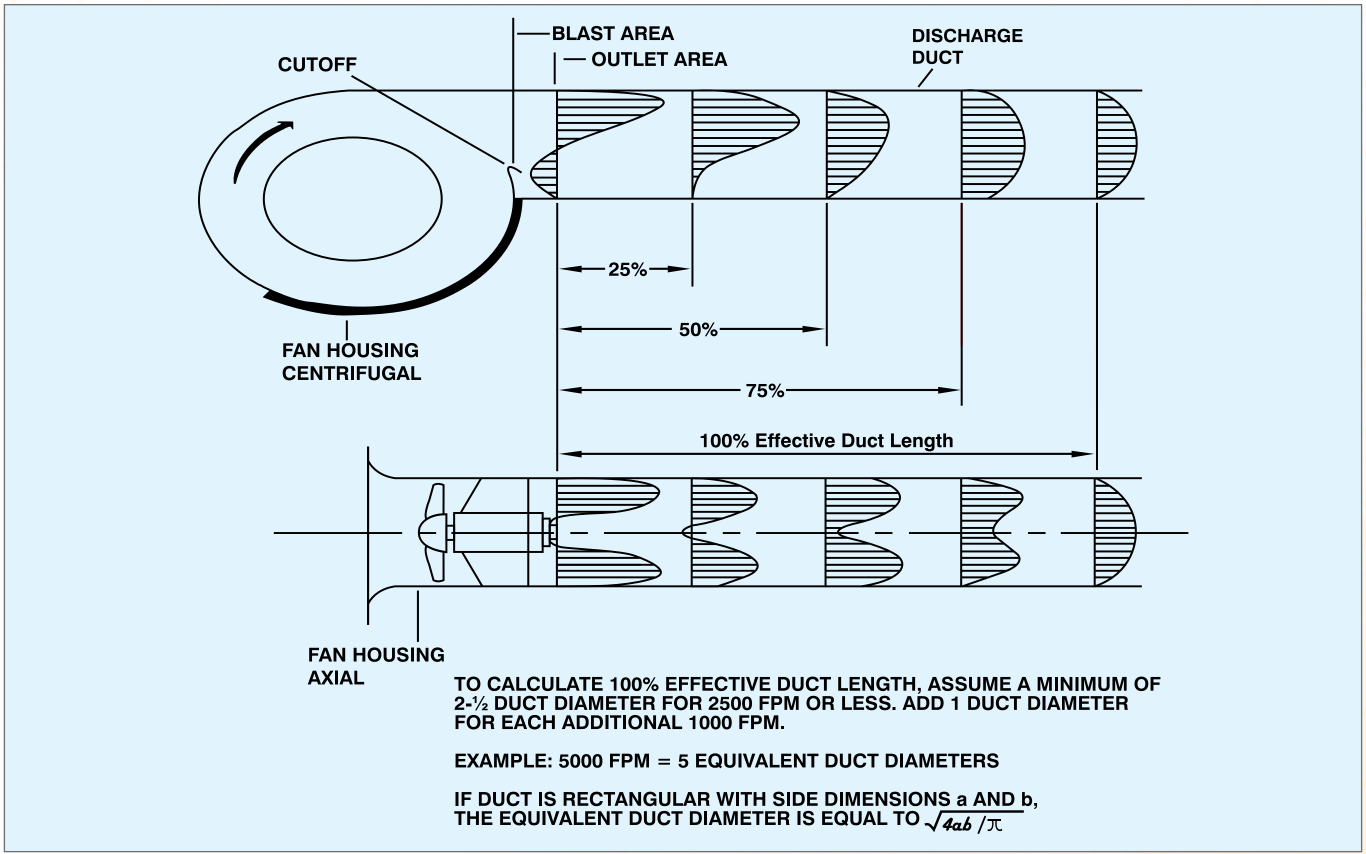


Figure H1.1: Controlled diffusion and establishment of a uniform velocity profile in a straight length of outlet duct.

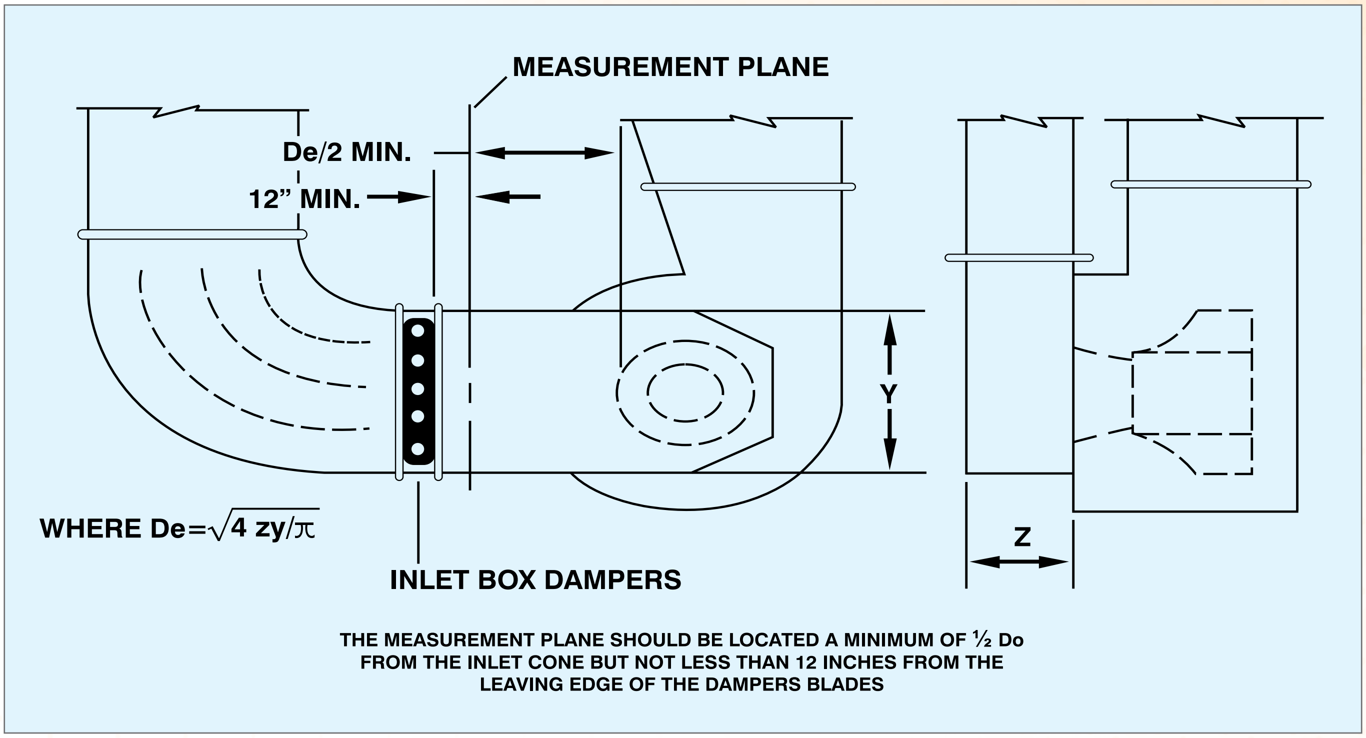


Figure H1.2: Conditions for measurement plane near fan.

Regions immediately downstream from elbows, obstructions, and abrupt changes in airway area are not suitable traverse plane locations. Regions where unacceptable levels of swirl are usually present should be avoided, such as the region downstream from an axial flow fan that is not equipped with straightening vanes.

Occasionally, an undesirable traverse plane location may not be avoidable, or each of a limited number of prospective locations may lack one or more desirable qualities. In such cases, the alternatives are as follows:

a. Accept the most suitable location and evaluate the effects of the undesirable aspects of the location on the accuracy of the test results.

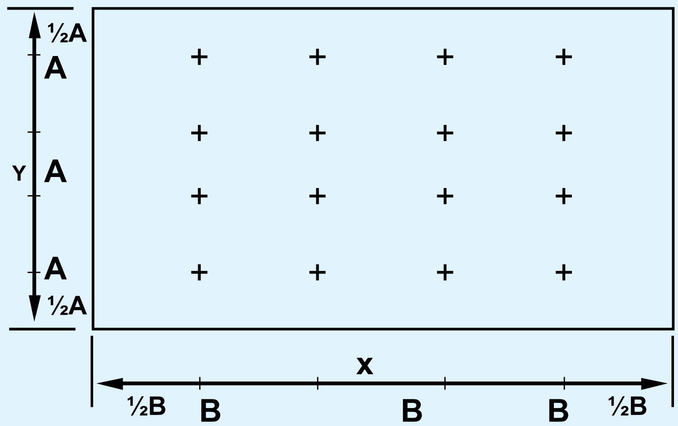
b. Provide a suitable location by modifying the system. The modifications may be temporary or permanent, minor or extensive, depending on the specific conditions encountered. Once a suitable location for the traverse plane has been established, the area of the traverse plane must be accurately determined. Measurement should be made by probing for the inside duct dimensions, and special care should be used when measuring lined duct. It is important to note, particularly in any case in which it is necessary to locate the traverse plane in a converging or diverging airway, that the traverse plane is located at the tip of the Pitot static tube.

The Traverse:

To determine the velocity in the traverse plane, a straight average of individual point velocities will give satisfactory results when point velocities are determined by the following rules:

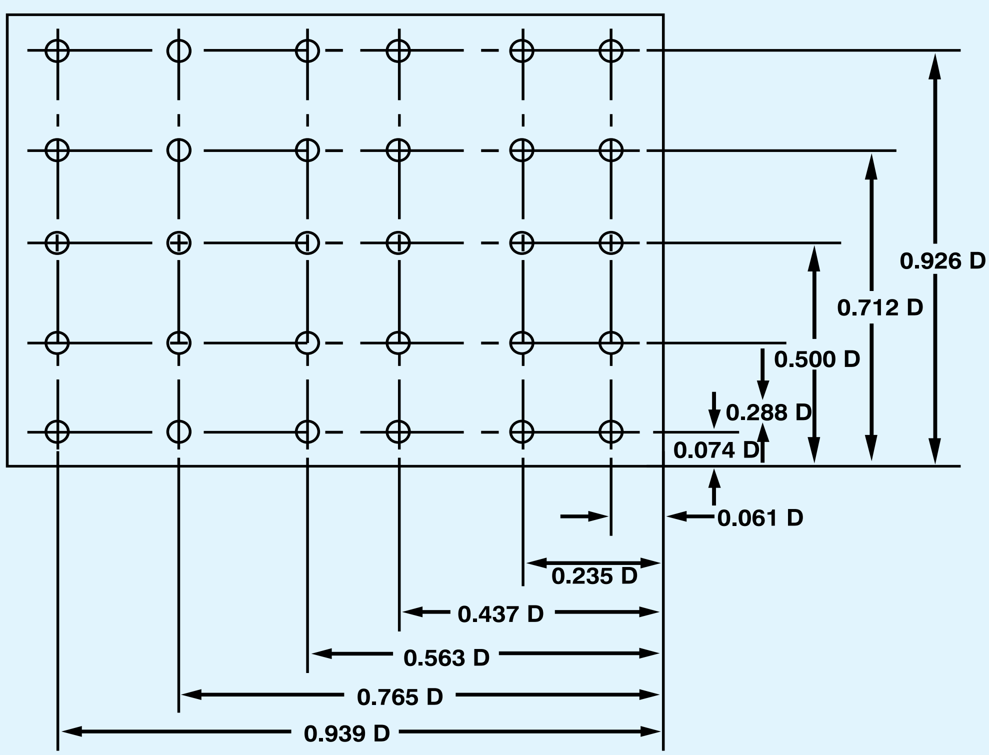
The Equal Area Rule is shown in Figure H1.3 for traverses in a rectangular duct.

The Log-Tchebycheff Rule (from ISO 3966)10 is shown in Figure H1.4.



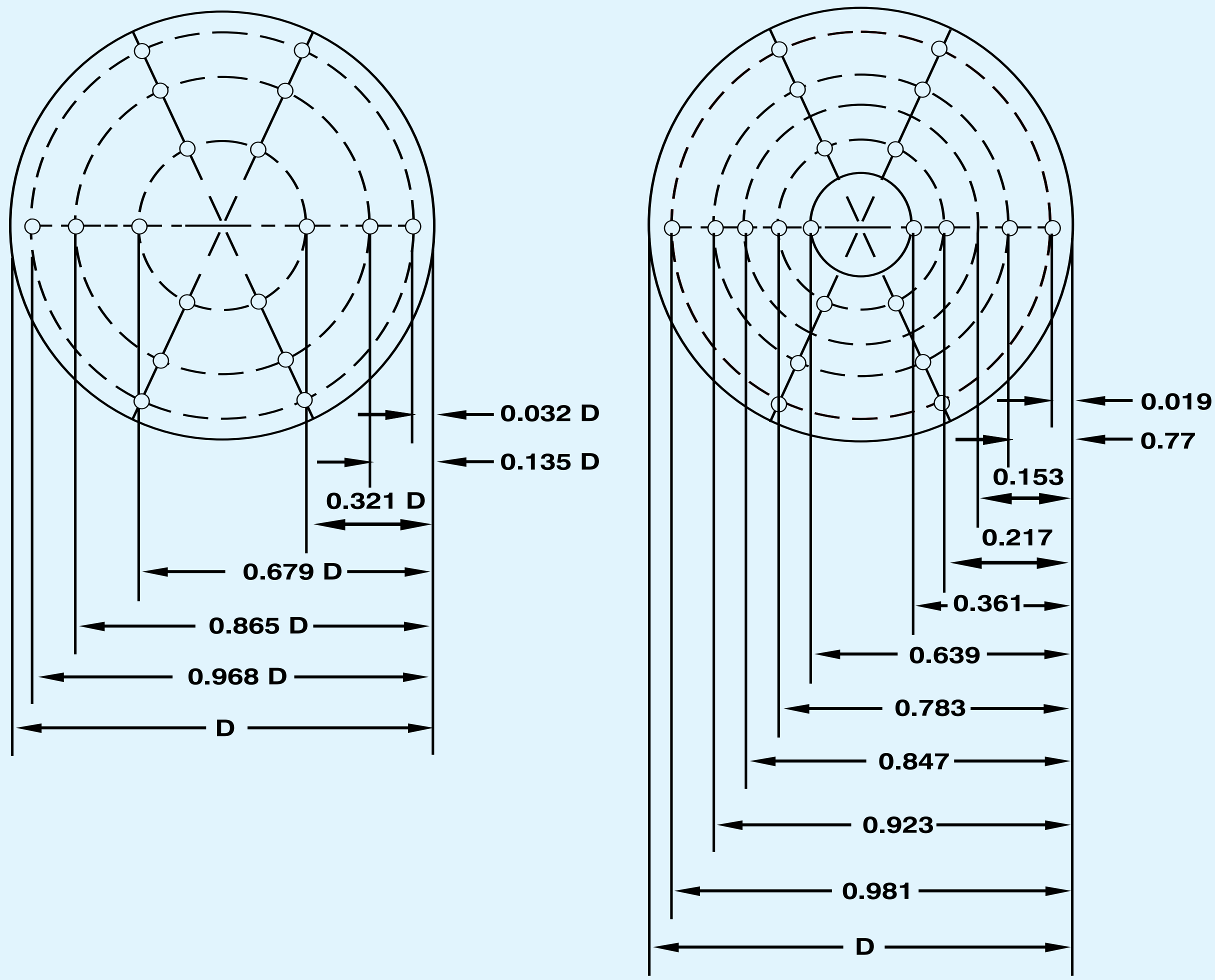
F X OR Y ARE LESS THAN OR EQUAL TO	MINIMUM NUMBER OF PLEAD NOS
4* OR LESS	2
15*	3
24*	4
35*	5
48*	6
63*	7
80*	8
99*	9
100* OR GREATER	10

Figure H1.3: Travers locations using equal area rule in a rectangular duct.



NO. OF POINTS OR TRAVERSE UNES	POSITION RELATIVE TO INNER WALL	USE WITH SIDE DIMENSIONS
5	0.074, 0.288, 0.500, 0.712, 0.926	< 30*
6	0.061, 0.235, 0437, 0.563, 0.765, 0.939	30* TO 63*
7	0.053, 0.203, 0366, 0.500, 0.634, 0.797, 0.947	>63*

Figure H1.4: Traverse locations using log- Tchebycheff rule in a rectangular duct.



NO. FO MEASURING POINTS PER DIAMETER	POSITION RELATIVE TO INNER WALL	USE WITH DIAMETER
6	0.032, 0.135, 0.321, 0.679, 0.865, 0968	<10'
10	0.019, 0.077, 0.153, 0.217, 0.361, 0.639, 0.783, 0.847, 0.923, 0.981	≥10'

Figure H1.5: Log linear rule for traverse points on two diameters of a circular duct.

Figure H1.5, shows the measuring points for a circular duct traverse using the log-linear rule and three symmetrically disposed diameters. Points on two perpendicular diameters may be used where access is limited.

Figure H1.6, shows the measuring points for a commonly accepted flat-oval duct traverse.

Since field measured airflows are rarely steady and uniform, accuracy can be improved by increasing the number of measuring points. When velocities at a traverse plane are fluctuating, two traverse readings in short succession will also help to average out velocity variations that occur with time. If negative-velocity pressure readings are encountered, they are considered a measurement value of "zero" and calculated into the average velocity pressure.

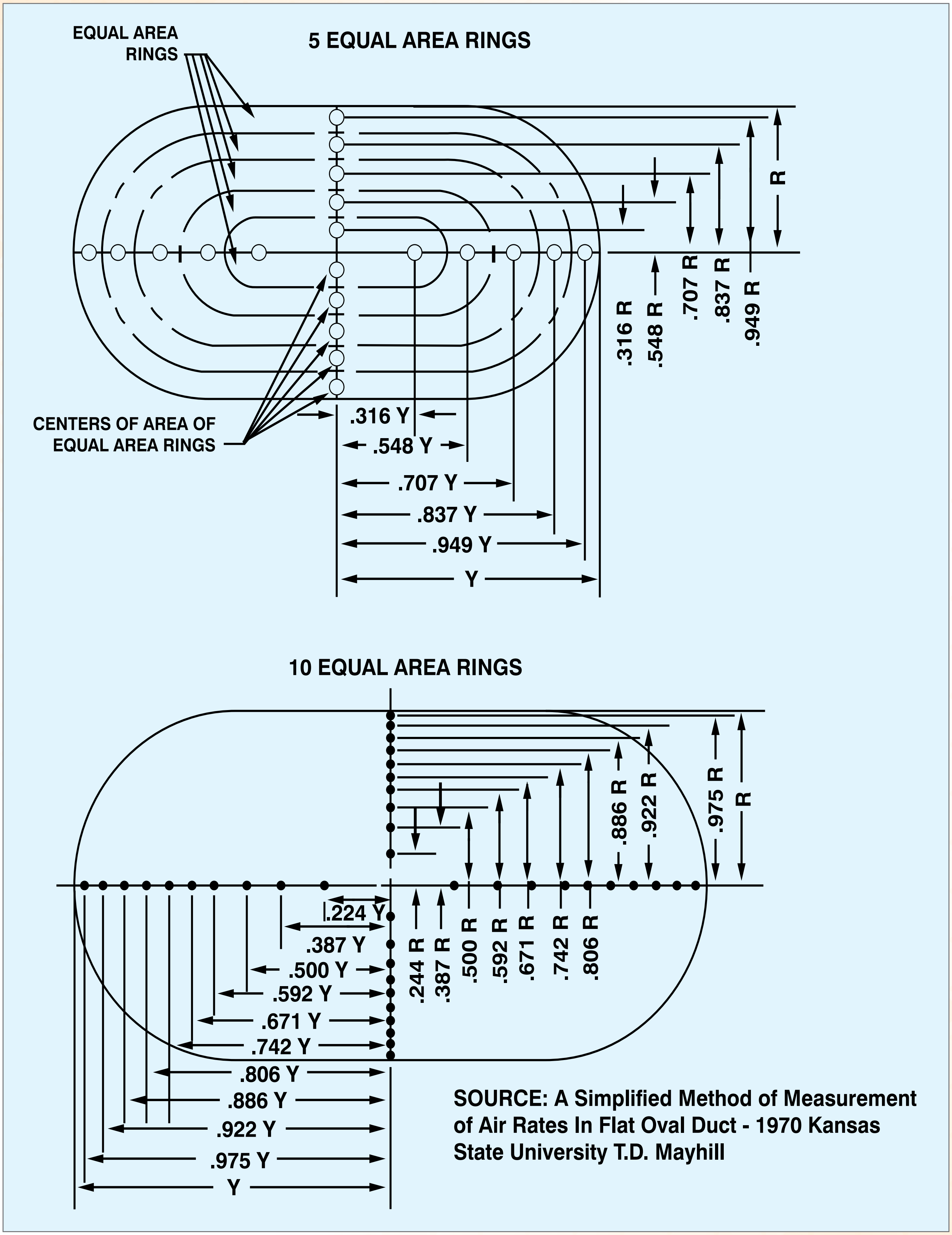


Figure H1.6: Traverse locations for five equal area rings and ten equal rings in flat oval duct.

6.1.2 Flow measuring hood/ matrix

The flow-measuring hood is a direct reading flow measurement device. It is designed with a fabric "sock" that covers the terminal air outlet device being measured. The conical or pyramid shaped hood collects all of the air entering or leaving an air outlet and guides the airflow over the flow measuring instrumentation. Hoods generally are constructed so that the outlet tapers down to the metering section. A velocity measuring grid and calibrated differential pressure manometer in the hood will display the airflow in l/s (cfm) directly.

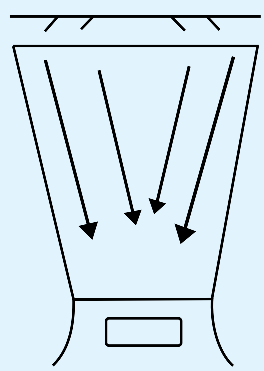
Velocity Matrix:

A velocity matrix provides a larger measurement area, reducing the total number of samples resulting in quicker measurements. The velocity matrix can be used on a supply opening with no grill or louvers and on the filters at the AHU room, but may not be the best choice if there are turbulent air flows. They can cause some turbulent air patterns which could affect the averaging function of the grid pressures.

Location of Instrument:

Capture hoods are popular instruments to use for measuring flow rates from supply grilles. Since they obtain measurements quickly, provide a direct air volume reading, are easy to use, and come with a variety of hood sizes to match various grilles, capture hoods are often the tool of choice (when measuring supply air volume).

ASHRAE Standard 111 recommends performing a duct traverse to determine if a correction factor is needed for air capture hood measurements. Different diffuser styles, elbows attached directly to the diffuser, and dampers located just upstream of the diffuser can impair the uniformity of the flow patterns coming out of the diffuser and affect the hood reading. Be sure to choose the hood size that most closely matches the outlet size being measured



610 mm x 610 mm (2 ft x 2 ft) diffuser
True air flow = 170 m3/h (100 ft3/min)
Hood air flow = 170 m3/h (100 ft3/min)

Figure H1.7

All capture hoods cause flow resistance on the air handling system. Just as different diffuser styles have their own characteristic flow resistance, so do capture hoods. This added resistance reduces the actual volume of air exiting the diffuser. In the majority of cases, this error is less than or equal to the accuracy of the instrument. Proportional balancing techniques will also assist in making these effects negligible.

To determine if flow resistance effects are important, perform duct traverses* to determine the volume rate exiting a diffuser both with and without the capture hood in place. The difference between the volume rate with and without the capture hood in place is the flow resistance effect for that diffuser.

Note: To determine a correction factor for flow resistance that can be used on similar diffusers and duct configurations, use the volume rates as determined from the duct traverses when performed with and without the hood applied to the diffuser or grill as follows.

$$C_f = V_{no\ hood} / V_{hood}$$

Where:

V_{hood} = Flow rate with the hood in place on the diffuser

$V_{no\ hood}$ = Flow rate without the hood in place on the diffuser

C_f = Correction factor

$$V_{corrected} = C_f \times V_{measured}$$

Where:

$V_{measured}$ = Volume rate as displayed by the capture hood.

$V_{corrected}$ = Volume rate corrected for the flow resistance of the capture hood.

*Note: *Be sure to traverse the duct connected to the diffuser being tested. Also verify that there are no leaks in the duct between the traverse location and the diffuser or in the duct to diffuser connection.*

Characterizing a Capture Hood to an Outlet Using a Correction Factor.

Capture hoods are to be calibrated on a wind tunnel with a 610 mm × 610 mm (2 ft × 2 ft) diffuser for supply and exhaust. To minimize recirculation regions (non-laminar flows on one side of the hood), hood sizes should match the diffuser being measured as closely as possible.

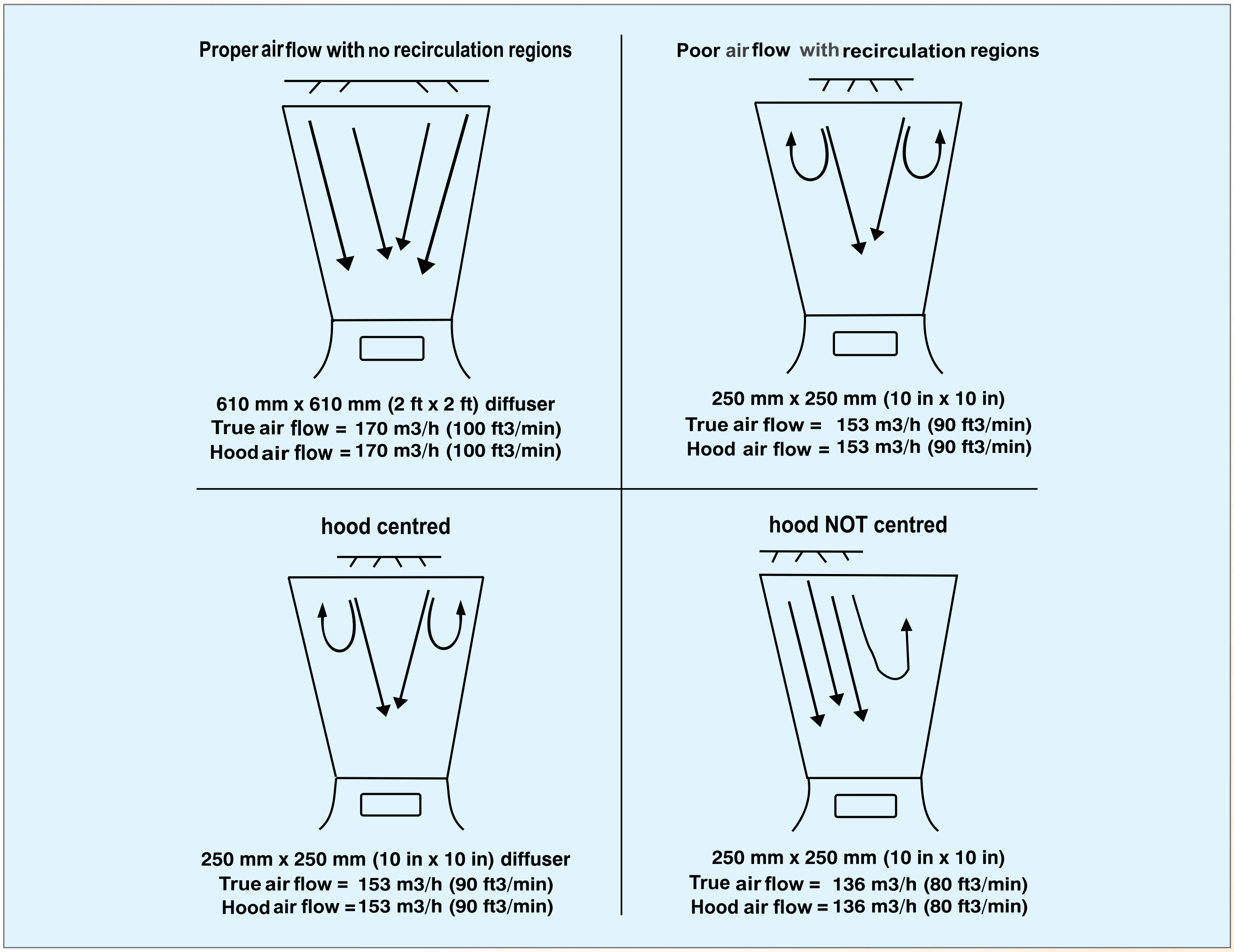


Figure H1.8

Large recirculation regions will affect volume flow readings. Different diffuser sizes cannot be directly compared. On a 610 mm × 610 mm (2 ft × 2 ft) diffuser using a 610 mm × 610 mm (2 ft × 2 ft) hood, there are no recirculation regions.

If the capture hood is used on a small diffuser, the recirculation regions will create turbulence and the accuracy will be impaired.

Characterizing the hood to the outlet being measured is accomplished by performing a duct traverse of the branch leading to the outlet and comparing it to the hood reading. Divide the duct traverse reading by the hood reading to come up with a correction factor to be applied to the hood readout. This correction factor can then be used on similar outlet and duct configurations

To determine a correction factor for the hood to match a duct traverse, use the following formula:

$$C_f = D_{tr} / H_r$$

Where:

C_f = Correction Factor

D_{tr} = Duct Traverse Reading

H_r = Hood Reading

To apply the correction factor to the hood readout, use the following formula:

$$H_c = H_r \times C_f$$

Where:

H_c = Corrected Hood Reading

H_r = Hood Reading

C_f = Correction Factor

6.1.4 Water flow Measurement

The instruments shall conform to the requirements of “Clause-5 Test equipment description”

6.1.4.1 Clamp on Ultrasonic flow meter

The flow measurements are made by penetrating the pipe with ultrasound. Time differences, frequency variations or phase shifts of the ultrasonic signals caused by the flowing liquid are subsequently evaluated.

The measurement of flow is based on the principle that sound waves traveling in the direction of flow of the fluid require less time than when traveling in the opposite direction. The difference in transit times of the ultrasonic signals is an indication for the flow rate of the fluid.

Since ultrasonic signals can also penetrate solid materials, the transducers can be mounted onto the outside of the pipe.

a) ***Transit-time principle:*** Transit time flow meters utilize two transducers, which function as both ultrasonic transmitters and receivers. The transducers are clamped to the outside of a closed pipe at a specific distance from each other.

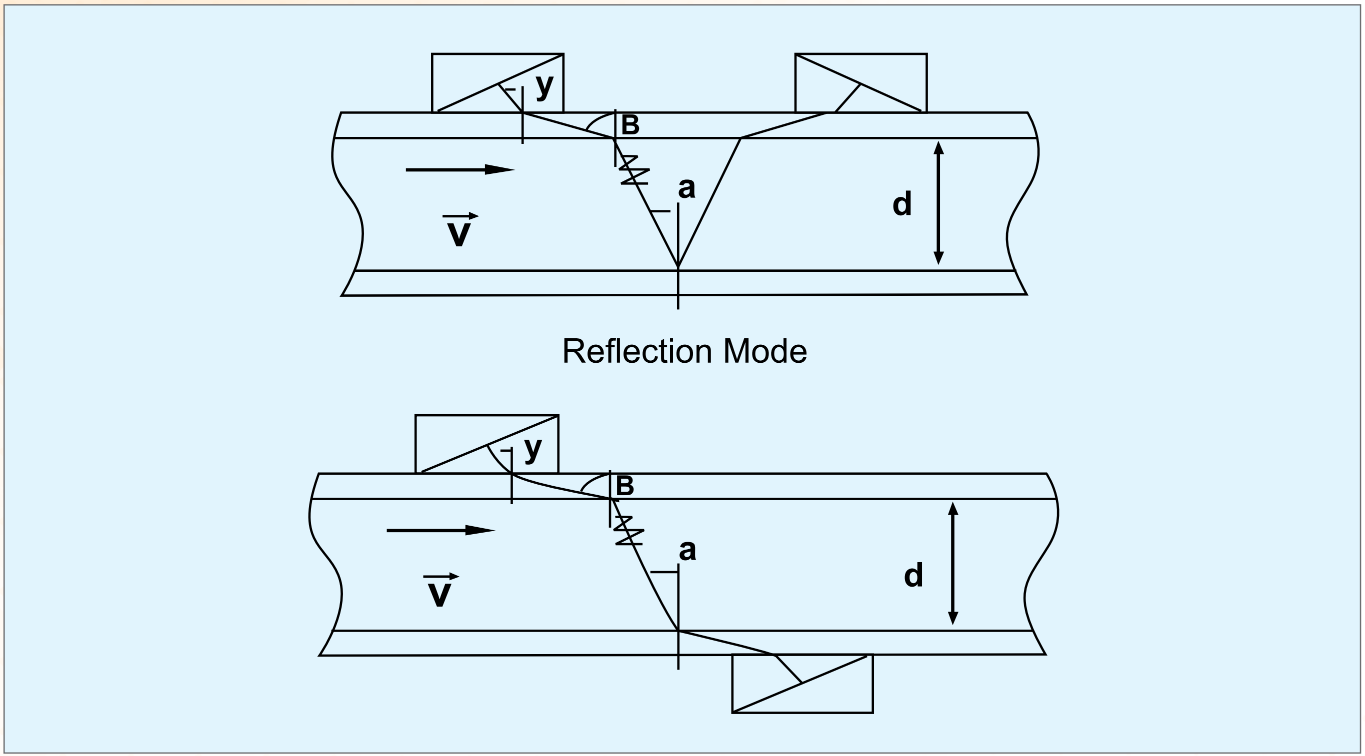


Figure H1.9: Diagonal Mode

The transducers can be mounted in reflection or in diagonal mode. This selection is based on pipe and liquid characteristics.

b) ***Doppler Ultrasonic Flow meters:*** Doppler ultrasonic flow meters measure the frequency change (doppler effect) of a signal sent into the flowing liquid stream across the pipe. The injected signal bounces off of bubbles or particles in the stream and this echo is returned to the transducer (Figure H1.10). The frequency of the signal is shifted lower in case of flow moving away from the sensor. The device compares the frequency shift to the original signal and computes the flow velocity. For accurate flow measurement with the doppler type ultrasonic flow meter, the fluid should contain sufficient concentration of particles and/or bubbles to reflect the signal adequately. Doppler ultrasonic flowmeters work well with suspension flows where particle concentration is more than 100 parts per million and particle size is larger than 100 micrometers, but less than 15% in concentration. Thus, these flowmeters are not recommended for use in clean water. Doppler

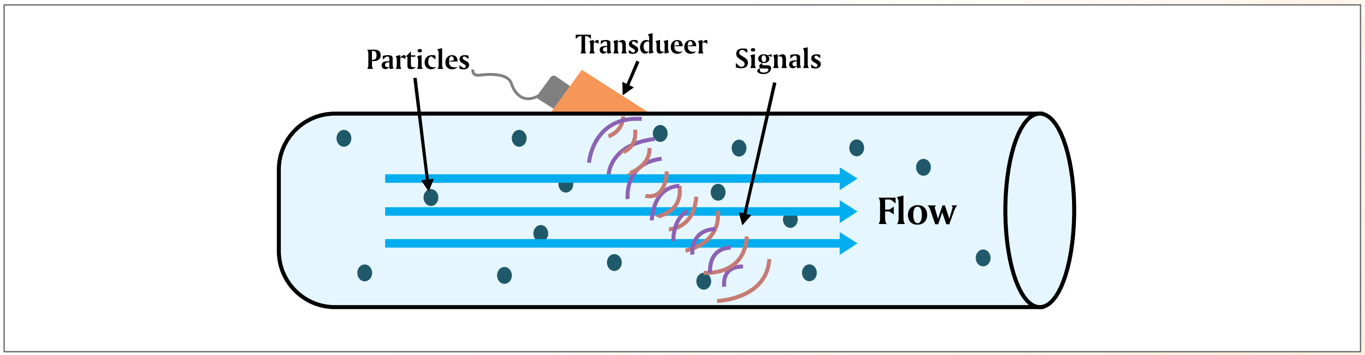


Figure H1.10: Selecting Portable Ultrasonic Flowmeters

flowmeters typically have just one transducer, therefore setup for measuring may be easier than the transit-time flowmeters.

There are a number of important factors to consider when choosing a good portable ultrasonic flowmeter. One factor is the sediment property of the water in terms of quantity and size. Generally, when water to be measured has sediment particles more than 100 parts per million and larger than 100 micrometers (the numbers may be different for different manufacturers), the doppler type should be considered. On the other hand, in the case of clear and clean water without sufficient sediments, the transit-type works better. The desired level of accuracy should be considered when selecting the best portable ultrasonic flow meter for the job.

Measurement procedure:

a. To ensure well-conditioned water flowing past the measuring location, a sufficient length of straight, unobstructed pipe is required from the meter location. It is suggested placing flowmeters at a distance of at least 10 times the diameters of straight pipe downstream of pipe fixtures.

b. Figure shows the straight pipe length requirements for some of the pipe fittings and configurations to ensure accurate flow measurement. The lengths (L) are in pipe diameter (D) multiples. For example, a 152.5 mm (6-inch) pipe with "10 D" recommendation is saying the meter should be at least 60 inches (5 feet) from the disturbance.

Note: The lengths are from the fixture to the center of the ultrasonic meter.

c. In case of the shorter straight length of the pipe, in which case correction factors may need to be employed. Correction factors for an ultrasonic meter can be derived from laboratory calibrations of manufacturer.

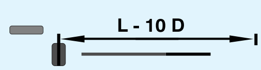
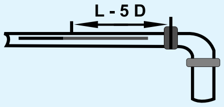
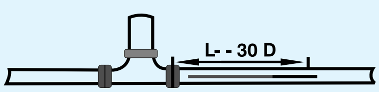
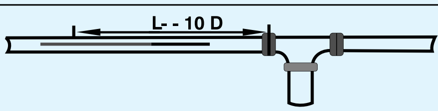
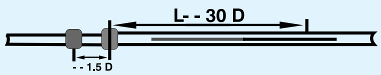
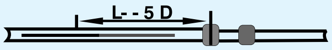
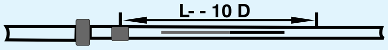
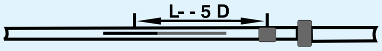
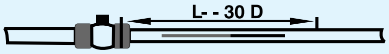
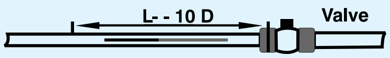
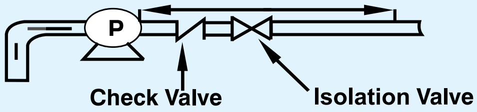
Classification	Upstream straight Length	Downstream straight Length
90° bend		
Tee		
Diffuser		
Reducer		
Valves		
Pump		

Table H1.1

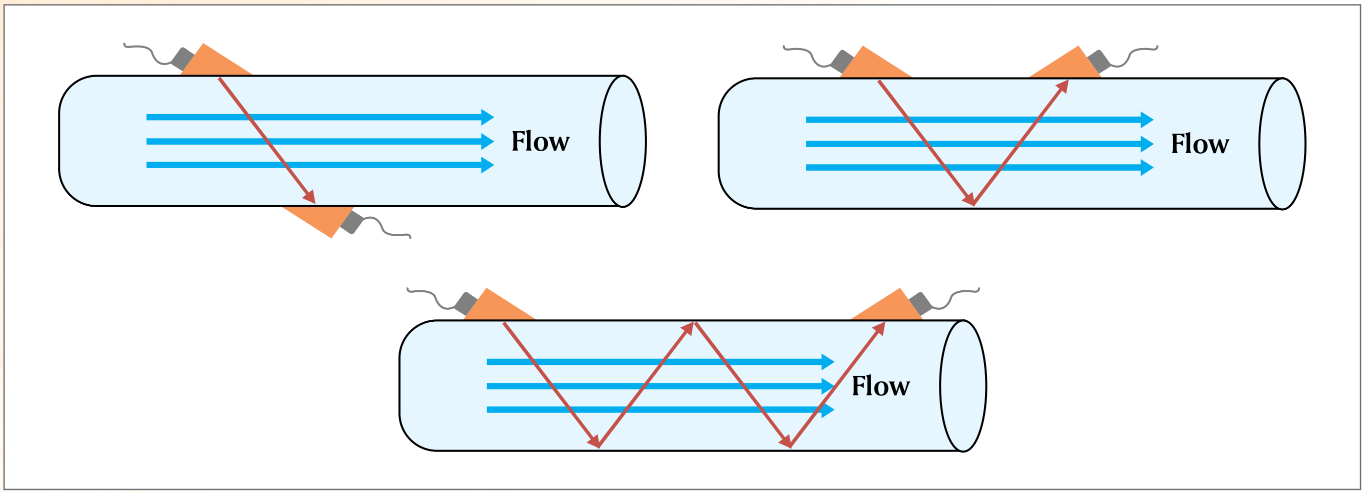


Figure H1.11

d. Clean the surface of the pipe intended for measurement and area shall be smooth section of pipe free of defects.

e. Apply the acoustic gel between the transducer and the pipe. This material makes a continuous path for the sound signal to pass through.

f. Applying the gel requires caution to ensure it does not dry out or air bubbles are not introduced from excessive spreading. Bubbles in the gel can cause signal echoes. The gel should be applied in a bead that will spread evenly along the transducer base and allow for full contact with the pipe wall when the transducer is pressed onto the pipe.

g. The transducers must be mounted exactly parallel to the liquid flow in the pipe.

h. Input the pipe wall thickness into the ultrasonic flow meter as per the pipe technical data sheet.

I. The transit-time flowmeter transducer pairs shall be mounted as per the arrangements. The three main configurations are the direct transmission (Z-method), the single reflection (V-method), and the multiple reflection (W-method). The first two configurations are most common. The direct method where transducers are mounted on the opposite sides are more commonly used in larger diameter pipes whereas the reflection methods, where the transducers are mounted on the same side, are normally applied for small diameter pipes.

j. Measure and record the water flow.

6.2 Temperature Measurement: Air side & Water side

6.2.1 Air side temperature measurement

Air temperatures consist of the dry-bulb temperature (DBT) and the wet-bulb temperature (WBT). These temperatures are required to determine density/specific volume of air, humidity (moisture content), and the heat content of the air handled by the system.

Instruments

Mercury thermometer

Electric resistance thermometer, including thermistors.

The instruments shall conform to the requirements of “Clause-5 of this annexure”

6.2.1.1 Dry bulb temperature (DBT) Measurements

The following shall be considered to ensure that temperature measurements are representative of the airstream being tested at the plane of interest:

If temperature stratification exists, a sufficient number of readings shall be obtained to ensure that the average value represents the true value.

When determining wet bulb depression, the two temperature measuring devices shall be calibrated against each other to obtain better accuracy. When DBT and WBT are being obtained simultaneously, the dry bulb (DB) measuring device shall be upstream from the WB measuring device to ensure that the DBT reading is not influenced by the effects that the wet bulb (WB) device may have on that portion of the airstream that flows over the DB device.

There shall be no moisture in the airstream at the point where the DB reading is obtained.

The sensor shall be shielded if thermal radiation is a factor that could influence the reading.

Consideration shall be given to appropriate immersion of the sensing device into the airstream and correction factors applied if necessary.

Temperature measurements shall be made over a sufficient length of time to ensure that a steady-state value is being recorded. If there are oscillations in the values, that representative average values can be determined.

6.2.2 Wet bulb temperature (WBT) measurements

The considerations noted in Section above also apply to wet bulb temperature measurements, as do the following:

Distilled water shall be used to wet the wick of the wet bulb sensing device.

The wick covering the sensor shall be clean and remain wet while the measurement is being made.

The time over which the measurement is made shall be sufficient for equilibrium to be achieved.

The air velocity across the sensor shall be between 3.5 to 10 m/s (700 to 2000 fpm) for minimum error.

The sling psychrometer is recommended for obtaining wet-bulb temperatures of ambient air.

System conditions can produce effects that cause temperature-measurement errors. The following are the most commonly encountered.

a. Stratification
b. Velocity
c. Temperature
d. Contamination
e. Dust (Wet Bulb)
f. Contaminated water (Wet Bulb)
g. Free moisture (Dry Bulb)

6.3 Water Side temperature measurement

Temperatures of fluids, such as water, oil, antifreeze solutions, heat transfer fluids, etc., will be used to determine the intensity of the heat content using the Celsius (°C) scale (or the Fahrenheit (°F) scale).

For HVAC work, the normal operating range is from 5°C to 99°C (40°F to 210°F).

The amount of heat in a fluid is measured in kilojoules (kJ) (or British Thermal Units (Btu)). Heat flow is measured in watts (W) (or British Thermal Units per hour (btu/h)).

6.3.1 The fluid temperatures shall be measured using the following instruments:

a. Mercury thermometer

b. Electric resistance thermometer

6.3.1a Fluid Immersion

Thermometer test wells installed at the desired locations permit accurate readings without removal or loss of the system fluid. A good heat transfer fluid (Glycerine) or thermal mastic should be used to ensure a good thermal contact between the thermometer and the test well.

Note: When the temperatures of the surrounding surfaces are substantially different from the measured fluid, there is considerable radiation effect upon the thermometer reading if the thermometer is left unprotected. Proper shielding or aspiration of the thermometer bulb and stem can minimize these radiation effects.

The complete stem- immersion type of calibrated thermometer must be used with the stem completely immersed in the fluid in which the temperature is to be measured. If complete immersion of the thermometer stem is not possible or practical, then a emergent stem correction must be made for the amount of emergent liquid column.

$$\text{Emergent stem correction} = k_n \times (t_b - t_s)$$

where

k = 1.00016 (for Mercury thermometer and measurement scale in °C)

k = 1.00009 (For Mercury thermometer and measurement scale in °F)

n = number of degrees of emergent liquid column

t_b = temperature of bath

t_s = temperature of stem

Thermometers calibrated for partial-stem immersion are more commonly used. They are used in conjunction with thermometer test wells designed to receive them. No emergent stem correction is required for the partial stem immersion type.

6.4 Pressure measurement: Air side and water side

6.4.1 Air Side

The pressures involved with air measurements are static pressure, velocity pressure, total pressure, and differential pressure. One or more of these pressures is required to determine air density, airflow rate, and resistance to airflow of system components and to make certain system component adjustments.

Experience must be used in selecting a pressure measurement plane. Even the best location available in the field must be evaluated for system effects that can influence the accuracy of the measurement. An example is the measurement of fan total pressure. Therefore, even experienced engineers should use this field-measurement method as a guide only.

Instruments:

The instruments shall conform to the requirements of "Section-5 Test equipment description.

Static Pressure:

When testing, adjusting, and otherwise evaluating a system, all values of static pressure (design values and test values) must be referenced to the same value of atmospheric (barometric) pressure. (Static pressure measurements can be either positive or negative. Positive values are those greater than atmospheric pressure. Negative values are those less than atmospheric pressure.)

A pitot static tube with a manometer or pressure taps with a manometer shall be used to measure static pressure. It is important that the inner duct surface or plenum be smooth and free from irregularities and that the velocity of the gas stream does not influence the pressure measurements.

A straight run of duct upstream of the measurement plane usually results in acceptable conditions at the plane. Regions immediately downstream from elbows or regions where there are obstructions and abrupt changes in airway area are generally unsuitable locations. Regions where unacceptable airflow irregularities are present shall be avoided. Refer to clause 5 Test Equipment description for details.

In any fan system installation, if the prospective locations for static pressure measurement are not stable, the alternative is to accept the best qualified locations and evaluate the effects of the undesirable aspects of the conditions on the accuracy of the test results.

Special consideration should be given to measuring static pressures for use in determining fan static. It is recommended that the measurements be made at locations near the fan inlet and near the fan outlet and that the duct between the measurement plane and the plane of interest be straight and without change in a cross-sectional area. In this situation, the duct friction loss between the measurement plane and the plane of interest is usually insignificant and considerations of velocity pressure conversions and calculations of pressure losses for duct fitting and other system components can be avoided.

Fan total pressure (P_{tf}) is the algebraic difference between the fan-outlet total pressure (P_{t2}) and the fan inlet total pressure (P_{t1}). It is the measure of the total mechanical energy added to the air by the fan

$$P_{tf} = P_{t2} - P_{t1}$$

Fan velocity pressure (P_{vf}) is the velocity pressure corresponding to the average velocity through the fan outlet. It is the kinetic energy per unit volume of air exiting the fan.

Differential fan static pressure (P_{sf}) is the algebraic difference between the discharge fan static pressure (P_{sf1}) and the suction static pressure of the fan (P_{sf2}).

P_{sf} = Fan discharge Static pressure (P_{sf1}) - Fan suction static pressure (P_{sf2}).

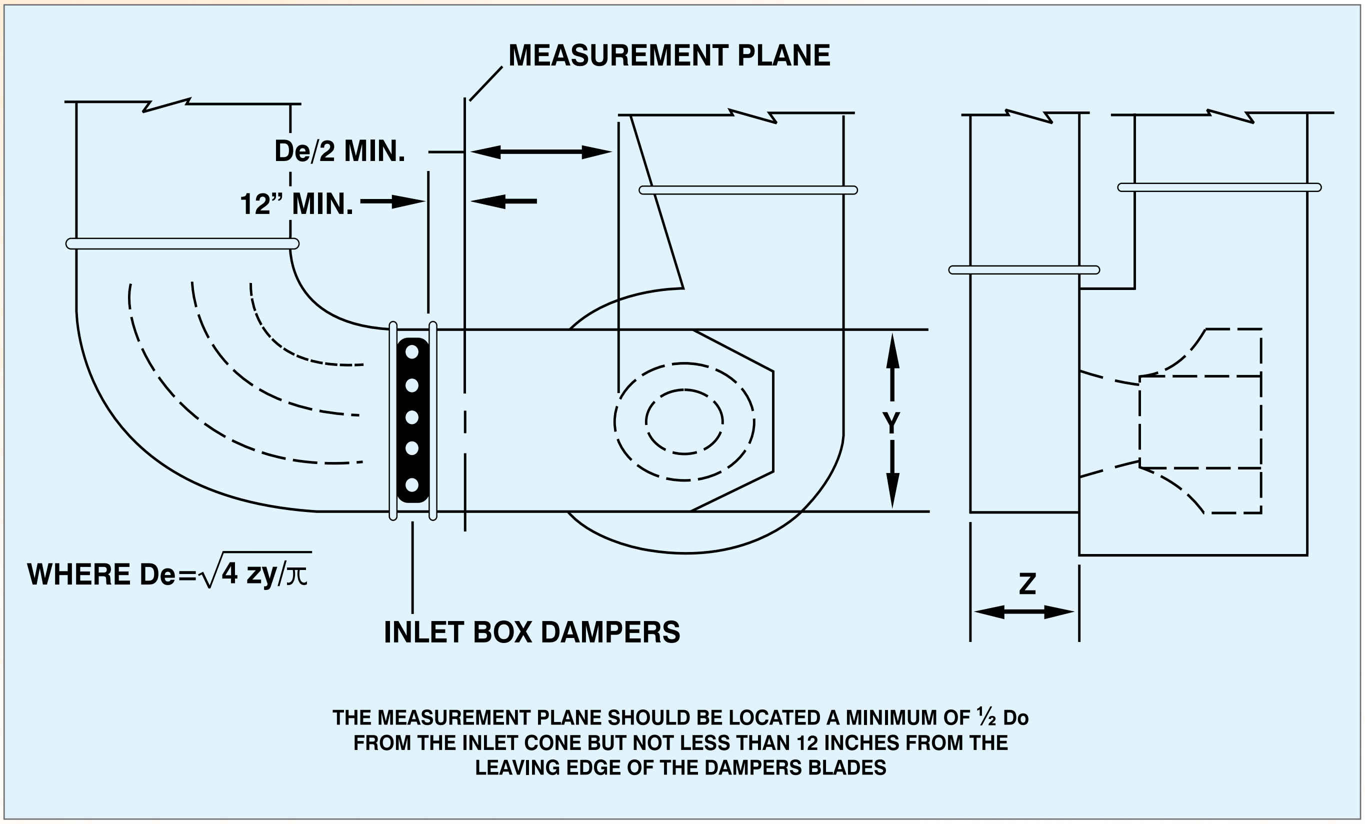


Figure H1.12

In the event the fan is ducted on the outlet side, the static pressure measurement plane downstream of the fan shall not be less than one equivalent diameter from the fan.

The location of the static pressure measurement plane upstream of the fan should not be less than 0.5 equivalent diameters from the fan inlet.

In the event that static pressure measurements must be obtained in an inlet box, the measurement plane should be located as indicated in Figure. In the case of double inlet fans, static pressure measurements must be made in both inlet boxes in order to determine the average static pressure on the inlet side of the fan.

6.4.2 Filters Static pressure drop

Measuring the pressure drop across a filter is effective method for verifying filter and system performance. An air filter should be changed when the filter fills up with dust and creates an excessive pressure drop, resulting in reduced airflow through the filter. Periodic visual inspections and monitoring the pressure drop across the filter with a mechanical or digital manometer is a simple solution for general ventilation system maintenance.

Differential filter static pressure (P_{sf}) is the algebraic difference between the discharge filter static pressure (P_{sf1}) and the suction static pressure at the filter (P_{sf2}).

P_{sf} = Filter discharge static pressure P_{sf1} – Filter suction static pressure P_{sf2}

6.5 Water Side

Instruments:

Pressure and/or vacuum measurements of fluids shall be made using the instruments referred in the section 5 Test Equipment description.

Gauge/Absolute Pressure: The pressure of most hydronic systems is measured in terms of pounds per square inch (psi [kPa]) or feet of water (ft wg [Pa]). This indicated pressure is known as the gauge pressure (psig), and for gauge pressure, the measuring device should indicate a zero reading when not connected.

For HVAC work, atmospheric pressure can be assumed to be 101.3 kPa (14.7 psi) at sea level, even though barometric conditions constantly change. Absolute pressure (psia) equals the gauge pressure plus the 101.3 kPa (14.7 psi) of atmospheric pressure.

Differential pressure: The pressure difference existing between two measured pressures. If possible, the same gauge should be used to take both readings.

6.6 Sound pressure Measurement with respect to AHU operation.

Present technology does not test whether equipment is operating with desired sound levels; field tests can only determine sound pressure levels, and equipment ratings are almost always in terms of sound power levels. Until new techniques are developed, the testing engineer can only determine (1) whether sound pressure levels are within desired limits and (2) which equipment, systems, or components are the source of excessive or disturbing transmission

Sound-Measuring Instruments:

Instruments used for sound pressure level. Refer to Section 5 - Test Equipment Description for details.

The precision sound level meter is used to measure sound pressure level. The most basic sound level meters measure overall sound pressure level and have up to three weighted scales that provide limited filtering capability. The instrument is useful in assessing outdoor noise levels in certain situations and can provide limited information on the low-frequency content of overall noise levels, but it provides insufficient information for problem diagnosis and solution. Its usefulness in evaluating indoor VAC sound sources is thus limited. Proper evaluation of HVAC sound sources requires a sound level meter capable of filtering overall sound levels into frequency increments of one octave or less.

Sound analyzers provide detailed information about sound pressure levels at various frequencies through filtering networks. The most popular sound analyzers are the octave band and center frequency, which break the sound into the eight octave bands of audible sound. Instruments are also available for 0.33, 0.1, and narrower spectrum analysis; however, these are primarily for laboratory and research applications. Sound analyzers (octave midband or center frequency) are required where specifications are based on noise criteria (NC) and room criteria (RC) curves or similar frequency criteria and for problem jobs where a knowledge of frequency is necessary to determine proper corrective action.

Sound Level Criteria:

Without specified values, the testing engineer must determine whether sound levels are within acceptable limits (Refer ASHRAE HVAC Application 2019 - Chapter 49). Note that complete absence of noise is seldom a design criterion, except for certain critical locations such as sound and recording studios. In most locations, a certain amount of noise is desirable to mask other noises and provide speech privacy; it also provides an acoustically pleasing environment, because few people can function effectively in extreme quiet. Table 1 in Chapter 8 of the 2017 ASHRAE Handbook – Fundamentals lists typical sound pressure levels. In determining allowable HVAC equipment noise, it is as inappropriate to demand 30 dB for a factory where the normal noise level is 75 dB as it is to specify 60 dB for a private office where the normal noise level might be 35 dB.

Most field sound-measuring instruments and techniques yield an accuracy of ±3 dB, the smallest difference in sound pressure level that the average person can discern. A reasonable tolerance for sound criteria is 5 dB; if 35 dBA is considered the maximum allowable noise, the design engineer should specify 30 dBA. The measured sound level of any location is a combination of all sound sources present, including sound generated by HVAC equipment as well as sound from other sources such as plumbing systems and fixtures, elevators, light ballasts, and outdoor noises. In testing for sound, all sources from other than HVAC equipment are considered background or ambient noise. Background sound measurements generally have to be made,

(1) when the specification requires that the sound levels from HVAC equipment only, as opposed to the sound level in a space, not exceed a certain specified level;

(2) when the sound level in the space exceeds a desirable level, in which case the noise contributed by the HVAC system must be determined; and

(3) in residential locations where little significant background noise is generated during the evening hours and where generally low allowable noise levels are specified or desired. Because background noise from outdoor sources such as vehicular traffic can fluctuate widely, sound measurements for residential locations are best made in the normally quiet evening hours. Procedures for residential sound measurements can be found in ASTM Standard E1574, Measurement of Sound in Residential Spaces.

6.7 Vibration analysis

The instruments shall conform to the requirements of "Section-5 Test equipment description". Vibration testing is necessary to ensure that

(1) equipment is operating within satisfactory vibration levels and

(2) objectionable vibration and noise are not transmitted to the building structure. Although these two factors are interrelated, they are not necessarily interdependent. A different solution is required for each, and it is essential to test both the isolation and vibration levels of equipment.

General Procedure

Make a visual check of all equipment for obvious errors that must be corrected immediately.

Make sure all isolation is free-floating and not short circuited by obstruction between equipment or equipment base and building structure.

Turn on the system for an aural check of any obviously rough operation. Checking bearings with vibration measurement instrumentation is especially important because bearings can become defective in transit or if equipment was not properly stored, installed, or maintained. Defective bearings should be replaced immediately to avoid damage to the shaft and other components

Adjust and balance equipment and systems so that final vibration tests are made on equipment as it will actually be operating.

6.8 Electrical parameters measurement for motor

Using the field test measurements of current, input, voltage, the typical motor-performance data values of power factor (pf), and the motor-efficiency corresponding to the measured amps input current, the motor power output is calculated as follows

For single phase motors:
bhp = (Current × Voltage × power factor × motor efficiency) / 746

For three phase motors:
bhp = (sqrt 3 × Current × Voltage × power factor × motor efficiency) / 746

Note: In both equations, input current and votage are the field test measurement values. In the case of three-phase motors, it is the averages of the measured phase values.

From field measurements of motor electrical input kilowatts, voltage, and current, the following relationship can be used to determine motor power factor:

Rearranging terms,

For three phase motors
pf = (kW × 1000)/(1.73205 × V × A)

For single phase motors
pf = (kW × 1000)/(V × A)

where:
kW = three-phase kilowatts
V = three-phase voltage
A = average current across all three-phases

Using the calculated power factor and the measured motor rpm, determine the estimated motor efficiency and the Percent of full-load horsepower from the manufacturer's motor performance curves.

The frequency of operation of the motor shall be considered as 50Hz as per Indian power regulations and in case variable frequency drive (VFD) provided for fans, actual frequency readings from the field VFD to be measured.

7.0 Test Procedures

Air volumetric measurement

7.1 General

The requirements of clause 5.0 and clause 6.0, "Air Measurement," shall apply.

7.1.1 System Preparation

Prior to the air volumetric measurement obtain and verify the following:

a) Obtain updated construction drawings, specifications, approved shop drawings and submittals, addenda, bulletins, and change orders related to the air systems.

b) Obtain /refer field-data forms for equipment delivery, Pre-commissioning and start up checklist. (refer clause 9 for air handling unit check list).

c) Conduct the pre-commissioning and start up as per the clause 9 checklist of air handling units, checks as per the section-9 checklist of Air handlers.

d) Verify that fans are installed, running as per the requirement to supply the required airflow rate, and that all installation, start-up, lubrication, and safety requirements have been met.

e) Check that filters are clean and properly mounted and sealed.

f) Verify that fire, smoke, automatic, and volume control dampers are operable and accessible and are in an open or normal position.

g) Verify that controls are installed, operable, and calibrated.

h) Verify that control boxes are installed, operable, and accessible.

i) Verify that terminal devices are installed and accessible.

j) Verify that access doors are installed and secured.

Perform the following in accordance with design documents before beginning Air volumetric measurement

i) Verify that all dampers are in an open position and all boxes or automatic air-volume control devices are in an acceptable mode.

ii) Verify that all air terminal deflectors are in the position indicated by the manufacturer when using effective area factors to determine airflow rate and obtain correction factors for all velocity measuring instruments.

iii) Record the nameplate data on the fan, motor, and air handling cabinet.

Air volumetric measurement procedure

a) Operate the associated Air handling unit fan to full capacity.

b) Set the system in the minimum outdoor air mode.

c) Refer clause 5 and clause 6 test method of air volumetric measurement "for methods of measurement.

d) Calculate the area of the filters, grills, louvers and apply the diversity factor for grills and louvers as per manufacturer data.

e) Perform the air balancing as per the section "air balancing "of this standard.

f) Perform a Pitot tube velocity traverse of the main ducts and record the average velocity at the main duct.

g) Calculate the supply air volume as per the below equation:

$$Q = VA$$

where
Q = flow rate in cfm m^3/s
A = cross sectional area at the traverse plane in m^2 (ft^2) /filter

h) Measure the return airflow rates across the filters, louvers, grills using the Vane anemometer /matrix velocity meter and record the average face velocity.

i) Calculate the return air volume as per the above.

j) The total design flow must include the estimated duct leakage (refer the ducting section of this standard) plus 10% of system total to allow for balancing effects. Minimum outdoor air quantities must be maintained during all system modes established by pitot-tube velocity traverse or matrix velocity meter.

k) Record the above data in operational data collection sheet provided in the clause 9.

l) Follow the above step 3 to 10 of this procedure for DOA exhaust and supply fan air volumetric measurement.

7.2 Water flow measurement

General

The requirements of clause 5, and clause 6, "Water flow measurement," shall apply as a minimum to system at the Air handlers.

7.2.1 System Preparation

a. Obtain updated construction drawings, specifications, approved shop drawings and submittals, addenda, bulletins, and change orders related to the air systems.

b. Obtain field-data forms for equipment delivery, Pre-commissioning & start up checklist. (refer section-9 AHU Checklist).

c. Conduct the pre-commissioning and Start up checks as per the section-9 for checklist of Air handlers.

d. Verify that coils, valves, strainers, insulation pipes and associated controls are installed and controlled to supply the designed water rate, and that all installation, start up, lubrication, and safety requirements have been met.

e. Perform the water balancing as per the section water balancing described else where in this standard.

f. Open all manual valves for maximum flow.

g. Check the strainers and see that they are clean and have the correct mesh for the system fluid.

h. Verify the commissioning of the associated chillers, pumps and cooling tower systems and associated controls as specified in this standard, refer clause 9 for checklist.

7.2.2 Water flow measurement

a. Operate the associated chilled water system like chillers, pumps and cooling towers to design capacity or full capacity.

b. Verify that butterfly valves are open fully, balancing valves are adjusted to design water flow.

c. Refer section-5 and section-6 test method of water flow measurement "for methods of measurement.

d. Install the water flow meter on the desired location of the air handler pipes.

e. Record the above data in operational data collection sheet provided in the section-9.

7.3 Temperature Measurement: To Air side & Waterside

7.3.1 General

The requirements of Section 5 and Section 6, "Air volumetric measurement and Water flow measurement," shall apply as a minimum to system at the Air handling unit.

7.3.2 System preparation

a) Obtain updated construction drawings, specifications, approved shop drawings and submittals, addenda, bulletins, and change orders related to the air systems.

b) Obtain field-data forms for equipment delivery, pre-commissioning & start up checklist. (refer section-9 for air handling unit checklist).

c) Conduct the pre-commissioning and start up checks as per the section-9 checklist of air handling unit.

d) Verify that coils, valves, strainers, insulation pipes and associated controls are installed and controlled to supply the designed water flow, and that all installation, start-up, lubrication, and safety requirements have been met.

e) Verify that fans are installed, rotation direction and speed and has controls, and controlled to supply the required air volume, and that all installation, start-up, lubrication, and safety requirements have been met.

f) Check that filters are clean and properly mounted and sealed.

g) Verify that fire, smoke, automatic, and volume-control dampers are operable and accessible and are in an open or normal position.

h) Verify that controls and gauges are installed, operable, and calibrated.

i) Verify that boxes are installed, operable, and accessible

j) Verify that terminal devices are installed and accessible.

k) Verify that access doors are installed and secured.

l) Verify that all dampers are in an open position and all boxes or automatic air-volume control devices are in an acceptable mode.

m) Verify that all air terminal deflectors are in the position indicated by the manufacturer when using Ak (effective area) factors to determine airflow rate and obtain correction factors for all velocity-measuring instruments.

n) Record the nameplate data on the fan, motor, and air handling cabinet.

o) Prior to recording the temperature, system shall be in equilibrium and operational from 30 Minutes.

7.3.3 Temperature Measurement: Air side & Water side procedure

a. Operate the associated chilled water system i.e Chillers, Pumps & Cooling towers to design /full capacity.

b. Operate the associated Air handler fan to full capacity.

c. Set the system in the minimum outdoor-air mode.

d. Refer section-5 and section-6 test method of Temperature measurement “for methods of measurement.

e. Verify that butterfly valves are open fully, balancing valves are adjusted to design water flow.

f. With the system at equilibrium, measure the coil temperatures by setting the coil to its design water flow and airflow. Measure the entering and leaving water temperatures, entering and leaving coil temperatures and supply and return air temperatures (dry-bulb and wet-bulb for cooling coils and dry bulb only for heating coils).

g. Record the above data in operational data collection sheet provided in the Section-9.

7.4 Air side & Water side pressure measurement

7.4.1. General

The requirements of section 5 and section 6 shall apply as a minimum to system at the air handling units.

7.4.2 System preparation

System preparation shall be as per 7.3.2.

7.4.3 Pressure measurement procedure - air side and water side

a. Operate the associated chilled water system i.e Chillers, Pumps & Cooling towers to design /full capacity.

b. Operate the associated Air handler fan to full capacity.

c. Set the system in the minimum outdoor air mode.

d. Refer to section 5 and 6 for measurement method.

e. Verify that butterfly valves are open fully, balancing valves are adjusted to allow design water flow rate. With the system at equilibrium, measure the coil temperatures by setting the coil to its design water flow and airflow. Measure the air side pressure across the all filters, coils and fan using the instrument as specified in the section-5.

f. Measure the water pressure with calibrated pressure gauges installed at the Air handlers pipe section.

g. Record the above data in operational data collection sheet provided in the section-9.

7.5 Rotational speed measurement

7.5.1 System preparation

a. Obtain updated construction drawings, specifications, approved shop drawings and submittals, addenda, bulletins, and change orders related to the air systems.

b. Obtain field-data forms for equipment delivery, pre-commissioning and start up checklist. (refer Section 9 for air handling unit checklist).

c. Conduct the pre-commissioning and start up checks as per the section-9 for checklist for air handling units.

d. Verify that fans are installed, rotating correctly as per defined rotation direction and speed and controlled to supply the required airflow rate, and that all installation, start-up, lubrication, and safety requirements have been met.

e. Check that filters are clean and properly mounted and sealed.

f. Verify that fire, smoke, automatic, and volume-control dampers are operable and accessible and are in an open or normal position.

g. Verify that controls are installed, operable, and calibrated.

h. Verify that boxes are installed, operable, and accessible.

i. Verify that terminal devices are installed and accessible.

7.5.2 Test Procedure

a. Open all air inlets and doors fully.

b. If fan blades are plastic a reflective sticker will need to be placed approximately 50 to 70 mm (2 to 3 inches) from the tip of the blade.

c. Turn on the fan to be tested. Turn on the fan to be tested.

Note: All fans shall be tested individually and rotation speed shall be measured at full speed of the fan.

d. The tachometer shall be held still at 600 to 1000 mm away from the fan with the laser focussed at the reflective sticker. The measurement shall be recorded only when the reading on tachometer is constant.

e. Compare fan rotational speed with manufacturers specifications.

f. If the fan has reflective or metal blades the recording on the tachometer must be divided by the number of blades the fan has. The RPM should be within manufacturer’s specification.

g. Record the above data in operational data collection sheet provided in the section-9.

7.6 Vibration analysis

7.6.1 Testing vibration isolation

Ensure that equipment is free-floating by applying an unbalanced load, which should cause the equipment to move freely and easily. For floor-mounted equipment, check that there are no obstructions between the base or foundation and the building structure that would cause transmission while still permitting equipment to move relatively free because of the application of an unbalanced force (Figure 13). For suspended equipment, check that hanger rods are not touching the hanger. Rigid connections such as pipes and ducts can prohibit mounts from functioning properly and from providing a transmission path.

Note: The equipment is free floating does not indicate that the vibration isolators are functioning properly. (example: A fan with speed of 500 revolution per minute (rpm) on isolators with a natural frequency of 500 cycles per minute (8.33 Hz) could be free-floating but actually be in resonance, resulting in transmission to the building and excessive movement.

Determine whether isolators are adjusted properly and providing desired isolation efficiency. All isolators supporting a piece of equipment should have approximately the

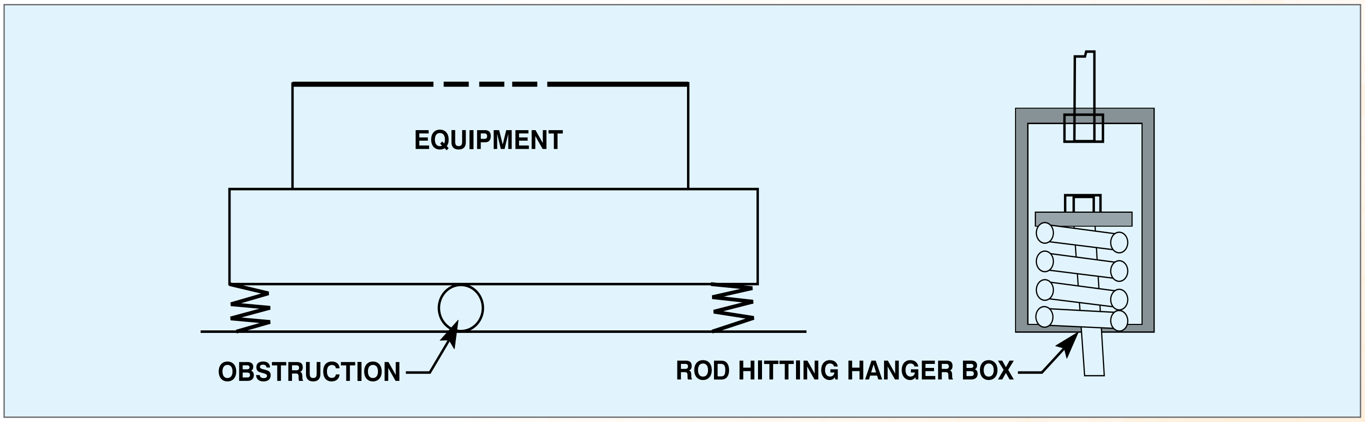


Figure H1.13: Obstructed Isolation Systems

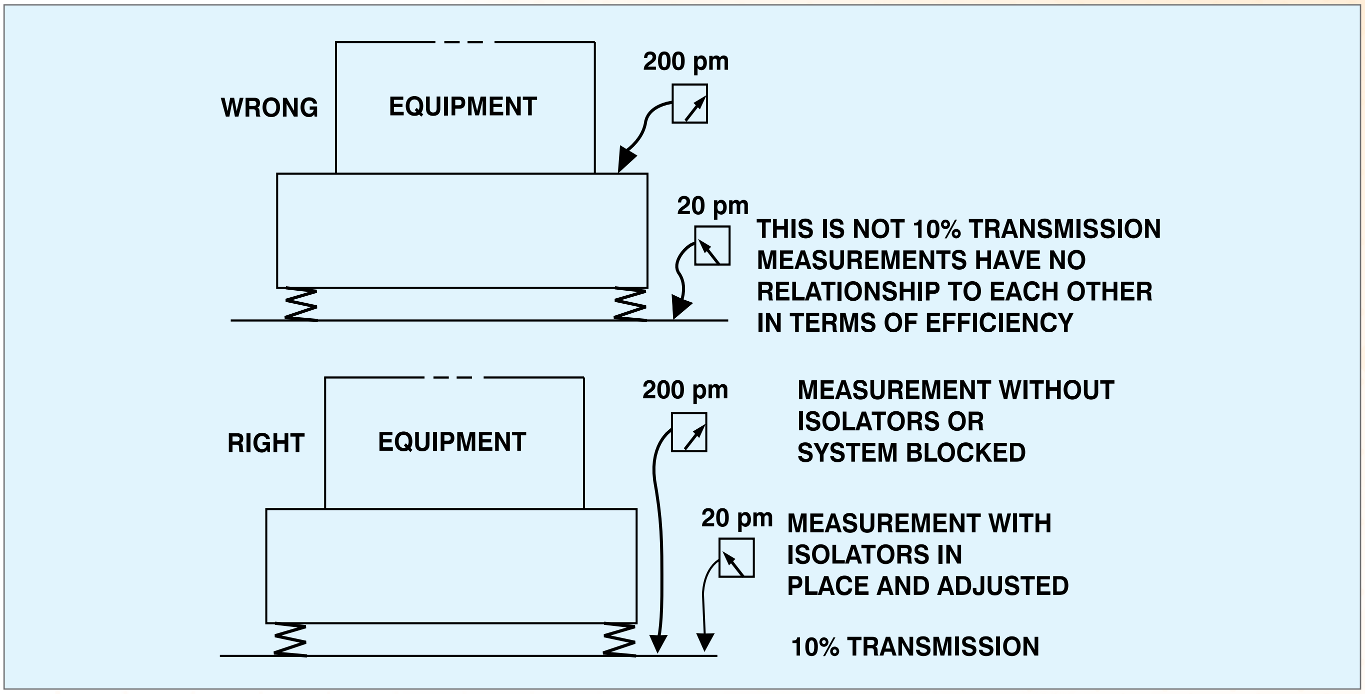


Figure H1.14: Testing Isolation Efficiency

same deflection (i.e., they should be compressed the same under the equipment). If not, they have been improperly adjusted, installed, or selected; this should be corrected immediately. Note that isolation efficiency cannot be checked by comparing vibration amplitude on equipment to amplitude on the structure (Figure H1.14).

The only accurate check of isolation efficiencies is to compare vibration measurements of equipment operating with isolators to measurements of equipment operating without isolators. Because this is usually impractical, it is better to check whether the isolator's deflection is as specified and whether the specified or desired isolation efficiency is being provided.

Although it is easy to determine the deflection of spring mounts by measuring the difference between the free heights with a measuring scale (information as shown on submittal drawings or available from a manufacturer), these measurements are difficult with most vibration pads or rubber mounts. Further, most pads and rubber mounts do not lend themselves to accurate determination of natural frequency as a function of deflection. For these mounts, the most practical approach is to check that there is no excessive vibration of the base and no noticeable or objectionable vibration transmission to the building structure.

If isolators are in the 90% efficiency range and there is transmission to the building structure, either the equipment is operating roughly or there is a flanking path of transmission, such as connecting piping or obstruction, under the base.

7.6.2 Procedure for equipment vibration testing

a. Determine operating speeds of equipment from nameplates, drawings, or a speed-measuring device such as a tachometer or stroboscope, and indicate them on the test form. For any equipment where the driving speed (motor) is different from the driven speed (fan wheel, rotor, impeller) because of belt drive or gear reducers, indicate both driving and driven speeds.

ISHRAE®

b. Determine acceptance criteria from specifications, and indicate them on the test form.

c. Ensure that the vibration isolation system is functioning properly.

d. Operate equipment and make visual and aural checks for any apparent rough operation. Any defective bearings, misalignment, or obvious rough operation should be corrected before proceeding further. If not corrected, equipment should be considered unacceptable.

e. Measure and record vibration at bearings of driving and driven components in horizontal, vertical, and, if possible, axial directions. At least one axial measurement should be made for each rotating component (fan motor, pump motor).

f. Evaluate measurements.

7.7. Electrical parameter measurement: voltage, current and power

7.7.1 System preparation

a. Obtain updated construction drawings, specifications, approved shop drawings and submittals, addenda, bulletins, and change orders related to the air systems.

b. Obtain field-data forms for equipment delivery, pre-commissioning and start up checklist. (refer section-9 for air handling unit checklist.)

c. Conduct the pre-commissioning and Start up checks as per the section-9 for checklist of air handling units.

7.7.2 Test procedure

a. Operate the associated air handling unit fan to full capacity.

b. Set the system in the minimum outdoor air mode.

c. Refer section-5 and section-6 test method of air volumetric measurement for methods of measurement.

d. With the system at equilibrium, measure the voltage and current.

e. Calculate the electrical power ratings as per the equation specified in the section 6: electrical power measurement.

f. Record the above data in operational data collection sheet provided in the section-9.

7.8 Sound pressure measurement of air handling unit operation.

Sound Testing:

Ideally, a building should be completed and ready for occupancy before sound level tests are taken. All spaces in which readings will be taken should be furnished with all the furnishings and interiors as they affect the room absorption, measured sound pressure levels and subjective quality of the sound.. In actual practice, because most tests must be conducted before the space is completely finished and furnished for final occupancy, the testing engineer must make some allowances. Because furnishings increase the absorption coefficient and reduce sound pressure level by approximately 4 dBA. Following guidelines should suffice for measurements made in unfurnished spaces. If the sound pressure level is 5 dBA or more over the specified or desired criterion, it can be assumed that the criterion will not be met, even with the increased absorption provided by furnishings. If the sound pressure level is 0 to 4 dBA greater than the specified or desired criterion, recheck when the room is furnished to determine compliance.

General procedure:

Obtain a complete set of accurate, as-built drawings and specifications, including duct and piping details. Review specifications to determine sound and vibration criteria and any special instructions for testing.

Visually check for noncompliance with plans and specifications, obvious errors, and poor workmanship. Turn system on for aural check. Listen for noise and vibration, especially duct leaks and loose fittings

Adjust and balance equipment, as described in other sections, so that final acoustical tests are made with the HVAC operational as per design. It is desirable to perform acoustical tests for both summer and winter operation, but where this is not practical, take measurements for the summer operating mode, as it usually has the potential for higher sound levels. Measurements shall be taken for all mechanical equipment and systems, including standby.

Measurements shall be taken for all.

a) Measure sound pressure level in all areas as required, combining measurements as indicated in 7.8.1 c if equipment or systems must be operated separately. Before final measurements are made in any particular area, survey the area using an A-weighted scale reading (dBA) to determine the location of the highest sound pressure level. Indicate this location on a testing form, and use it for test measurements. Restrict the preliminary survey to determine location of test measurements to areas that can be occupied by standing or sitting personnel.

b) Measure the background sound pressure level first.

c) If specification requires determining sound pressure level from HVAC equipment only, background noise readings must be taken with HVAC equipment turned off.

d) If specification requires compliance with a specific sound pressure level or criterion (e.g., sound levels in office areas not to exceed 35 dBA), ambient sound pressure level measurements must be made only if the sound pressure level in any area exceeds the specified value.

Note: For residential locations and areas requiring very sound pressure level, such as sound recording studios and locations used during the normally quieter evening hours, it is usually desirable to take sound measurements in the evening and/or take ambient noise measurements.

8.0 Data collection frequency

8.1 Air volumetric measurement – sound pressure level

The output shall be measured in equilibrium condition. The recording of data shall continue for time period of atleast 30 minutes during which tolerance specified in section 10 shall be met and at least 6 set of readings on each cross sectional area on the measurement plane shall be taken at every 15 minutes interval and recoded. Data shall be sampled at equal intervals of 60 seconds or less.

8.2 Air volume measurement - Digital vane type anemometer method

The output shall be measured in equilibrium condition. The recording of data shall continue for time period of atleast 30 Minutes during which tolerance specified in section 10 shall be met and The total rectangular opening or core area is to be divided into squares or rectangles 75mm to 125mm on a side, and the average velocity for the instrument will be the arithmetical average of the readings in these squares. Totalizing instruments may be moved from one square to another; for these instruments, a reading time of at least 10 seconds in each square is recommended.

8.3 Water flow measurement

The output shall be measured in equilibrium condition. The recording of data shall continue for time period of atleast 30 minutes during which tolerance specified in section 10 shall be met and at least 3 set of readings shall be taken at every 10 minutes interval and recoded. Data shall be sampled at equal intervals than span 60 sec or less.

9.0 Test Report Formats – Refer attachment for formats.

10.0 Measurement Equipment – Accuracy, Tolerances.

Readings	Variations of Arithmetical mean valves from the specified test conditions	Maximum variation of individual readings from the specified test condition
Temperature of Air		
Dry Bulb	+/- 0.30°C	+/- 0.50°C
Wet Bulb	+/- 0.20°C	+/- 0.30°C
Temperature of Water	+/- 0.30°C	+/- 0.50°C
Air Flow Colume	+/- 5%	+/- 10%
Water Flow Rate	+/- 3%	+/- 5%
Water Pressure	Less than 1/2 scale of the scale division mark	1/2 scale of the scale division mark
Air Pressure	+/- 5%	+/- 10%
Sound Pressure Level	+/- 3 dBA	+/- 5 dBA
Vibration levels-rms Velocity, mm/s	+/- 2.0	+/- 2.3

Table: Variation allowed during steady state conditions

ANNEXURE HA.1 (Informative)
Unitary and Packaged AC Systems

1.0 A unitary system typically combines the cooling, air distribution and controls in one unit called indoor unit (IDU) and the compressor, air cooled condenser, condenser fan and controls in another unit called outdoor unit (ODU).

2.0 The packaged air conditioning system can either be air cooled or water cooled. The air cooled system will be similar to the unitary system while the water-cooled system will have compressor, water cooled condenser, evaporator and evaporator fan combined in one package.

3.0 The IDU and ODU of unitary and packaged air conditioning system are factory made and tested and accepted before it reaches site.

4.0 Site work usually involves the refrigeration pipe work, electrical and condensate water removal connections and commissioning.

5.0 A typical checklist for unitary and packaged air conditioners is as in Table HA-1.

Table HA-1:
Delivery, Installation, Startup and Operation Checklist for - Unitary and Packaged Air Conditioner Units

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	**HA-1D**	**A**	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No - Evaporator	-		
		A4	Air Flow - Evaporator	m^3/s(cfm)		
		A5	Evaporator fan motor power	kW		
		A6	Evaporator fan motor V/Ph/Freqency	-		
		A7	Total cooling/ Heating capacity	kW		
		A8	Airflow - Condenser	m^3/s(cfm)		
		A9	Ambient Temperature	°C		
		A10	Condenser fan motor power	kW		
		A11	Condenser fan motor V/Ph/Frequency	-		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	Copper pipes sealed at both ends	-	Y/N	
		B4	Unit tags present	-	Y/N	
		B5	Installation manual provided	-	Y/N	
		B6	Test/warranty certificate provided	-	Y/N	
2	**HA-1C**	**A**	**EVAPORATOR SECTION**			
		A1	Unit adequately supported	-	Y/N	
		A2	Adequate service clearences available for maintenance and unit removal	-	Y/N	
		A3	Condensate drain properly installed with slope	-	Y/N	
		A4	Unit label visible	-	Y/N	
		B	**CONDENSER SECTION**			
		B1	Unit adequately supported	-	Y/N	
		B2	Adequate service clearences available for maintenance and unit removal	-	Y/N	
		B3	Unit label visible	-	Y/N	
		C	**REFRIGERANT PIPING**			
		C1	Piping correctly installed as per drawing and specifications	-	Y/N	
		C2	Disconnection for unit removal is easy	-	Y/N	
		C3	Pipe pressure tested and found OK	-	Y/N	
		C4	Pipe insulated as per specifications	-	Y/N	
		C5	Valves and test ports are accessible	-	Y/N	
		C7	Unit charged with refrigerant	-	Y/N	
		D	**ELECTRICAL**			
		D1	Isolator in accessible location	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
2	HA-1C contd...	D2	Motor rotation correct	-	Y/N	
		D3	Terminations checked	-	Y/N	
		D4	Earthing is proper	-	Y/N	
		E	**CONTROLS**			
		E1	Thermostat installed	-	Y/N	
		E2	Thermostat calibrated	-	Y/N	
		E3	Control wiring correct	-	Y/N	
		E4	Control sequence verified	-	Y/N	
		E5	No abnormal noice or vibration	-	Y/N	
		E6	Manufacturers checklist completed	-	Y/N	
		E7	Filters installed and are clean	-	Y/N	
3	HA-10				**Actual**	**Design**
		A1	Room Temperature DB/WB	°C		
		A2	Grill temperature	°C		
		A3	Voltage	V		
		A4	Starting current	A		
		A5	Full load current	A		
		A6	High pressure cutout setting	Pa(psi)		
		A7	Low pressure cutout setting	Pa(psi)		
		A8	Suction pressure	Pa(psi)		
		A9	Discharge pressure	Pa(psi)		
		A10	Evaporator entering temperature - DB/WB	°C		
		A11	Evaporator leaving temperature DB/WB	°C		
		A12	Condenser entering temperature DB/WB	°C		
		A13	Condenser leaving temperature DB/WB	°C		
		A14	Air flow Evaporator	l/sec		
		A15	Air flow Condenser	l/sec		
		A16	Noise at 1 m from Evaporator	dBA		
		A17	Noise at 1 m from Condenser	dBA		

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.2 (Normative)
Variable Refrigerant Flow Systems

1.0 The VRF (Variable Refrigerant Flow) System will have multiple indoor units connected with a single outdoor or multiple outdoor units. These are factory made and tested and accepted before it reaches site.

2.0 Site work involves the refrigeration pipe work from Indoor units to our door units, pressure testing, vacuuming the entire refrigerant piping system, charging the refrigerant to the system, mechanical, electrical and condensate water removal connections and control system and BMS connectivity and finally testing and commissioning the system.

3.0 Sample check lists are given in attachments for Delivery (HA-2D), Installation (HA-2C), Start Up (HA-2S) and operation (HA-2O)

Table HA-2:
Delivery, Installation, Startup and Operation Checklist for - Variable Refrigerant Flow System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA -2D	A	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	No of Units	-		
		A4	Unit Serial No	-		
		A5	Compressor type	-		
		A6	Cooling Capacity	kW(TR)		
		A7	Condensor type Water/Air	-		
		A8	Condenser flow rate (Water cooled)	m^3/s(LPM)		
		A9	Condenser fan air quantity (Air cooled)	m^3/s(cfm)		
		A10	Refrigerant type	-		
		A11	Compressor motor power	kW		
		A12	Voltage/Phase/Frequency	V/-/Hz		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Copper piping and fittings are free from damage	-	Y/N	
		B4	Incomer MCB of correct size and capacity	-	Y/N	
		B5	Motor bearings sealed/lubricated	-	Y/N	
		B6	Refrigerant piping insulation intact	-	Y/N	
		B7	Condensate drain properly installed with slope	-	Y/N	
		B8	Foundation for ODU installed properly	-	Y/N	
		B9	Testing & Commssioning instruments availabe	-	Y/N	
		B10	Vibration isolators OK	-	Y/N	
		B11	Unit label visible	-	Y/N	
		B12	Installation manual provided	-	Y/N	
		B13	Test/warranty certificate provided	-	Y/N	
		B14	Unit tags affixed	-	Y/N	
2	HA-2C	A	**VRF - INDOOR UNITS**			
		A1	Low side (Cassette / High Wall / AHU)	-		
		A2	Unit adequately supported	-	Y/N	
		A3	Refrigerant piping laid as per design / layout	-	Y/N	
		A4	Central Remote controller Connected to IDUs	-	Y/N	
		A5	Adequate service clearences available for maintenance and unit removal	-	Y/N	
		A6	Condensate drain properly installed with slope	-	Y/N	
		A7	Refrigerant piping connection to IDU properly	-	Y/N	
		A8	Unit label visible	-	Y/N	
		B	**DUCTING (IN CASE OF AHU)**	-		
		B1	Grill / Diffuser properly connected	-	Y/N	
		B2	Sufficient duct length available upstream	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
2	HA-2C contd...	B3	Ductwork is adequately supported	-	Y/N	
		B4	Flexible connector installed at duct input	-	Y/N	
		B5	Ducting internally Clean	-	Y/N	
		B6	Testing locations available	-	Y/N	
		C	**CONTROLS**			
		C1	Dampers/sensors accessible	-	Y/N	
		C2	Airflow sensor calibration	-	Y/N	
		C3	BMS Connectivity correcly established	-		
		C4	Control wiring correct	-	Y/N	
		C5	Control sequence verified	-	Y/N	
		D	**REFRIGERANT PIPING**			
		D1	Piping correctly installed as pee drawing and adequately supported	-	Y/N	
		D2	Piping arranged for easy unit removal	-	Y/N	
		D3	Flare tool, cutter, nuts available for maintenance	-	Y/N	
		D4	Piping is clean and no external visible damage	-	Y/N	
		D5	All valves as per design drawings	-	Y/N	
		D6	Pipe insulation correct as applicable	-	Y/N	
		D7	Valve tags installed	-	Y/N	
		E	**ELECTRICAL**			
		E1	Safety disconnect in accessible location	-	Y/N	
		E2	Central Remote Controller with PC Connected	-	Y/N	
		E3	Cable lugs correct size	-	Y/N	
		E4	Electrical connections are tight	-	Y/N	
		E5	Earthing adequate	-	Y/N	
		E6	Main Incomer installed correct	-	Y/N	
		E7	Control voltage provided correct	-	Y/N	
		E8	Withstand ratings exeed fault levels	-	Y/N	
		F	**INSTRUMENTATION**			
		F1	Control panel accessible	-	Y/N	
		F2	Sensors correctly installed	-	Y/N	
		F3	Safety controls installed correct	-	Y/N	
		F4	Electrical protections correctly installed	-	Y/N	
3	HA-2S	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist Completed	-	Y/N	
		A2	Safety controls verified	-	Y/N	
		A3	Leak test Procedure followed properly	-	Y/N	
		A4	Refrigerant (system) pressure as per design	-	Y/N	
		A5	Low oil flow protection	-	Y/N	
		A6	Set of required tools available	-	Y/N	
		A7	Low design Condenser water flow(for water cooled)	-	Y/N	
		A8	Loss of refrigerant / Less refrigerant Charge	-	Y/N	
		A9	Motor overload	-	Y/N	
		A10	Phase imbalance / reversal	-	Y/N	
		A11	Over / under voltage	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
3	HA-2S contd...	A12	Water temp sensor operating correct (water cooled)	-	Y/N	
		A13	No unusual noise or vibration	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	Power available for commissioning	-	Y/N	
		B3	Central Remote Controller with PC verified	-	Y/N	
		B4	BMS control system tested	-	Y/N	
		B5	Unit voltage / amps verified	-	Y/N	
		B6	Remote start / stop signal verified	-	Y/N	
		B7	Sequence of compresor operation verified	-	Y/N	
		B8	Demand limiting signal verified	-	Y/N	
		B9	Unit "run" sequence verified	-	Y/N	
		B10	Unit "alarm" sequence verified	-	Y/N	
		C	**START UP / TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Refrigerant charge as per design	-	Y/N	
		C3	No unusual noise or vibration	-	Y/N	
		C4	Calibrated insruments used	-	Y/N	
		C5	Motor full load current in limits	-	Y/N	
		C6	Motor voltage/amps verified	-	Y/N	
		C7	Check and confirm proper function of control algorithms in BMS	-	Y/N	
		C8	Check Operation sequence	-	Y/N	
4	HA-20	**A**	**VRF**			
		A1	Room Temperature	°C		
		A2	Grille temperature	°C		
		A3	Voltage	V		
		A4	Starting current - ODU	A		
		A5	Full load current - ODU	A		
		A6	High pressure cutout setting	Pa(psi)		
		A7	Low pressure cutout setting	Pa(psi)		
		A8	Suction pressure	Pa(psi)		
		A9	Discharge pressure	Pa(psi)		
		A10	Room Temperature DB/WB	°C		
		A11	Cond entering DB/WB	°C		
		A12	Cond leaving DB/WB	°C		
		A13	Air flow - Evaporator	m^3/s(cfm)		
		A14	Air flow - Condenser	m^3/s(cfm)		
		A15	Noise at 1 m from Evap	dBA		
		A16	Noise at 1 m from Cond	dBA		
		A17	Ambient Temperature DB/WB	°C		

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.3 (Normative)
Liquid Cooling Chillers - Vapor Compression System

1.0 The chillers comprise of compressor (reciprocating, scroll, screw or centrifugal type), condenser(air cooled or water cooled), chiller (direct expansion type (DX) or flooded type) and expansion device all connected in series through refrigerant piping. The compressors may be hermetically sealed, semi hermetic, directly coupled or belt driven depending on the capacity and the type of manufacture, mounted on a steel frame work. These chillers will work on given type of refrigerant as specified by the manufacturer. Chillers are factory made and tested at the factory for acceptance prior to reaching installation site.

2.0 The chillers are classified as

a) Water cooled chillers

b) Air cooled chillers

The chillers are installed either in a plant room or on building roof. The numbers of chillers installed shall be based on the capacity and usage pattern.

a) ***Water cooled Chillers:*** The water cooled chillers will have cooling tower and condenser water pumps connected to the chillers through water piping for its proper functioning. The water cooled chillers will have single / multiple chillers connected to single or multiple condenser pumps single or multiple cooling towers and single or multiple chilled water pumps.

b) ***Air Cooled Chillers:*** The air cooled chillers will have air cooled condensers and connected directly to the evaporator and then compressor through refrigerant piping. The air cooled chillers will have single or multiple chillers, single or multiple air cooled condensers connected in parallel, single or multiple chilled water pump.

3.0 **Site Work**

Site work involves the proper foundation for the chillers, pump sets, condenser water piping (in case of water cooled system), refrigerant piping in case of air cooled system, mechanical, power and control wiring, electrical panel and control system including BMS connectivity.

4.0 Sample check lists are given in attachments for delivery (HA-3D), for installation (HA-3C), and for Start up (HA-3S).

Table HA-3:
Delivery, Installation, Startup and Operation Checklist for - Chiller - Vapor Compression System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA-3D	A	**MODEL VERIFICATION**	-		
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Compressor type	-		
		A5	Cooling Capacity	kW (TR)		
		A6	Condensor type Water/Air	-		
		A7	Condenser flow rate	m^3/s(LPM)		
		A8	Chiller flow rate	m^3/s(LPM)		
		A9	Refrigerant type	-		
		A10	Compressor motor powe	kW		
		A11	Voltage/Phase/Frequency	V/-/Hz		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Water openings plugged	-	Y/N	
		B4	Motor bearings sealed/lubricated	-	Y/N	
		B5	Installation manual provided	-	Y/N	
		B6	Test/warranty certificate provided	-	Y/N	
		B7	Unit tags affixed	-	Y/N	
2	HA-3C	A	**CHILLER**			
		A1	Unit adequately supported and secured	-	Y/N	
		A2	Adequate service clearences available	-	Y/N	
		A3	All components accessible for maintenance	-	Y/N	
		A6	Vibration isolators OK	-	Y/N	
		A7	Unit label visible	-	Y/N	
		B	**PIPING**			
		B1	Piping correctly installed	-	Y/N	
		B2	Piping arranged for easy unit removal	-	Y/N	
		B3	Piping adequately supported	-	Y/N	
		B4	All components accessible for maintenance	-	Y/N	
		B5	Piping is clean	-	Y/N	
		B6	All valves as per design drawings	-	Y/N	
		B7	Pipe insulation correct as applicable	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-3C contd...	B8	Valve tags installed	-	Y/N	
		C	**ELECTRICAL**			
		C1	Safety disconnect in accessible location	-	Y/N	
		C2	Cable lugs correct size	-	Y/N	
		C3	Electrical connections are tight	-	Y/N	
		C4	Eearthing adequate	-	Y/N	
		C5	VFD / Starter installed correct	-	Y/N	
		C6	Control voltage provided correct	-		
		C7	Withstand ratings exeed fault levels	-		
		D	**INSTRUMENTATION**	-		
		D1	Control panel accessible	-	Y/N	
		D2	Sensors correctly installed	-	Y/N	
		D3	Calibrations verified	-	Y/N	
		D4	Safety controls installed correct	-	Y/N	
		D5	Electrical protections correctly installed	-	Y/N	
3	**HA-3S**	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Safety controls verified	-	Y/N	
		A3	Low chilled water temperature	-		
		A4	High refrigerant pressure	-	Y/N	
		A5	Low oil flow protection	-	Y/N	
		A6	Low chilled water flow	-	Y/N	
		A7	Low condenser water flow	-		
		A8	Loss of refrigerant	-		
		A9	Motor overload	-		
		A10	Phase imbalance/ reversal	-		
		A11	Over/ under voltage	-		
		A12	Water temperature sensor operating correct	-		
		A13	No unusual noise or vibration	-		
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	Power available for commissioning	-	Y/N	
		B3	BMS Connectivity correcly established	-	Y/N	
		B4	Unit voltage/amps verified	-		
		B5	Remote start/stop signal verified	-		
		B6	Chilled water reset signal verified	-		
		B7	Demand limiting signal verified	-		

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-3S contd...	B8	Unit "run" sequence verified	-		
		B9	Unit "alarm" sequence verified	-		
		C	**START UP/ TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Flow rate measured	-	Y/N	
		C3	No unusual noise or vibration	-	Y/N	
		C4	Calibrated insruments used	-	Y/N	
		C5	Motor full load current in limits	-	Y/N	
		C6	Motor voltage/amps verified	-	Y/N	
		C7	Strainers removed and cleaned	-	Y/N	
		C8	Check and confirm proper function of control algorithms in BMS	-		
		C9	Check Operation sequence	-	Y/N	
		C10	Chilled water temperature in/out	-	---/---	
		C11	Evaporator pressure drop OK	-	Y/N	
		C12	Chilled water flow rate OK	-	Y/N	
		C13	Condenser water temperature in/out	-	----/----	
		C14	Condenser water pressure drop OK	-	Y/N	
		C15	Ambient DB Temperature	-	-----	
		C16	Chiller noise level at 1 m OK	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.4 (Normative)
Cooling Towers

1.0 The cooling tower is a device which rejects heat from the system to the atmosphere. It can be natural draft atmospheric type, induced draft counter-flow, or induced draft cross-flow and are installed outside the building or on the terrace of building. The cooling towers will be in single or multiple units depending on the plant capacity and plant design parameters. Induced draft cooling tower fans are driven by single or multiple motors with or without VFD.

2.0 The cooling towers are factory made as per manufacturers design parameters and shifted to site in assembled or dismantled condition. These cooling towers are mounted on foundation outside the building or on the terrace.

3.0 Site work involves usually assembly of components if sent to site in dismantled condition, condenser water connection with valves, strainers, make up water piping, electrical cabling and mechanical work.

4.0 A typical checklist for cooling towers is as in Table HA-4.

Table HA-4:
Delivery, Installation, Startup and Operation Checklist for - Cooling Tower

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	**HA-4D**	**A**	**MODEL VERIFICATION**			
		A 1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Capacity	-		
		A5	Fan speed/power	RPM/ kW		
		A6	Motor power/speed	kW/ RPM		
		A7	Voltage/Phase/Frequency	V/-/Hz		
		B	Physical Checks	-		
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Water openings plugged	-	Y/N	
		B4	Access doors are operable	-	Y/N	
		B5	Installation manual provided	-	Y/N	
		B6	Test/warranty certificate provided	-	Y/N	
		B7	Unit tags affixed	-	Y/N	
2	**HA-4C**	**A**	**COOLING TOWER**			
		A1	Unit adequately supported and secured	-	Y/N	
		A2	Adequate service clearences available	-	Y/N	
		A3	Ladder provided is adequate	-		
		A4	Vibration isolators OK	-	Y/N	
		A5	Unit label visible	-	Y/N	
		B	**PIPING**			
		B1	Piping correctly installed and adequately supported	-	Y/N	
		B2	All components accessible for maintenance	-	Y/N	
		B3	Piping is clean	-	Y/N	
		B4	All valves as per design drawings	-	Y/N	
		B5	Make up water supply provided	-	Y/N	
		B6	Pipe insulation correct as applicable	-	Y/N	
		B7	Valve tags installed	-	Y/N	
		C	**ELECTRICAL**			
		C1	Isolator in accessible location	-	Y/N	
		C2	Direction of motor rotation correct	-	Y/N	
		C3	Electrical connections are tight	-	Y/N	
		C4	Earthing adequate	-	Y/N	
		C5	VFD / Starter installed correct	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-4C contd...	**D**	**INSTRUMENTATION**			
		D1	Control panel accessible	-	Y/N	
		D2	Sensors correctly installed	-	Y/N	
		D3	Valve actuators installed	-	Y/N	
		D4	Calibrations verified	-	Y/N	
		D5	Safety controls installed correct	-	Y/N	
		D6	Electrical protections correctly installed	-	Y/N	
3	HA-4S	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Tower basin filled	-	Y/N	
		A3	Sump nozzles and strainers are clean	-		
		A4	Motor/gear box lubricated	-	Y/N	
		A5	Fan pitch adjusted	-	Y/N	
		A6	No unusual noise or vibration	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	Power available for commissioning	-	Y/N	
		B3	BMS Connectivity correcly established	-	Y/N	
		B4	High/Law water alarms operational	-		
		B5	VFD Operational (if applicable)	-		
		B6	Float switch, make up water operational	-		
		C	**START UP / TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Flow rate measured	-	Y/N	
		C3	Motor rotating in correct direction.	-	Y/N	
		C4	No unusual noise or vibration	-	Y/N	
		C5	Calibrated insruments used	-	Y/N	
		C6	Motor full load current in limits	-	Y/N	
		C7	Motor voltage/amps verified	-	Y/N	
		C8	Strainer removed and cleaned	-	Y/N	
		C9	Check and confirm proper function of control algorithms in BMS	-		
		C10	Check Operation sequence	-	Y/N	
		C11	Water distributed evenly even at 50% flow	-	Y/N	
		C12	Make up water quality OK	-	Y/N	
		C13	Blow down control verified	-	Y/N	
		C14	Make up flow meter signal	-	Y/N	
		C15	Water temperature at inlet/outlet	-	---/---	
		C16	Ambient wet bulb temperature	-	---/---	
		C16	Determine range / approach	-	---/---	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.5 (Normative)
Pumps

1.0 In HVAC System, or pumps are used for circulation of condenser water between condenser and cooling tower, chilled water and/or brine circulation between chiller and coils in AHUs and FCUs, room cooling units etc. The pumps used in air conditioning system are either mono-block or long-coupled. These pumps installed will be single or multiple pumps as per the design requirements and can be connected in parallel or in series with the chiller / condenser. The pumps are installed in primary, secondary or tertiary circuit depending on the system design. The pump motors are operated directly or through VFDs.

2.0 The pumps are factory made and tested and accepted before it reaches site.

3.0 Site work involves installation on the foundation, leveling, pipe connection, electrical and control system. The chilled water pumps will be insulated as per the design mentioned in the specification sheet.

4.0 A typical checklist for pumps is as in Table HA-5.

Table HA-5:
Delivery, Installation, Startup and Operation Checklist for - Pumps

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	**HA-5D**	**A**	**MODEL VERIFICATION**	-		
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Pump type	-		
		A5	Impeller size	mm		
		A6	Inlet/outlet Dia	mm		
		A7	Capacity Flow/Head	m^3/s (lpm); m water		
		A8	Motor power/speed	kW/rpm		
		A9	Voltage/Phase/Frequency	V/-/Hz		
		B	**PHYSICAL CHECKS**	-		
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Water openings plugged	-	Y/N	
		B4	Installation manual provided	-	Y/N	
		B5	Test/warranty certificate provided	-	Y/N	
		B6	Unit tags affixed	-	Y/N	
2	**HA-5C**	**A**	**PUMP**			
		A1	Unit adequately supported and secured	-	Y/N	
		A2	Adequate service clearences available for manitenance and removal	-	Y/N	
		A3	Vibration isolators OK	-	Y/N	
		A4	Unit label visible	-	Y/N	
		B	**PIPING**			
		B1	Piping correctly installed and adequately supported	-	Y/N	
		B2	All components accessible for maintenance	-	Y/N	
		B3	Piping is clean	-	Y/N	
		B4	Shut off valves at inlet and outlet, Strainer at Inlet	-	Y/N	
		B5	Pressure gauges at inlet and outlet	-	Y/N	
		B6	Pipe insulation correct as applicable	-	Y/N	
		B7	Valve tags installed	-	Y/N	
		C	**ELECTRICAL**			
		C1	Isolator in accessible location	-	Y/N	
		C2	Direction of motor rotation correct	-	Y/N	
		C3	Electrical connections are tight	-	Y/N	
		C4	Eearthing adequate	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-5C contd...	**D**	**INSTRUMENTATION**			
		D1	Control panel accessible	-	Y/N	
		D2	Sensors correctly installed	-	Y/N	
		D4	Valve actuators installed	-	Y/N	
		D5	Electrical protections correctly installed	-	Y/N	
3	**HA-5S**	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Unit and motor lubricated	-	Y/N	
		A3	Pump shaft rotates freely	-		
		A4	Sensors correctly installed	-	Y/N	
		A5	Valve on supply header is open	-	Y/N	
		A6	No unusual noise or vibration	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	Power available for commissioning	-	Y/N	
		B3	BMS Connectivity correcly established	-	Y/N	
		C	**START UP / TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Flow rate measured	-	Y/N	
		C3	Inlet/Outlet pressure noted	-	Y/N	
		C4	Motor rotating in correct direction.	-	Y/N	
		C5	No unusual noise or vibration	-	Y/N	
		C6	Calibrated insruments used	-	Y/N	
		C7	Motor full load current in limits	-	Y/N	
		C8	Motor voltage/amps verified	-	Y/N	
		C9	Strainer removed and cleaned	-	Y/N	
		C10	Check and confirm proper function of control algorithms in BMS	-		
		C11	Check Operation sequence	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.6 (Normative)
Air Handling Units

1.0 Air handling units are of two types.

a) Direct expansion system (DX system) where refrigerant is supplied to the cooling coil through expansion device.

b) Chilled water system (Indirect cooling system) where chilled water is supplied to the heat exchanger through water piping.

In both the cases conditioned air is delivered to the air conditioned space through ducting.

2.0 Air handling units may be floor mounted or ceiling mounted.

3.0 The air conditioning system will have single or multiple air handling units. These are factory assembled or assembled at site as per manufacturer's recommendations.

Note: It is always recommended to use factory assembled and tested air handling units.

4.0 Site work involves mounting the air handling units on a foundation, assembling the cooling or heating coils, damper connection, canvas and duct connection, pipe connection, fixing the motor and drive assembly, filter section, control valves, mechanical, electrical and control system and building management system (BMS) connectivity where applicable.

5.0 A typical checklist for air handling units is as in Table HA-6.

Table HA-6:
Delivery, Installation, Startup and Operation Checklist for - Air Handling Units

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA-6D	**A**	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Cooling / Heating Capacity	-		
		A5	Supply air Flow	m^3/s(cfm)		
		A6	Supply fan motor power/speed	kW; rpm		
		A7	Return Fan motor power/speed	kW; rpm		
		A8	Voltage/Phase/Frequency	V/-/Hz		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Coil surface free of damage	-	Y/N	
		B4	Air openings sealed	-	Y/N	
		B5	Water openings plugged	-	Y/N	
		B6	Access doors operable	-	Y/N	
		B7	Installation manual provided	-	Y/N	
		B8	Test/warranty certificate provided	-	Y/N	
		B9	Unit tags affixed	-	Y/N	
2	HA-6C	**A**	**AIR HANDLING UNIT**			
		A1	Unit adequately supported	-	Y/N	
		A2	Adequate service clearences	-	Y/N	
			available for maintenance	-		
		A3	Condensate drain properly installed	-	Y/N	
		A4	Vibration isolators OK	-	Y/N	
		A5	Unit label visible	-	Y/N	
		B	**WATER PIPING**			
		B1	Piping correctly installed and adequately supported	-	Y/N	
		B2	Unit/coil removal possible	-	Y/N	
		B3	Piping is clean	-	Y/N	
		B4	Pipe insulation correctly installed	-	Y/N	
		B5	Valve tags installed	-	Y/N	
		C	**DUCTING**			
		C1	Dampers/sensors accessible	-		
		C2	Mixing of outdoor/return air possible	-	Y/N	
		C3	Ductwork is adequately supported	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-6C contd...	C4	Dampers open/close properly	-	Y/N	
		C5	Ducting internally clean	-	Y/N	
		C6	Testing locations available	-	Y/N	
		D	**ELECTRICAL**			
		D1	Isolator in accessible location	-	Y/N	
		D2	Direction of motor rotation correct	-	Y/N	
		D3	Electrical connections are tight	-	Y/N	
		D4	Eearthing adequate	-	Y/N	
		D5	Stater/VFD installed	-	Y/N	
		E	**INSTRUMENTATION**			
		E1	Control panel accessible	-	Y/N	
		E2	Sensors correctly installed	-	Y/N	
		E3	Damper actuators installed	-	Y/N	
		E4	Control valve actuators installed	-	Y/N	
		E5	Electrical protections correctly installed	-	Y/N	
		F	**CONTROLS**			
		F1	Thermostat installed	-	Y/N	
		F2	Thermostat calibrated	-	Y/N	
		F3	Control wiring correct	-	Y/N	
		F4	Control sequence verified	-	Y/N	
3	HA-6S	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist complted	-	Y/N	
		A2	Filters installed and are clean	-	Y/N	
		A3	Fans/motors lubricated/aligned	-	Y/N	
		A4	Fan belts correct and in good condition	-	Y/N	
		A5	Unit pressure tested and correct	-	Y/N	
		A6	Belt guards in place	-	Y/N	
		A7	Canvas connection proper	-	Y/N	
		A8	Sensors correctly installed	-	Y/N	
		A8	Unit dampers fully open	-	Y/N	
		A9	No unusual noise or vibration	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	Lighting within unit installed	-	Y/N	
		B3	Power available for commissioning	-	Y/N	
		B4	BMS Connectivity correcly established	-	Y/N	
		C	**START UP/ TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Duct work balancing done	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-6S contd...	C3	Air flow/pressure measured	-	Y/N	
		C4	Fan operating point marked in fan curve	-	Y/N	
		C5	Water side measurements done	-	Y/N	
		C6	Supply air quantity correctas per design	-	Y/N	
		C7	No unusual noise or vibration	-	Y/N	
		C8	Calibrated insruments used	-	Y/N	
		C9	VCD Positions marked	-	Y/N	
		C10	Fan motor full load current in limits	-	Y/N	
		C11	Flow rates in ducts within allowable tolerances	-	Y/N	
		C12	Compare fan air flow in front of filter section with air flow in main ducts	-	Y/N	
		C13	Measure fan speed and compare with design	-	Y/N	
		C14	Check and confirm proper function of control algorithms in BMS	-	Y/N	
		C15	Check AHU Operation sequence	-	Y/N	
		C16	Entering and leaving air temp at coil	-	Y/N	
		C17	Entering and leaving air temp at heating coil	-	Y/N	
		C18	Entering and leaving chilled water temp	-	Y/N	
		C19	Entering and leaving hot water temp	-	Y/N	
		C20	Coil flow and air/water pressure drops at each coil	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.7 (Normative)
Ducting Systems

1.0 Ducting is used to distribute air to single or multiple zones and collect it back to the fan room as per layout drawing. The ducting for air conditioning and ventilation system categorized as supply air, return air, fresh air, exhaust air ducts and are generally made of metallic sheets such as galvanised iron, stainless steel, aluminium or other suitable material.

2.0 The ducts are provided with canvass connection at the fan outlet, dampers to adjust the volume of air flow to various zones of air conditioned space.

3.0 The ducts are factory made and delivered to site or site fabricated. The ducts are suspended from the ceiling or run along the wall mounted on fixed brackets .

4.0 The ducts are of rectangular, circular or oval cross section based on the design requirements. The duct construction including thickness of the sheet, type of transverse joint for duct construction rigidity, leakage and sealing shall conform to Indian standard BIS IS 655 and / or SMACNA standard for HVAC Duct construction standards metal and flexible.

5.0 A typical checklist for ducts is as in Table HA-7.

Table HA-7:
Delivery, Installation, Startup and Operation Checklist for - Ducting System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HB-7D	A	**SYSTEM CHECKS**			
		A1	Pre-commissioning checks completed	-	Y/N	
		A2	Ductwork correctly installed as per drawing	-	Y/N	
		A3	Duct work properly tagged	-	Y/N	
		A4	Joints are leak tight	-	Y/N	
		A5	Ductwork clean and free of damage	-	Y/N	
		A6	Duct construction standard is followed	-	Y/N	
		A7	Access doors installed as per drawing	-	Y/N	
		A8	Insulation done correctly (if applicable)	-	Y/N	
		A9	Gaskets are installed correct	-	Y/N	
		A10	Ductwork structurally sound/no sagging	-	Y/N	
		A11	All transverse and longitudinal joints area sealed	-	Y/N	
		A12	Ductwork meets leakage class specified	-	Y/N	
		A13	All ductwork leak tested as specified	-	Y/N	
		A14	Elbows have adequate inside radius	-	Y/N	
		A15	Elbows larger than 450 mm have turning vanes	-	Y/N	
		A16	All civil penetrations are sealed and made fire proof	-	Y/N	
		A17	Volume control dampers installed as per drawing	-	Y/N	
		A18	All maintenance points are accessible	-	Y/N	
		A19	Updated as-built drawings are made available	-	Y/N	
2	HB-7C	B	**START UP**			
		B1	All precommissioning checks are completed	-	Y/N	
		B2	Leakage test reports are available	-	Y/N	
		B3	Duct internals are clean	-	Y/N	
		B4	All VCD/VAV dampers are open	-	Y/N	
		B5	AHU / TFA airflow exeeds / meets the design flow before balancing	-	Y/N	
		B6	Adjust zone air diffusion	-	Y/N	
		B7	Measure air flow at each outlet and match with design flow	-	Y/N	
		B8	Carryout balancing of flows in each branch and finally adjust fan speed.	-	Y/N	
		B9	Verify for excess noise in any segment	-	Y/N	
3	HB-7S	C	**OPERATION**			
		C1	All pre-commissioning and start up procedures are completed	-	Y/N	
		C2	Airflow balancing records are verified	-	Y/N	
		C3	Check airflow at each VAV box at maximum and minimum positions	-	Y/N	
		C4	Correct and calibrated instruments are used for all measurements	-	Y/N	
		C5	All ductwork components operate as per specifications and correct airflow rates are achieved in each space	-	Y/N	
		C6	There is no draught or excess air noise in occupied zone	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.8 (Normative)
Variable Air Volume Systems

1.0 Variable Air Volume (VAV) units are installed in the supply air path. The air conditioning system will have single or multiple VAV units connected with a single duct or multiple ducting branches.

2.0 These are factory made and tested and accepted before it reaches site. Site work involves mounting the VAVs in duct line, canvass connection, sensors, mechanical, electrical, control system and Building Management System (BMS) connectivity where applicable.

3.0 A typical checklist for variable air volume system is as in Table HA-8.

Table HA-8:
Delivery, Installation, Startup and Operation Checklist for - Variable Air Volume systems

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA-8D	**A**	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Cooling/ Heating Capacity	-		
		A5	Supply air Flow Max	m^3/s(cfm)		
		A6	Supply Air Flow Min	m^3/s(cfm)		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Air openings sealed	-	Y/N	
		B4	Air flow sensing tube connected	-	Y/N	
		B5	Enclosure for control panel OK	-	Y/N	
		B6	Installation manual provided	-	Y/N	
		B7	Test/warranty certificate provided	-	Y/N	
		B8	Unit tags affixed	-	Y/N	
2	HA-8C	**A**	**VARIABLE AIR VOLUME UNIT**			
		A1	Unit adequately supported	-	Y/N	
		A2	Adequate service clearences available for maintenance and unit removal	-	Y/N	
		A3	Unit label visible	-	Y/N	
		B	**DUCTING**			
		B1	Dampers/sensors accessible	-		
		B2	Sufficient duct length available upstream	-	Y/N	
		B3	Ductwork is adequately supported	-	Y/N	
		B4	Flexible connector installed at duct inlet	-	Y/N	
		B5	Ducting internally clean	-	Y/N	
		B6	Testing locations available	-	Y/N	
		C	**CONTROLS**			
		C1	Temp sensor calibration	-	Y/N	
		C2	Airflow sensor calibration	-	Y/N	
		C3	Control wiring correct	-	Y/N	
		C4	Control sequence verified	-	Y/N	
3	HA-8S	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Canvas connection proper	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-8S contd...	A3	Sensors correctly installed	-	Y/N	
		A4	Unit dampers fully open	-	Y/N	
		A5	No unusual noise or vibration	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	BMS Connectivity correcly established	-	Y/N	
		C	**START UP/TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Duct work balancing done	-	Y/N	
		C3	Air flow/pressure measured	-	Y/N	
		C4	Supply air quantity correctas per design	-	Y/N	
		C5	No unusual noise or vibration	-	Y/N	
		C6	Calibrated insruments used	-	Y/N	
		C7	VCD Positions marked	-	Y/N	
		C8	Flow rates in ducts within allowable tolerances	-	Y/N	
		C9	Check and confirm proper function of control algorithms in BMS	-	Y/N	
		C10	Minimum air flow design vs measured	-	Y/N	
		C11	Max air flow design vs measured	-	Y/N	
		C12	Space temperature design vs measured	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.9 (Normative)
Fans

1.0 The fans used in HVAC systems are for supply air, return air, exhaust air and any other types of ventilation requirements.

2.0 The ventilation system will have single or multiple supply, return or exhaust air fans connected with or without ducting. The fans are factory made and tested and accepted before it reaches site.

3.0 Site work shall involve installation of fans with proper foundation mounted motor on floor or wall with properly designed mounting bracket, ducting with canvas connection, mechanical, electrical, structural and control system.

4.0 A typical checklist for fans is as in Table HA-9.

Table HA-9:
Delivery, Installation, Startup and Operation Checklist for - Fans

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA-9D	**A**	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Fan Type	-		
		A5	Capacity	m^3/s(cfm)		
		A6	Static Pressure	mm of water		
		A7	Motor power/speed	kW; rpm		
		A8	Voltage/Phase/Frequency	V/-/Hz		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Air openings sealed	-	Y/N	
		B4	Installation manual provided	-	Y/N	
		B5	Test/warranty certificate provided	-	Y/N	
		B6	Unit tags affixed	-	Y/N	
2	HA-9C	**A**	**EXHAUST FAN**			
		A1	Unit adequately supported	-	Y/N	
		A2	Adequate service clearences available for maintenace and unit removal	-	Y/N	
		A3	Vibration isolators OK	-	Y/N	
		A4	Fan belts are in order and tight	-		
		A5	Back draft damper installed and correct	-		
		A6	Drive guard in place	-		
		A7	Unit label visible	-	Y/N	
		B	**DUCTING**			
		B1	Dampers/sensors accessible	-		
		B3	Ductwork is adequately supported	-	Y/N	
		B4	Dampers open/close properly	-	Y/N	
		B5	Ducting internally clean	-	Y/N	
		B6	Testing locations available	-	Y/N	
		C	**ELECTRICAL**			
		C1	Isolator in accessible location	-	Y/N	
		C2	Direction of motor rotation correct	-	Y/N	
		C3	Electrical connections are tight	-	Y/N	
		C4	Earthing adequate	-	Y/N	
		C5	Stater/VFD installed	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-9C contd...	**D**	**INSTRUMENTATION**			
		D1	Control panel accessible	-	Y/N	
		D2	Sensors correctly installed	-	Y/N	
		D3	Damper actuators installed	-	Y/N	
		D4	Electrical protections correctly installed	-	Y/N	
3	**HA-9S**	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Fans/motors lubricated/aligned	-	Y/N	
		A3	Fan belts correct and in good condition	-	Y/N	
		A4	Belt guards in place	-	Y/N	
		A5	Canvas connection proper	-	Y/N	
		A6	Sensors correctly installed	-	Y/N	
		A7	Dampers fully open	-	Y/N	
		A8	No unusual noise or vibration	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	Power available for commissioning	-	Y/N	
		B3	BMS Connectivity correcly established	-	Y/N	
		C	**START UP/ TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Duct work balancing done	-	Y/N	
		C3	Air flow/pressure measured	-	Y/N	
		C4	Fan operating point marked in fan curve	-	Y/N	
		C5	Supply air quantity correct as per design	-	Y/N	
		C6	No unusual noise or vibration	-	Y/N	
		C7	Calibrated insruments used	-	Y/N	
		C8	VCD Positions marked	-	Y/N	
		C9	Fan motor full load current in limits	-	Y/N	
		C10	Flow rates in ducts within allowable tolerance	-	Y/N	
		C11	Measure fan speed and compare with design	-	Y/N	
		C12	Check and confirm proper function of control algorithms in BMS	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.10 (Normative)
Boilers and Hot Water Generators

1.0 A packaged boiler is a steam or hot water generator, manufactured and unit supplied ready for installation.

1.1 Heat input is the heat value of the fuel used by the unit during test based on the gross or net calorific value (as per specification) plus the sensible heat in the fuel above ambient temperature and any heat supplied to the unit from a separate source.

1.2 Heat output is the heat absorbed by the working fluid, steam or water.

1.3 Thermal efficiency is the heat output divided by the heat input expressed as a percentage.

1.4 For testing of boilers and hot water generators following typical measurement instrumentation is used:

- Thermocouple
- Infrared thermometer
- Differential pressure measurement devices
- Flow meter
- Data logger

1.5 A typical checklist for boilers and hot water generators is as in Table HA-10.

Table HA-10:
Delivery, Installation, Startup and Operation Checklist for - Boilers and Hot Water Generators

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA-10D	A	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model Number	-		
		A3	Serial Number	-		
		A4	System type	-		
		A5	Output capacity	kJ (kCal/Hr)		
		A6	Input required	kJ (kCal/Hr)		
		A7	Stage/ Modulating	-		
		A8	Fuel type	-		
		A9	Entering Fuel Pressure	Pa		
		A10	Entering Fuel Temp	°C		
		A11	Combustion Efficiency	%		
		A12	Working pressure	Pa		
		A13	Power connection V/Ph/Fre/Full Load Current	-		
		A14	Entering water temp	°C		
		A15	Leaving temp Water/Steam	°C		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from External damage	-	Y/N	
		B2	Water openings are sealed	-	Y/N	
		B3	All components are present	-	Y/N	
		B4	Installation/start up manual provided	-	Y/N	
		B5	Unit tags fixed	-	Y/N	
		B6	Access door space is adequate	-	Y/N	
		B7	Restraints are in place	-	Y/N	
2	HA-10C	A	**BOILER**			
		A1	Unit secured as per specifications	-	Y/N	
		A2	Adequate clearance for maintenance	-	Y/N	
		A4	All accessories installed	-	Y/N	
		A5	No visible water leaks	-	Y/N	
		A6	Instruments installed as per design	-	Y/N	
		A7	Siesmic restraints in place	-	Y/N	
		A8	Flue/ Chimney correctly installed	-	Y/N	
		A9	Combustion air supply	-	Y/N	
		B	**PIPING**			
		B1	Water/ Steam piping correctly installed	-	Y/N	
		B2	Fuel supply piping correctly installed	-	Y/N	
		B3	Blow down system correctly installed	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-10C contd...	B4	Make up water connection	-	Y/N	
		B5	Safety relief valves installed	-	Y/N	
		B6	Pipes insulated as required to specs	-	Y/N	
		B7	Check valves correctly installed	-	Y/N	
		B8	Flow switches correctly installed	-	Y/N	
		B9	System flushed to specs	-	Y/N	
		B10	Stainers cleaned	-	Y/N	
		B11	Isolation valves correctly installed	-	Y/N	
		B12	Balancing valves correctly installed	-	Y/N	
		B13	Expansion tank with air seperator installed as per design	-	Y/N	
		B14	Air vents and bleeds installed and functional	-	Y/N	
		B15	Steam traps installed and functional	-	Y/N	
		B16	Hot water and condensate pumps installed correctly and operational	-	Y/N	
		B17	Instruments installed on supply/return	-	Y/N	
		B18	All valves/ test ports accessible	-	Y/N	
		B19	Valve tags attached	-	Y/N	
		C	**ELECTRICAL**			
		C1	Isolator in accessible location	-	Y/N	
		C2	Terminations checked	-	Y/N	
		C3	Earthing is proper	-	Y/N	
		D	**CONTROLS**			
		D1	Control panel accessible	-	Y/N	
		D2	Control panel labelled	-	Y/N	
		D3	Remote start/stop verified	-	Y/N	
		D4	Test ports available close to all sensors	-	Y/N	
		D5	Actuators installed	-	Y/N	
		D6	Actuator calibration checked	-	Y/N	
		D7	All control devices, pneumatic tubing and control wiring completed/checked	-	Y/N	
		E	**START UP**			
		E1	System flushed	-	Y/N	
		E2	System filled and air purged	-	Y/N	
		E3	Cheked for unusal noise/ vibration	-	OK / Not OK	
		E4	Manufacturer's start up check list completed	-	Y/N	
		E5	Boiler safeties energized/tested	-	Y/N	
		E6	CO and CO_2 values from burner adjustment	-	Y/N	
		E7	Start up reports include optimal and actual percentages of Oxygen, Carbon Dioxide and Carbon Monoxide	-	Y/N	
		E8	Primary heating water set point	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
3	**HA-10S**	A1	Space temperature set point	°C		
		A2	Outdoor air temperature	°C		
		A3	Fire damper opening	%		
		A4	Firing rate set point Low limit	-		
		A5	Firing rate set point High limit	-		
		A6	Rate of fuel firing	kg/sec		
		A7	Operating Control set point	°C		
		A8	Inlet water temperature	°C		
		A9	Hot water supply temperature	°C		
		A10	Hot water return temperature	°C		
		A11	Hot water/steam temperature reset	°C		
		A12	Hot water/steam pressure reset	Pa		
		A13	Pressure at water inlet	Pa		
		A14	Presssure at water/steam outlet	Pa		
		A15	Inlet water flow rate	kg/sec		
		A16	Outlet water/steam flow rate	kg/sec		
		A17	Blow down rate	kg/sec		
		A18	Fuel consumption	kCal/Hr		
		A19	Power consumption	kWh		
		A20	Drain water temperature	°C		
		A21	Flue gas temperature	°C		
		A22	Carbon Dioxide (% by volume)	%		
		A23	Carbon Monoxide (% by volume)	%		
		A24	Nitrogen (% by volume)	%		
		A25	Excess air (% by volume)	%		

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.11 (Normative)
Fan Coil Units

1.0 The fan coil units (FCU) are mounted directly on the wall of air-conditioned rooms with or without ducting & canvas connection and with supply air grill. The FCUs can be single or multiple units in a chilled water air conditioning system. These are factory made and tested and accepted before it reaches site.

2.0 Site work involves mounting the FCU on pre-decided location, connecting the temperature controller, cabling, treated fresh air connection if required, mechanical, electrical, chilled water pipe connection and condensate water removal connections, control system and BMS connectivity if applicable.

3.0 A typical checklist for FCU is as in Table HA-11.

Table HA-11:
Delivery, Installation, Startup and Operation Checklist for - Boilers and Hot Water Generators

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA-11D	A	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Air flow/ Static Pressure	m^3/s(cfm); /mm water		
		A5	Cooling/ Heating capacity	-		
		A6	Supply fan motor power/speed	kW; rpm		
		A7	Chilled water flow/ Pr drop	m^3/s(lpm); mm water		
		A8	Hot water flow/Pr drop	m^3/s(lpm); mm water		
		A9	Voltage/Phase/Frequency	V/-/Hz		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Coil surface free of damage	-	Y/N	
		B4	Water openings plugged	-	Y/N	
		B5	Installation manual provided	-	Y/N	
		B6	Test/warranty certificate provided	-	Y/N	
		B7	Unit tags affixed	-	Y/N	
2	HA-11C	A	**FAN COIL UNIT**			
		A1	Unit adequately supported	-	Y/N	
		A2	Adequate service clearences available for maintenance and unit removal	-	Y/N	
		A3	Condensate drain properly installed with adequate slope	-	Y/N	
		A4	Vibration isolators OK	-	Y/N	
		A5	Unit label visible	-	Y/N	
		B	**WATER PIPING**			
		B1	Piping correctly installed & adequately supported	-	Y/N	
		B2	Piping is clean	-	Y/N	
		B3	Pipe insulation correctly installed	-	Y/N	
		B4	Valve tags installed	-	Y/N	
		C	**DUCTING**			
		C1	Dampers/sensors accessible	-		
		C2	Ductwork is adequately supported	-	Y/N	
		C3	Dampers open/close properly	-	Y/N	
		C4	Filters correctly installed and clean	-		
		C5	Ducting internally clean	-	Y/N	
		C6	Testing locations available	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-11C contd...	**D**	**ELECTRICAL**			
		D1	Isolator in accessible location	-	Y/N	
		D2	Direction of motor rotation correct	-	Y/N	
		D3	Electrical connections are tight	-	Y/N	
		D4	Eearthing adequate	-	Y/N	
		E	**INSTRUMENTATION**			
		E1	Control panel accessible	-	Y/N	
		E2	Sensors correctly installed	-	Y/N	
		E3	Control valve actuators installed	-	Y/N	
		E4	Electrical protections correctly installed	-	Y/N	
		F	**CONTROLS**			
		F1	Thermostat installed	-	Y/N	
		F2	Thermostat calibrated	-	Y/N	
		F3	Control wiring correct	-	Y/N	
		F4	Control sequence verified	-	Y/N	
2	HA-11S	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Fans/motors lubricated/aligned	-	Y/N	
		A3	Unit pressure tested and correct	-	Y/N	
		A4	Canvas connection proper	-	Y/N	
		A5	Sensors correctly installed	-	Y/N	
		A6	Unit dampers fully open	-	Y/N	
		A7	No unusual noise or vibration	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Power available for commissioning	-	Y/N	
		B2	BMS Connectivity correcly established	-	Y/N	
		C	**START UP/ TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Air flow/pressure measured	-	Y/N	
		C3	Water side measurements done	-	Y/N	
		C4	Supply air quantity correct as per design	-	Y/N	
		C5	No unusual noise or vibration	-	Y/N	
		C6	Calibrated insruments used	-	Y/N	
		C7	Fan motor full load current in limits	-	Y/N	
		C8	Flow rates in ducts within allowable tolerance	-	Y/N	
		C9	Measure fan speed and compare with design	-	--/--	
		C10	Check and confirm proper function of control algorithms in BMS	-	--/--	
		C11	Check Operation sequence	-	Y/N	
		C12	Entering and leaving air temp at coil	-	--/--	
		C13	Entering and leaving air temp at heating coil	-	--/--	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HA.12 (Normative)
Meters and Measurement Instruments

1.0 Meters and Gauges are primarily used in the air conditioning system during installation, commissioning, testing, operation and system balancing of the air as well as water.

2.0 Meters are normally used to measure the pressure, velocity, volume, temperature of air, water, refrigerant or any other gas and or fluid flowing through the pipeline, chiller, condenser, fan etc. of HVAC system. Meters are also used to measure the electrical parameters such as voltage, continuity, current, electric power and or any variations in flow of electric current.

3.0 The instruments are used to measure the pressure of air, water, refrigerant and any other liquid, gas used in the air conditioning system.

4.0 The meters and measurement instruments shall be with valid calibration from a NABL or equivalent accredited agency. The calibration of meters and measurement instruments shall be done at defined frequency.

5.0 A list of meters and measurement instruments and typical checklist is as in Table HA-12.

Table HA-12:
Delivery, Installation, Startup and Operation Checklist for - Equipment / System - Meters and Gauges

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA-12D	A	**MODEL VERIFICATION - METERS AND GAUGES**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Capacity / Range	-		
		A4	Serial No / Identification No	-		
		A5	Type	-		
		B	**PHYSICAL CHECKS**			
		B1	Meters & Gauges free from Physical damage	-	Y/N	
		B2	Calibration done	-	Y/N	
		B3	Accuracy - Acceptable	-	Y/N	
		B4	Connecting socket / port provided	-	Y/N	
		B5	Installation manual provided Test/warranty certificate provided	-	Y/N	
		B6	Unit tags affixed	-	Y/N	
2	HA-12C	A	**METERS AND GAUGES**			
		A1	All items fitted properly	-	Y/N	
		A2	Able to read the parameters properly	-	Y/N	
		A3	Easy access for maintenance	-	Y/N	
		A4	Removal of unit possible	-	Y/N	
		A5	Unit label visible	-	Y/N	
		A6	All fitting joints are not leaking	-	Y/N	
		A7	All Meters & Gauges tested for its functioning	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Temp sensor calibration	-	Y/N	
		B2	Airflow sensor calibration	-	Y/N	
		B3	Control wiring correct	-	Y/N	
		B4	All items calibration period valid	-	Y/N	
		B5	Control sequence verified	-		
		B6	BMS Connectivity correcly established	-		
3	HA-12S	A	**MECHANICAL**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Commissioning format ready	-	Y/N	
		A3	Sensors correctly installed	-	Y/N	
		A4	Permissible parameter chart available	-	Y/N	
		A5	Readings verified of actual performance	-	Y/N	
		B	**START UP/ TAB**		Y/N	
		B1	Precommissioning checks complete	-	Y/N	
		B2	Air distribution balancing done	-		
		B3	Air flow/pressure measured	-	Y/N	
		B4	Supply air quantity correct as per design	-	Y/N	
		B5	Water distribution balancing done	-	Y/N	
		B6	Water flow / pressure measured	-	Y/N	
		B7	DP sensors installed at specified locations	-	Y/N	
		B8	Check & confirm proper function of control algorithms in BMS	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.1 (Normative)
Refrigerant Piping

1.0 In a vapor compression type refrigeration system the major components like compressor, condenser, evaporator and the expansion device and control valves are connected through copper or steel pipes. The performance of above components and the system depends on correctness of the installed piping. The factors to be considered while installing the refrigerant piping are:

a) Design and selection of right size of pipe and laying them for suction, hot gas and liquid line as prescribed in original equipment manufacturers installation manual.

b) Carry out pressure testing at manufacturers recommended test pressure after completing the piping to ensure the system will with stand pressure while in operation.

c) Vacuum the piping to minimum of 500 microns (0.6 millibar) and hold it for minimum of 10 minutes.

d) Charge system with specified quantity of refrigerant after breaking the vacuum.

2.0 The pipes used for refrigerant piping shall withstand the burst pressure of refrigerant used in the system.

3.0 A typical checklist for refrigerant pipe is as in Table HB-1.

Table HB.1:
Delivery, Installation, Startup and Operation Checklist for - Refrigerant Piping

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HB-1D	**A**	**SYSTEM CHECKS**			
		A1	ODUs have been levelled and installed properly	-	Y/N	
		A2	Vibration isolation pads of correct size have been provided below ODUs	-	Y/N	
		A3	IDUs have been installed as per design layout	-	Y/N	
		A4	Drain piping of IDUs properly laid with required slope and connected to main drain	-	Y/N	
		A5	Grade of copper piping selected is as recommended for specific installation	-	Y/N	
		A6	Routing of copper piping from ODU to IDU is as per detailed & approved layout	-	Y/N	
		A7	Refrigerant piping has been laid properly as shown in Drawing	-	Y/N	
		A8	There are no visible dents / damages in piping and fittings	-	Y/N	
		A9	Connecting piping between ODU & IDU have been supported properly	-	Y/N	
		A10	Refrigerant piping running out side the building are properly covered to protect from any damages	-	Y/N	
		A11	Selection of refrigerant piping material as per IS Standard IS 10773	-	Y/N	
		A12	Selection of various pipe fittings such as T joint, Y / branching joint and multiple branching	-	Y/N	
		A13	Brazing material shall confirm to IS 2927	-		
		A14	Selection of insulation material - size thickness and grade as defined in BOQ / Specification	-	Y/N	
		A15	Proper tools used for cutting , flaring , bending etc	-	Y/N	
		A16	Nitrogen gas used for pressure testing the system	-	Y/N	
		A17	Valves and fittings provided in refrigarnat line are of standard make / as recommended by the Commissioning agent	-	Y/N	
		A18	Suction piping has been insulated properly from IDU to ODU	-		
		A19	Test ports for BMS as per PID provided	-	Y/N	
		A20	Main incoming with MCB and earthing is terminated at the ODU	-	Y/N	
		A21	All compressors and other motors and electrically operated controls are connected with proper cable size , earthing and terminated as per electrical rules	-	Y/N	
		A22	All cables used are as specified in BOQ without any deviation	-	Y/N	
		A23	Final as built drawings are available	-	Y/N	
		A24	All equipment and component details are avaiilable and recorded	-	Y/N	
		A25	Gas cylinders are identified with proper marking such as Nitrogem, CO_2, Oxygen and Acetiline	-	Y/N	
		A26	The refrigerant cylinders also have identification mark on the cylinder such as R 22, R 32, R 407C, R 410A etc	-	Y/N	
		A27	Pressure regulator in working condition is used for brazing and pressure tesing purpose	-	Y/N	
		A28	There is sufficient space around the ODUs for maintenance purpose with a proper access	-	Y/N	
		A29	Isolatation switch is porvided near the condensing unit in case the the condensers are located far away from the compressor	-	Y/N	
		A30	While carrying out copper pipe brazing, the brazing procedure has been followed as per IS 2927	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
2	**HB-1C**	**B**	**START UP**			
		B1	Pressure testing of the refrigarant lines is complete and system having no leak. Readings recorded	-	Y/N	
		B2	Vacuum test has been carried out for the entire system and readings recorded	-	Y/N	
		B3	All Service valves are in open position before startimg the machines	-	Y/N	
		B4	After the vacuum testing , vacuum was broken by charging minimum quantity of refrigerant to maintain positive pressure	-	Y/N	
		B5	All the electrical work including the laying cable, termination of power wiring at the motor are done as per the local electrical guidelines	-	Y/N	
		B6	Electrical safety items / alarm bells / indicating lamps etc are in place	-	Y/N	
		B7	Electrical incoming supply is having proper balanced voltage	-	Y/N	
		B8	Megger testing has been done for the cabling and readings are OK	-	Y/N	
		B9	Refrigerant charging line with calbrated pressure gauge and connecting tube is vailable at site	-	Y/N	
		B10	LOG book having required columns to record all the readings as per the guidelines is available	-	Y/N	
		B11	First Aid Kit is available at the location in case of multi unit / large installations	-	Y/N	
		B12	Water connection / provision for water is available at site near the plant room	-	Y/N	
		B13	Trained operating staff present during commissioning	-	Y/N	
3	**HB-1S**	**C**	**OPERATION**			
		C1	All the controls and the control wiring are checked for its opeartion on no load condition	-	Y/N	
		C2	All pre-commissioning and start up procedures are completed	-	Y/N	
		C3	Measuring instruments are calibrated and in working condition	-	Y/N	
		C4	Refrigerant charged to the system and pressure readings recorded	-	Y/N	
		C5	Individual indoor units are run and checked for any vibration / noise	-	Y/N	
		C6	Air flow of IDUs measured for individual units and achieved as specified	-	Y/N	
		C7	All low side equipment / AHU parameters are as per design	-	Y/N	
		C8	Current drawn is measured and recorded for individual units	-	Y/N	
		C9	Condenser in and out pressure and temperature readings are inline with the design and recorded	-	Y/N	
		C10	Inside conditions are recorded	-	Y/N	
		C11	Compressor in and out temperature / pressure readings are recorded	-	Y/N	
		C12	All operating parameters are recorded and as per design	-	Y/N	
		C13	Noise level of ODUs are measured and does not exceed desired limits	-	Y/N	
		C14	Operation / Instruction Mannual including technical leteratures of all equipment / controls are available at site	-	Y/N	
		C15	Any deviation in parameters recorded and corrective action taken to resolve	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.2 (Normative)
Water Piping

1.0 Water piping consists of condenser water, chilled water, make up water and condensate / drain water. The condenser and chilled water piping design is very important for the system to function efficiently.

2.0 The piping can be laid above the ground level, or on the ground or in a trench below the ground level. The condenser / chilled water piping is laid to connect the condenser / chiller and the respective pumps installed in the plant room or outside the plant room.

3.0 The site work involves laying the pipes on the ground with proper support and above the ground with proper suspension method using vibration isolation where required after the equipment are properly levelled and grouted.

4.0 The condenser and chillers are connected by using necessary valves / strainers and vibration isolation as per design / layout drawing.

5.0 The pipe shall be tested for pressure with standing capacity at pressure specified for the system.

6.0 A typical checklist for water piping is as in Table HB-2.

Table HB.2:
Delivery, Installation, Startup and Operation Checklist for - Water Piping

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	**HB-2D**	**A**	**SYSTEM CHECKS**			
		A1	Pre-commissioning checks completed	-	Y/N	
		A2	Piping correctly laid as per drawing with adequate supports	-	Y/N	
		A3	Piping properly tagged with flow directions	-	Y/N	
		A4	Pipes are adequately flushed	-	Y/N	
		A5	Strainers removed and cleaned	-	Y/N	
		A6	Pipes pressure tested	-	Y/N	
		A7	Insulation done correctly (if applicable)	-	Y/N	
		A8	All valves as per design drawings	-	Y/N	
		A9	Piping clean and free of damage	-	Y/N	
		A10	Drainage/Venting possible	-	Y/N	
		A11	All fittings are as per specifications	-	Y/N	
		A12	Valves are accessible for operation and maintenance	-	Y/N	
		A13	Pipes do not block access to equipment	-	Y/N	
		A14	All openings sealed till ready for use	-	Y/N	
		A15	As built drawings available	-	Y/N	
		A16	Flexible connections installed where specified	-	Y/N	
		A17	Test ports installed near all sensors	-	Y/N	
		A18	Motorised valves are ready to operate	-	Y/N	
2	**HB-2C**	**B**	**START UP**			
		B1	All manual shut off valves are open	-	Y/N	
		B2	All by pass valves are closed	-	Y/N	
		B3	Balancing of water flow rates done where manual balancing valves are provided	-	Y/N	
		B4	Where PIBCVs provided , manual	-	Y/N	
			balancing valves set to operating point before PIBCV operation is verified	-		
		B5	No unusal noise or vibration when valves are opened or closed	-	Y/N	
		B6	Pressure & flow measurements to be recorded at each control valve	-	Y/N	
3	**HB-3S**	**C**	**OPERATION**			
		C1	All pre-commissioning and start up procedures are completed	-	Y/N	
		C2	Pipes pressure tested before insulation	-	Y/N	
		C3	Pressure testing records available and verified	-	Y/N	
		C4	Pipe flows balanced and all balancing records verified	-	Y/N	
		C5	Water flow measurements carried out at each valve a) Fully open b) 10 % open	-	Y/N	
		C6	No unusual hydraulic noise	-	Y/N	
		C7	If any additives are used same is correctly authorised	-	Y/N	
		C8	Calibrated instruments are used	-	Y/N	
		C9	All components operate as specified	-	Y/N	
		C10	All flow rates are achieved as specified	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.3 (Normative)
Chilled Water System

1.0 Chilled water system comprises of single or multiple chillers, chilled water pumps single or multiple mounted on a RCC or metallic frame foundation having isolation pad / material below it, complete chilled water piping from the chillers to (AHUs, FCUs) air distribution system, isolation / modulating valves, check valves, strainers, controls etc.

2.0 The chilled water system will have primary circuit, secondary circuit or tertiary circuit depending upon the type of system chosen, number of floors etc. Each circuit will have different sets of Pumps with flow /capacity control mechanism.

3.0 The chilled water system will have isolation valves at branches, modulating valves, check valves and strainers wherever required.

4.0 There will be single of multiple AHUs, FCUs, all connected through chilled water piping from the plant room to various spaces to be conditioned.

5.0 The AHUs and FCUs will be installed with Control valves operated with pressure / temperature sensors which will control flow of water through each AHU and FCU thereby controlling the flow through each pump set.

6.0 The control system comprises of flow control and temperature control at various points in smaller plants while the larger system will have automatic control mechanism using BMS connectivity.

7.0 The site work will involve laying the piping as per layout drawing, fabricating and welding using proper bends, Tees, reducers and installation of valves, fittings and controls, mechanical, electrical and control system.

8.0 The pressure testing carried out and system is flushed and fresh water is filled in to the system.

9.0 All the piping, valves fittings from chiller, to pump and to AHU, FCU are insulated as per the specification.

10.0 Sample check lists are given in attachments for Delivery (HB-3D), Start Up (HB-3C) and operation (HB-3S).

Table HB.3:
Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Chilled Water System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HB-3D	A	**SYSTEM CHECKS**			
		A1	Chiller/s Installed as per approved drawing	-	Y/N	
		A2	Foundation for chiller/s are proper, Enough access provided for maintenance	-	Y/N	
		A3	Vibration Isolator of chiller/s installed as per approved specs	-	Y/N	
		A 5	Chilled Water Pumps Installed as per approved drawing	-	Y/N	
		A7	Foundation and inertia blcoks (if any)for pumps are proper, Enough access provided for maintenance	-	Y/N	
		A8	Vibration Isolator of pumps installed as per approved specs	-	Y/N	
		A9	Pipes are connected to chillers and pumps with required valves as per PID	-	Y/N	
		A10	Tagging of equipments and valve is done	-	Y/N	
		A11	Supports for chilled water piping is checked, Necessary supports near diversion , near equipments are provided	-	Y/N	
		A12	Chilled water piping & drain piping is laid as per approved shop drawing and PID including for AHUs, FCUs etc	-	Y/N	
		A13	Insulation is checked properly	-	Y/N	
		A14	Piping clean and free of damage	-	Y/N	
		A15	Equipment clean and free of damage	-	Y/N	
		A16	Drainage/Venting is provided at proper location	-	Y/N	
		A17	All Piping fittings are as per specifications	-	Y/N	
		A18	Flow directions marked on pipes	-	Y/N	
		A19	Flexible connections installed where specified	-	Y/N	
		A20	Test ports installed near all sensors	-	Y/N	
		A21	Motorised valves are ready to operate	-	Y/N	
		A22	Piping is tested with hydrotested and reports signed off	-	Y/N	
		A23	The blank off are provided at equipment end to avoid water flow (Chillers, Pumps, AHUS etc)	-	Y/N	
		A24	Flushing & passivation activity is done and reports are signed off	-	Y/N	
		A25	All test ports including for BMS as per PID are provided. Pressure and temperature Guages Provided	-	Y/N	
		A26	All duct works are checked, the installation cheklist is signed	-	Y/N	
		A27	Equipments are electrically connected with proper cable size and earthing	-	Y/N	
		A28	Megger test of cabling is done	-	Y/N	
		A29	All openings sealed with proper sealant till ready for use	-	Y/N	
		A30	As built drawings available	-	Y/N	
		A31	All installation check list are approved with snags	-	Y/N	
		A32	Allequipments details are taken and recorded	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
2	**HB-3C**	**B**	**START UP**			
		B1	All manual shut off valves are open	-	Y/N	
		B2	All by pass valves are closed	-	Y/N	
		B3	Water Balancing of water flow done where manual balancing valves are provided	-	Y/N	
		B4	Where PIBCVs provided, manual balancing valves set to operating point Before PIBCV operation is verified	-	Y/N	
		B5	No unusal noise or vibration when valves are opened or closed (Pumps, Chillers, Piping Supports)	-	Y/N	
		B6	Pressure and flow measurements to be recorded at each control valve. Valves are adjusted accordingly	-	Y/N	
		B7	Electrical mains are charged and checked	-	Y/N	
		B8	Electrical Paramaters are checked for all equipments	-	Y/N	
		B9	OLR settings done as per limit	-	Y/N	
		B10	Checking of VCD and FD Operation	-	Y/N	
3	**HB-3S**	**C**	**OPERATION**			
		C1	All pre-commissioning and start up procedures are completed	-	Y/N	
		C2	Calibrated instruments are used	-	Y/N	
		C3	All water and air flow rates are achieved as specified Pipe flows balanced and all balancing records verified	-	Y/N	
		C4	Chiller Paramters (Electrical/Mechanical) are noted and recorded.	-	Y/N	
		C5	Chiller parameters are as per design Pumps Paramters (Electrical/Mechanical) are noted and recorded	-	Y/N	
		C6	Pumps parameters are as per design	-	Y/N	
		C7	All Low side equipments parameters are checked All Low side equipments parameters (Electrical/Mechanical) are as per design	-	Y/N	
		C8	Inside Conditions / Process parameters are recorded	-	Y/N	
		C9	Any deviation in parameters recorded and resolved	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.4 (Normative)
Condenser Water System

1.0 Condenser water system comprises of single or multiple chillers, Cooling towers single or multiple, condenser water pump sets single or multiple mounted on a RCC or metallic frame foundation having isolation pad / material below it, isolation / modulating valves, check valves, strainers and controls etc.

2.0 Condenser water system will have isolation valves at condenser inlet and outlet, pump in and out and cooling tower in and out, check valves and strainers wherever required.

3.0 The site work will involve laying the piping as per layout drawing, fabricating and welding using proper bends, Tees, reducers and installation of valves, fittings and controls, mechanical, electrical and control system.

4.0 The pressure testing carried out and system is flushed and soft and uncontaminated fresh water is filled in to the system.

5.0 Sample check lists are given in attachments for Delivery (HB-4D), Start Up (HB-4C) and operation (HB-4S).

Table HB.4:
Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Condenser Water System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	**HB-4D**	**A**	**SYSTEM CHECKS**			
		A1	Cooling towers Installed as per approved drawing	-	Y/N	
		A2	Foundation for cooling tower r/s are proper, enough access provided for maintenance	-	Y/N	
		A3	Enough area is provided for air circulation	-	Y/N	
		A4	Condenser Water Pumps Installed as per approved drawing	-	Y/N	
		A5	Foundation and inertia blcoks (if any) for pumps are proper, Enough access provided for maintenance	-	Y/N	
		A6	Vibration Isolator of pumps installed as per approved specs	-	Y/N	
		A7	Pipes are connected to equipements with required valves as per PID	-	Y/N	
		A8	Tagging of equipments and valve is done	-	Y/N	
		A9	Supports for condenserd water piping is checked, Necessary supports near diversion, near equipments are provided	-	Y/N	
		A10	Piping clean and free of damage	-	Y/N	
		A11	Equipment clean and free of damage	-	Y/N	
		A12	Drainage / Venting / Over flow is provided at proper location	-	Y/N	
		A13	All Piping fittings are as per specifications	-	Y/N	
		A14	Flow directions marked on pipes	-	Y/N	
		A15	Flexible connections installed where specified	-	Y/N	
		A16	Test ports installed near all sensors	-	Y/N	
		A17	Motorised valves are ready to operate	-	Y/N	
		A18	Piping is tested with hydrotested and reports signed off	-	Y/N	
		A19	The blank-off are provided at equipment end to avoid water flow	-	Y/N	
		A20	Flushing and passivation activity is done and reports are signed off	-	Y/N	
		A21	All test ports including for BMS as per PID are provided. Pressure and temperature Guages Provided	-	Y/N	
		A22	Equipments are electrically connected with proper cable size and earthing	-	Y/N	
		A23	Megger test of cabling is done	-	Y/N	
		A24	As built drawings available	-	Y/N	
		A25	Allequipments details are taken and recorded	-	Y/N	
2	**HB-4C**	**B**	**START UP**	-		
		B1	All manual shut off valves are open	-	Y/N	
		B2	All by pass valves are closed	-	Y/N	
		B3	Water Balancing of water flow done where manual balancing valves are provided	-	Y/N	
		B4	No unusal noise or vibration when valves are opened or closed (Pumps, Towers, Piping Supports)	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HB-4C contd...	B5	Pressure and flow measurements to be recorded at each control valve. Valves are adjusted accordingly	-	Y/N	
		B6	Electrical mains are charged and checked	-	Y/N	
		B7	Electrical Paramaters are checked for all equipments	-	Y/N	
		B8	OLR settings done as per limit	-	Y/N	
3	**HB-4S**	**C**	**OPERATION**			
		C1	All pre-commissioning and start up procedures are completed	-	Y/N	
		C2	Calibrated instruments are used	-	Y/N	
		C3	All water and air flow rates are achieved as specified	-	Y/N	
		C4	Pipe flows balanced and all balancing records verified	-	Y/N	
		C5	Cooling Tower Paramters (Electrical/Mechanical) are noted and recorded	-	Y/N	
		C6	Cooling Tower parameters are as per design	-	Y/N	
		C7	Pumps Paramters (Electrical/Mechanical) are noted and recorded.	-	Y/N	
		C8	Pumps parameters are as per design	-	Y/N	
		C9	Any deviation in parameters recorded and resolved	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.5 (Normative)
Direct Expansion System

1.0 Direct Expansion system (DX) comprises of Indoor Unit single or multiple connected to outdoor Unit single or multiple through refrigerant piping. The DX system may have air cooled condensers or water cooled condensers with cooling tower and pumps connected through water piping.

2.0 The out door unit comprises of compressor, motor, condenser, all in a enclosed casing either factory made or site assembled. These are factory made and tested and accepted before it reaches site.

3.0 Site work involves:

a) Installation of Indoor unit and outdoor unit on prefixed foundation refrigerant piping between indoor unit and out door unit including fixing valves, pressure testing the entire refrigerant piping, vacuuming

b) Installation of controls, electrical power and control wiring

c) Mechanical works like providing supports for piping

d) Duct with canvas connection from the indoor unit to the air conditioned space

e) Insulation of suction piping and

f) Commissioning and balancing the system.

4.0 Sample check lists are given in attachments for Delivery (HB-5D), Start Up (HB-5C) and operation (HB-5S).

Table HB.5:
Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Direct Expansion System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA-5D	A	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No - Indoor Units	-		
		A4	Air Flow - Indoor Units	m^3/s(cfm)		
		A5	Indoor Unit fan motor power	kW		
		A6	Indoor Units fan motor V/Ph/Frequency	-		
		A7	Total cooling / Heating capacity	kW		
		A9	Airflow- Outdoor Unit	m^3/s(cfm)		
		A10	Ambient Temp	°C		
		A11	Condenser fan motor power	kW		
		A12	Condenser fan motor V/Ph/Frequency	-		
		B	**Physical Checks**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Copper pipes sealed at both ends	-	Y/N	
		B4	Unit tags present	-	Y/N	
		B5	Installation manual provided	-	Y/N	
		B6	Test/warranty certificate provided	-	Y/N	
2	HA-5C	A	**EVAPORATOR SECTION**			
		A1	Unit adequately supported	-	Y/N	
		A2	Adequate service clearances available for maintenance	-	Y/N	
		A3	Condensate drain properly installed	-	Y/N	
		A4	Unit label visible	-	Y/N	
		B	**Condenser Section**			
		B1	Unit adequately supported	-	Y/N	
		B2	Adequate service clearances available for maintenance	-	Y/N	
		B3	Unit label visible	-	Y/N	
		C	**REFRIGERANT PIPING**			
		C1	Piping correctly installed as per drawing	-	Y/N	
		C2	Disconnection for unit removal is easy	-	Y/N	
		C3	Pipe supports are as per specifications	-	Y/N	
		C4	Pipe pressure tested and found OK	-	Y/N	
		C5	Pipe insulated as per specifications	-	Y/N	
		C6	Valves and test ports are accessible	-	Y/N	
		C7	Valves are tagged	-	Y/N	
		C8	Unit charged with refrigerant	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HA-5C contd...	**D**	**ELECTRICAL**			
		D1	Isolator in accessible location	-	Y/N	
		D2	Motor rotation correct	-	Y/N	
		D3	Terminations checked	-	Y/N	
		D4	Earthing is proper	-	Y/N	
		E	**CONTROLS**			
		E1	Thermostat installed	-	Y/N	
		E2	Thermostat calibrated	-	Y/N	
		E3	Control wiring correct	-	Y/N	
		E4	Control sequence verified	-	Y/N	
		E5	No abnormal notice or vibration	-	Y/N	
		E6	Manufacturers checklist completed	-	Y/N	
		E7	Filters installed and are clean	-	Y/N	
3	**HB-5S**				**Actual**	**Design**
		A1	Room Temperature	°C		
		A2	Grill temperature	°C		
		A3	Voltage	V		
		A4	Starting current	A		
		A5	Full load current	A		
		A6	High pressure cutout setting	Pa(psi)		
		A7	Low pressure cutout setting	Pa(psi)		
		A8	Suction pressure	Pa(psi)		
		A9	Discharge pressure	Pa(psi)		
		A10	Evaporator entering DB/WB	°C		
		A11	Evaporator leaving DB/WB	°C		
		A12	Condenser entering DB/WB	°C		
		A13	Condenser leaving DB/WB	°C		
		A14	Air flow Evaporator	m^3/s(cfm)		
		A15	Air flow Condenser	m^3/s(cfm)		
		A16	Noise at 1 m from Evaporator	dBA		
		A17	Noise at 1 m from Condenser	dBA		

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.6 (Normative)
Air Distribution System

1.0 The HVAC systems use air ducts installed in a building to supply conditioned air to various spaces through supply air duct with terminal outlets, vents such as diffusers grilles, cassettes registers etc. The air from the conditioned space is received through return air ducts with terminal such as grilles and diffusers.

2.0 Based on the heat load and air quantity requirement, layout of the space to be air conditioned with the supply air duct routing and return air path to the air handling unit room is prepared. Sizing of the supply air duct has a bearing on the pressure drop and outlet velocities.

3.0 Air distribution of HVAC system comprises of single or multiple AHUs / Fans from where the cooled / treated / dehumidified air is circulated and collected back from the conditioned areas though supply and return air ducting.

4.0 The material used for ducting shall have properties which are user friendly such as rust resistance, least friction for flow of air, easily malleable and giving air tight seal when installed. The recommended materials for the ducting are galvanized steel, aluminium or stainless steel sheets. The ducts can be either rectangular or circular as preferred by the designer and will have insulation where required as per design.

5.0 The duct fabrication, joinery, installation and flanges are carried out in line with BIS IS 655 or SMACNA standard.

6.0 The site work will involve laying the installation of main ducts, connecting and terminating the branches as per layout drawing, fixing dampers, grilles and diffusers, canvas connections, joining all joints and making them air tight.

7.0 Sample check lists are given in attachments for Delivery (HB-6D), Installation (HB-6C), Start Up (HB-6B) and operation (HB-6S).

Table HB.6:
Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Air Distribution System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HB-6D	**A**	**MODEL VERIFICATION**			As Applicable
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Cooling /Heating Capacity	-		
		A6	Supply air Flow	m^3/s(cfm)		
		A7	Supply fan motor power/speed	kW; rpm		
		A8	Return Air Flow	m^3/s(cfm)		
		A9	Return Fan motor power/speed	kW; rpm		
		A10	Voltage/Phase/Frequency	V/-/Hz		
		A11	Filters rating	MERV		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Air openings sealed	-	Y/N	
		B4	Access doors operable	-	Y/N	
		B6	Installation manual provided	-	Y/N	
		B7	Test/warranty certificate provided	-	Y/N	
		B8	Unit tags affixed	-	Y/N	
2	HB-6C	**A**	**AIR DISTRIBUTION SYSTEM**			
		A1	Unit adequately supported	-	Y/N	
		A2	Adequate service clearances available for maintenance	-	Y/N	
		A3	Clear acess available for Dampers / Duct / VAV / CAV / filters removal	-	Y/N	
		A5	Fan / Chamber / Air Handling Unit / Ductwork system internally clean	-	Y/N	
		A6	Air filters installed and clean	-		
		A7	Air leakage tests completed with all test blanks removed	-	Y/N	
		A7	Fan / AHU / Coil drains and traps complete	-		
		A8	Unit label visible	-	Y/N	
		B	**DUCTING**			
		B1	Mixing of outdoor/return air possible	-	Y/N	
		B3	Ductwork is adequately supported	-	Y/N	
		B4	Dampers open/close properly	-	Y/N	
		B5	Ducting internally clean	-	Y/N	
		B6	Testing locations available	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HB-6C contd...	**C**	**ELECTRICAL**			
		C1	Isolator in accessible location	-	Y/N	
		C2	Direction of motor rotation correct	-	Y/N	
		C3	Electrical connections are tight	-	Y/N	
		C4	Earthing adequate	-	Y/N	
		C5	Starter/VFD installed	-	Y/N	
		D	**INSTRUMENTATION**			
		D1	Control panel accessible	-	Y/N	
		D2	Sensors correctly installed	-	Y/N	
		D3	Damper actuators installed	-	Y/N	
		D4	Control valve actuators installed	-	Y/N	
		D5	Electrical protections correctly installed	-	Y/N	
		E	**CONTROLS**			
		E1	Control wiring for distribution control complete and tested (ie. Motorised dampers, VAV's/CAV'setc.)	-	Y/N	
		E2	Controls point checked for distribution controls (Motorised dampers, VAV's / CAV's etc. can be driven to required positions	-	Y/N	
		E3	Control wiring correct	-	Y/N	
		E4	Control sequence verified	-	Y/N	
3	**HB-6B**	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Filters installed and are clean	-	Y/N	
		A3	Fan belts correct and in good condition	-	Y/N	
		A4	Unit pressure tested and correct	-	Y/N	
		A5	Belt guards in place	-	Y/N	
		A6	Canvas connection proper	-	Y/N	
		A7	Sensors correctly installed	-	Y/N	
		A8	Unit dampers fully open		Y/N	
		B	**CONTROLS STARTUP**	-		
		B1	Control sequence verified	-	Y/N	
		B2	Lighting within unit installed	-	Y/N	
		B3	Power available for commissioning	-	Y/N	
		B4	BMS Connectivity correctly established	-	Y/N	
4	**HB-6S**	**A**	**START UP/ TAB**			
		A1	Precommissioning checks complete	-	Y/N	
		A2	Air flow/pressure measured	-	Y/N	
		A3	Fan operating point marked in fan curve	-	Y/N	
		A4	CAV/VAV Pre-Commissioning Checks complete	-	Y/N	
		A5	Supply air quantity correct as per design	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HB-6S contd...	A6	No unusual noise or vibration	-	Y/N	
		A7	Calibrated instruments used	-	Y/N	
		A8	Fan motor full load current in limits	-	Y/N	
		A9	Flow rates in ducts within allowable tolerance.	-	Y/N	
		A10	Compare fan air flow in front of filter section with air flow in main ducts	-	Y/N	
		A11	Check and confirm proper function of control algorithms in BMS	-	Y/N	
		A12	Check Fan Operation sequence	-	Y/N	
		A13	Measure the air flow at the terminal diffuser/grill to ensure that air is reaching to the farthest terminal units	-	Y/N	
		A14	Adjust the dampers at each terminal unit to match to the design flow as per the approved ducting layout.	-	Y/N	
		A15	After adjusting the dampers for each diffuser recheck for the air flow at each diffuser to match the design flow	-	Y/N	
		A16	VCD positions marked as per desired air flow setting	-	Y/N	
		A17	Check for the air flow at the return air filter side. If the air flow at the return air filter side is excess of the deign total air flow reduce the speed of the fan through supply air dampers/VFD to achieve the design air flow.	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.7 (Normative)
Hot Water System

1.0 The hot water system is installed for heating of the space air conditioned. The hot water system will have separate sets of pumps with flow / capacity control mechanism.

2.0 The hot water system will also have isolation valves at branches, modulating valves, check valves and strainers wherever required.

3.0 There will be single of multiple AHUs, FCUs, may have additional heating coils connected through hot water piping from the plant room.

4.0 The control system comprises of flow control and temperature control at various points in smaller plants while the larger system will have automatic BMS system with all controls connected to it.

5.0 The site work will involve laying of piping as per layout drawing, fabricating and welding joints, with proper bends, Tees, reducers and installation of dampers, valves, fittings and controls, mechanical work.

6.0 The pressure testing carried out and system is flushed and fresh water is filled in to the system.

7.0 All the piping, valves fittings from condenser / hot water boiler to pump and AHU, FCU are insulated as per the specification.

8.0 Sample check lists are given in attachmentsfor Delivery (HB-7D), Installation (HB-7C), Start Up (HB-7M) and operation (HB-7S).

Table HB.7:
Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Hot Water System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HB-7D	**A**	**SYSTEM CHECKS**			
		A1	Hot water generators Installed as per approved drawing	-	Y/N	
		A2	Foundation for generators are proper, Enough access provided for maintenance	-	Y/N	
		A3	Vibration Isolator of installed as per approved specs	-	Y/N	
		A4	Ventilation is provided in plant room	-	Y/N	
		A5	Hot Water Pumps Installed as per approved drawing	-	Y/N	
		A7	Foundation and inertia blcoks (if any) for pumps are proper, Enough access provided for maintenance	-	Y/N	
		A8	Vibration Isolator of pumps installed as per approved specs	-	Y/N	
		A9	Pipes are connected to Hot water generator and pumps with required valves as per PID	-	Y/N	
		A10	Tagging of equipments and valve is done	-	Y/N	
		A11	Supports for hot water piping is checked, Necessary supports near diversion , near equipments are provided	-	Y/N	
		A12	Hot water piping & drain piping is laid as per approved shop drawing and PID including for AHUs, FCUs etc	-	Y/N	
		A13	Insulation is checked properly	-	Y/N	
		A14	Piping clean and free of damage	-	Y/N	
		A15	Equipment clean and free of damage	-	Y/N	
		A16	Drainage/Venting is provided at proper location	-	Y/N	
		A17	All Piping fittings are as per specifications	-	Y/N	
		A18	Flow directions marked on pipes	-	Y/N	
		A19	Flexible connections installed where specified	-	Y/N	
		A20	Test ports installed near all sensors	-	Y/N	
		A21	Motorised valves are ready to operate	-	Y/N	
		A22	Piping is tested with hydrotested and reports signed off	-	Y/N	
		A23	The blank off are provided at equipment end to avoid water flow (Hot water generator, Pumps, AHUS etc)	-	Y/N	
		A24	Flushing & passivation activity is done and reports are signed off	-	Y/N	
		A25	All test ports including for BMS as per PID are provided. Pressure and temperature Guages Provided	-	Y/N	
		A26	All duct works are checked, the installation cheklist is signed	-	Y/N	
		A27	Equipments are electrically connected with proper cable size and earthing	-	Y/N	
		A28	Megger test of cabling is done	-	Y/N	
		A29	All openings sealed with proper sealant till ready for use	-	Y/N	
		A30	As built drawings available	-	Y/N	
		A31	All installation check list are approved with snags	-	Y/N	
		A32	Allequipments details are taken and recorded	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
2	**HB-7C**	**B**	**START UP**			
		B1	All manual shut off valves are open	-	Y/N	
		B2	All by pass valves are closed	-	Y/N	
		B3	Water Balancing of water flow done where manual balancing valves are provided	-	Y/N	
		B4	Where PIBCVs provided, manual balancing valves set to operating point Before PIBCV operation is verified	-	Y/N	
		B5	No unusal noise or vibration when valves are opened or closed (Pumps, Hot water generator, Piping Supports)	-	Y/N	
		B6	Pressure and flow measurements to be recorded at each control valve. Valves are adjusted accordingly	-	Y/N	
		B7	Electrical mains are charged and checked	-	Y/N	
		B8	Electrical Paramaters are checked for all equipments	-	Y/N	
		B9	OLR settings done as per limit	-	Y/N	
		B10	Checking of VCD and FD Operation	-	Y/N	
		B11	Water flow quality is checked	-		
3	**HB-7S**	**C**	**OPERATION**			
		C1	All pre-commissioning and start up procedures are completed	-	Y/N	
		C2	Calibrated instruments are used	-	Y/N	
		C3	All water and air flow rates are achieved as specified	-	Y/N	
		C4	Pipe flows balanced and all balancing records verified	-	Y/N	
		C5	Hot water generator Paramters (Electrical / Mechanical) are noted and recorded	-	Y/N	
		C6	Hot water generator parameters are as per design	-	Y/N	
		C7	All the settings are done and recorded	-	Y/N	
		C8	Pumps Paramters (Electrical/Mechanical) are noted and recorded	-	Y/N	
		C9	Pumps parameters are as per design	-	Y/N	
		C10	All the settings are done and recorded	-	Y/N	
		C11	All Low side equipments parameters are checked	-	Y/N	
		C12	All Low side equipments parameters (Electrical/Mechanical) are as per design	-	Y/N	
		C13	All the settings are done and recorded	-	Y/N	
		C14	Inside Conditions / Process parameters are recorded	-	Y/N	
		C15	Any deviation in parameters recorded and resolved	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.8 (Normative)
Basement Ventilation System

1.0 Basement Ventilation system comprises of jet fans, supply and exhaust fans, controls and control panel and BMS connectivity. The jet fans will be suspended from the ceiling as per layout prepared. The operation of these fans is controlled by sensors installed at various pre-decided locations based on CFD (Computational Fluid Dynamics) analysis.

2.0 The basement ventilation system will have multiple jet fans directly suspended from the ceiling. The supply and exhaust air fans are installed in the outer wall of the building may or may not have duct connections based on the design of layout.

3.0 The ventilation fans are factory made and tested and accepted before it reaches site.

4.0 Site work involves usually installation of jet fans, supply and exhaust fans, ducting when required, mechanical, cabling, electrical and control system and BMS connectivity.

5.0 Sample check lists are given in attachments for Delivery (HB-8D), Start Up (HB-8C) and operation (HB-8S)

Table HB.8:
Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Basement Ventilation System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HB-8D	**A**	**SYSTEM CHECKS**			
		A1	Jet fans, Supply & exhaust fans Installed as per approved drawing	-	Y/N	
		A2	Enough access provided for maintenance for all fans	-	Y/N	
		A3	No clash of fans with other services, civil works, walls etc	-	Y/N	
		A4	PLC and starter panels installed as per approved drawngs	-	Y/N	
		A5	Cables, cables trays, termination done as per approved SLD, shop drawings	-	Y/N	
		A6	Ducts works are done with as per approved drawings with fire coating	-	Y/N	
		A7	Fire dampers if required are installed as per approved drawings	-	Y/N	
		A8	Vibration Isolator of jet fans, supply and exhaust fans installed as per approved specs	-	Y/N	
		A9	Co sensors are installed as per appropriate location as per approved drawing	-	Y/N	
		A10	Tagging of equipments is done	-	Y/N	
		A11	Equipment clean and free of damage	-	Y/N	
		A12	Equipments are electrically connected with proper cable size and earthing	-	Y/N	
		A13	Megger test of cabling is done	-	Y/N	
		A14	Approved CFD anaylsis is available	-	Y/N	
		A15	Approved logic is available	-	Y/N	
		A16	As built drawings available	-	Y/N	
		A17	All equipments details are taken and recorded	-	Y/N	
2	HB-8C	**B**	**START UP**			
		B1	Electrical mains are charged and checked	-	Y/N	
		B2	Electrical Paramaters are checked for all equipments	-	Y/N	
		B3	OLR settings done as per limit	-	Y/N	
		B4	No unusal noise or vibration noticed during startup of fans	-	Y/N	
		B5	Air paths are clear and there is no blockage	-		
		B6	Interface with Fire Protection system is done and checked	-	Y/N	
3	HB-8S	**C**	**OPERATION**			
		C1	All pre-commissioning and start up procedures are completed	-	Y/N	
		C2	Calibrated instruments are used	-	Y/N	
		C3	All the settings are done and recorded	-	Y/N	
		C4	All fans parameters (Mechanical and Electrical) are noted	-	Y/N	
		C5	Any deviation in parameters recorded and resolved	-	Y/N	
		C6	PLC panels readings and checked and recorded	-	Y/N	
		C7	Fir dampers oopeartion and its interface is checked & recorded	-	Y/N	
		C8	Interface with fire protection is checked manually as well as in AUTO mode	-	Y/N	
		C9	Scenarios as per approved logics are created and verified	-	Y/N	
		C10	The readings are cross chekced with approved CFD report and deviations are recorded	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.9 (Normative)
Kitchen Ventilation System

1.0 Kitchen ventilation system comprises of exhaust fan and hood with filters, ducting and necessary controls and sensors.

2.0 The kitchen ventilation system will have single or multiple systems, return or exhaust air fans connected with or without ducting. These are factory made and tested and accepted before it reaches site.

3.0 Site work involves installation of fans with proper isolation material, kitchen hood, ducting, mechanical, electrical work, sensors, controls and BMS connectivity.

4.0 Sample check lists are given in attachments for Delivery (HB-9D), Installation (HB-9C), and operation (HB-9S).

Table HB.9:
Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Kitchen Ventilation System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	**HB-9D**	**A**	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Fan Type	-		
		A5	Capacity	m^3/s (cfm)		
		A6	Static Pressure	mm of water		
		A7	Motor power/speed	kW; rpm		
		A8	Voltage/Phase/Frequency	V/-/Hz		
		B	**PHYSICAL CHECKS**	-		
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Air openings sealed	-	Y/N	
		B4	Installation manual provided	-	Y/N	
		B5	Test/warranty certificate provided	-	Y/N	
		B6	Unit tags affixed	-	Y/N	
		B7	Grease Filter installed and clean.	-		
2	**HB-9C**	**A**	**EXHAUST FAN**			
		A1	Unit adequately supported	-	Y/N	
		A2	Adequate service clearances available for maintenance	-	Y/N	
		A3	Vibration isolators OK	-	Y/N	
		A4	Shipping bolts removed	-	Y/N	
		A5	Fan belts are in order and tight	-		
		A6	Back draft damper installed and correct	-		
		A7	Drive guard in place	-		
		A8	Unit label visible	-	Y/N	
		B	**DUCTING**			
		B1	Dampers/sensors accessible	-		
		B2	Vibration isolators OK	-		
		B3	Ductwork is adequately supported	-	Y/N	
		B4	Dampers open/close properly	-	Y/N	
		B5	Ducting internally clean	-	Y/N	
		B6	Testing locations available	-	Y/N	
		C	**ELECTRICAL**			
		C1	Isolator in accessible location	-	Y/N	
		C2	Direction of motor rotation correct	-	Y/N	
		C3	Electrical connections are tight	-	Y/N	
		C4	Earthing adequate	-	Y/N	
		C5	Starter/VFD installed	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HB-9C contd...	**D**	**INSTRUMENTATION**			
		D1	Control panel accessible	-	Y/N	
		D2	Sensors correctly installed	-	Y/N	
		D3	Damper actuators installed	-	Y/N	
		D4	Electrical protections correctly installed	-	Y/N	
3	**HB-9S**	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Fan belts correct and in good condition	-	Y/N	
		A3	Canvas connection proper	-	Y/N	
		A4	Sensors correctly installed	-	Y/N	
		A5	Dampers fully open	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	Power available for commissioning	-	Y/N	
		B3	BMS Connectivity correctly established	-	Y/N	
		C	**START UP/ TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Duct work balancing done	-	Y/N	
		C3	Air flow/pressure measured	-	Y/N	
		C4	Fan operating point marked in fan curve	-	Y/N	
		C5	Supply air quantity correct as per design	-	Y/N	
		C6	No unusual noise or vibration	-	Y/N	
		C7	Calibrated instruments used	-	Y/N	
		C8	VCD Positions marked	-	Y/N	
		C9	Fan motor full load current in limits	-	Y/N	
		C10	Flow rates in ducts within allowable tolerance.	-	Y/N	
		C11	Measure fan speed and compare with design	-	Y/N	
		C12	Check and confirm proper function of control algorithms in BMS	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.10 (Normative)
Exhaust System

1.0 The Exhaust system comprises of, supply and exhaust fans, controls and control panel and BMS connectivity. Exhaust fans may or may not have duct connections based on the design of layout.

2.0 The fans factory made and tested and accepted before it reaches site.

3.0 Site work involves usually installation of fans with proper vibration isolation system ducting and fire dampers whereever required, mechanical, cabling, electrical and control system with BMS connectivity.

4.0 Sample check lists are given in attachments for Delivery (HB-10), Start up (HB-10C), and operation (HB-10S).

Table HB.10: Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Exhaust System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	**HB-10D**	**A**	**SYSTEM CHECKS**			
		A1	Supply and exhaust fans Installed as per approved drawing	-	Y/N	
		A2	Enough access provided for maintenance for all fans	-	Y/N	
		A3	No clash of fans with other services, civil works, walls etc	-	Y/N	
		A4	Starter panels installed as per approved drawngs	-	Y/N	
		A5	Cables, cables trays, termination done as per approved SLD, shop drawings	-	Y/N	
		A6	Duct works are done as per approved shop drawings	-	Y/N	
		A7	Fire dampers if required are installed as per approved drawings	-	Y/N	
		A8	Access doors are provided in exhaust duc work	-	Y/N	
		A9	Vibration Isolator for supply and exhaust fans installed as per approved specs	-	Y/N	
		A10	Tagging of equipments is done	-	Y/N	
		A11	Supports for all fans are as per approved drawings	-	Y/N	
		A12	Equipment clean and free of damage	-	Y/N	
		A13	Equipments are electrically connected with proper cable size and earthing	-	Y/N	
		A14	As built drawings available	-	Y/N	
		A16	All equipments details are taken and recorded	-	Y/N	
2	**HB-10C**	**B**	**START UP**			
		B1	Electrical mains are charged and checked	-	Y/N	
		B2	Electrical Paramaters are checked for all equipments	-	Y/N	
		B3	OLR settings done as per limit	-	Y/N	
		B4	No unusal noise or vibration noticed during startup of fans	-	Y/N	
		B5	Condition of fliters checked	-		
		B6	Air paths are clear and there is no blockage	-		
3	**HB-10S**	**C**	**OPERATION**			
		C1	All pre-commissioning and start up procedures are completed	-	Y/N	
		C2	Calibrated instruments are used	-	Y/N	
		C3	All the settings are done and recorded	-	Y/N	
		C4	All fans parameters (Mechanical and Electrical) are noted	-	Y/N	
		C5	Fir dampers oopeartion and its interface is checked and recorded	-	Y/N	
		C6	Any deviation in parameters recorded and resolved	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.11 (Normative)
Pressurisation System

1.0 The pressurization system will have single or multiple fans, connected with ducting dampers & actuators, motors and controls. The fans are factory made and tested and accepted before it reaches site.

2.0 Site work involves usually installation of fans with vibration isolation pads, ducting with dampers & damper actuators, Starter / VFD, mechanical, electrical panel, cabling, control system and BMS connectivity

3.0 Sample check lists are given in attachments for Delivery (HB -11D), Installation (HB-11C) Start Up (HB-11S)

Table HB.11:
Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Pressurisation System

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	**HB-11D**	**A**	**MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No	-		
		A3	Unit Serial No	-		
		A4	Fan Type	-		
		A5	Capacity	m^3/s (cfm)		
		A6	Static Pressure	mm of water		
		A7	Motor power/speed	kW; rpm		
		A8	Voltage/Phase/Frequency	V/-/Hz		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B3	Air openings sealed	-	Y/N	
		B4	Installation manual provided	-	Y/N	
		B5	Test/warranty certificate provided	-	Y/N	
		B6	Unit tags affixed	-	Y/N	
2	**HB-11C**	**A**	**PRESSURISATION FAN**			
		A1	Unit adequately supported	-	Y/N	
		A2	Adequate service clearences available for maintenance	-	Y/N	
		A3	Vibration isolators OK	-	Y/N	
		A4	Shipping bolts removed	-	Y/N	
		A5	Fan belts are in order and tight	-		
		A6	Dampers installed properly	-		
		A7	Drive guard in place	-		
		A8	Unit label visible	-	Y/N	
		B	**DUCTING (IF PROVIDED)**			
		B1	Dampers/sensors accessible	-		
		B3	Ductwork is adequately supported	-	Y/N	
		B4	Dampers open/close properly	-	Y/N	
		B5	Ducting internally clean	-	Y/N	
		B6	Testing locations available	-	Y/N	
		C	**ELECTRICAL**			
		C1	Isolator in accessible location	-	Y/N	
		C2	Direction of motor rotation correct	-	Y/N	
		C3	Electrical connections are tight	-	Y/N	
		C4	Eearthing adequate	-	Y/N	
		C5	Stater/VFD installed	-	Y/N	

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
	HB-11C contd...	**D**	**INSTRUMENTATION**			
		D1	Control panel accessible	-	Y/N	
		D2	Sensors correctly installed	-	Y/N	
		D3	Damper actuators installed	-	Y/N	
		D4	Electrical protections correctly installed	-	Y/N	
2	**HB-11S**	**A**	**MECHANICAL STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Fan belts correct and in good condition	-	Y/N	
		A3	Canvas connection proper	-	Y/N	
		A4	Sensors correctly installed	-	Y/N	
		A5	Dampers fully open	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	Power available for commissioning	-	Y/N	
		B3	BMS Connectivity correcly established	-	Y/N	
		C	**START UP/ TAB**			
		C1	Precommissioning checks complete	-	Y/N	
		C2	Electrical tests complete and verified	-	Y/N	
		C3	Air flow/pressure measured	-	Y/N	
		C4	Fan operating point marked in fan curve	-	Y/N	
		C5	Supply air quantity correct as per design	-	Y/N	
		C6	No unusual noise or vibration	-	Y/N	
		C7	Calibrated insruments used	-	Y/N	
		C8	VCD Positions marked	-	Y/N	
		C9	Fan motor full load current in limits	-	Y/N	
		C10	Measure and record pressure difference across doors (doors closed/ open as per design	-	Y/N	
		C11	Measure fan speed and compare with design	-	Y/N	
		C12	Check and confirm proper function of control algorithms in BMS	-	Y/N	

For all "NO" responses, please fill in details in Remarks column

ANNEXURE HB.12 (Normative)
Control System (HVAC)

1.0 Functioning of HVAC equipment mainly depends on the control system that is provided which regulates the operational parameters and controlling and maintaining the desired output, energy consumed and health of various components / equipment with the help of sensing devices.

2.0 Building automation is the centralized control of a building's heating, ventilation and air conditioning, lighting and other systems through a building management system or building automation system. Modern BAS can also control indoor and outdoor lighting as well as security, fire alarms, and basically everything else that is electrical in the building.

3.0 The building automation system helps to improve occupant comfort, efficient operation of building systems, reduction in energy consumption and operating costs, and improved life cycle of utilities often referred to as intelligent building or smart building.

4.0 Central controllers and most terminal unit controllers are programmable. The program features include time schedules, setpoints, controllers, logic, timers, trend logs, and alarms. The unit controllers typically have analog and digital inputs that allow measurement of the variable (temperature, humidity, or pressure) and analog and digital outputs for control of the transport medium (hot/cold water and/ or steam).

5.0 Various types of control system are:

a) ***Chiller:*** Capacity modulation/ control, temperature of chiller outlet , chilled water pump speed, condenser water pump speed, water quantity delivered by individual pumps, cooling tower fan motor, and heat rejection by cooling tower, pump motor speed regulation, compressor capacity modulation etc.

b) ***AHU:*** Chilled water flow though the coil, supply and return air temperature, air quantity delivered by the AHU and back to the AHU, air quantity supplied to various rooms

c) ***Mechanical:*** Noise, vibration, pressure readings, temperature readings, flow of water / liquid and air

d) ***Electrical:*** High / low Voltage, current, continuity, power factor.

Table HB.12:
Delivery, Installation, Startup and Operation Checklist for - Equipment/System - Controls and BMS Systems (HVAC)

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	**HB-12D**	**A**	**SENSORS AND ACTUATORS MODEL VERIFICATION**			
		A1	Manufacturer	-		
		A2	Model No.	-		
		A3	Range if mentioned	-		
		B	**PHYSICAL CHECKS**			
		B1	Unit free from Physical damage	-	Y/N	
		B2	All components present	-	Y/N	
		B5	Installation manual provided	-	Y/N	
		B6	Test/warranty certificate provided	-	Y/N	
		B7	Unit tags affixed	-	Y/N	
2	**HB-12C**	**A**	**CONTROL COMPONENTS**			
		A1	SENSORS / ACT SECURED	-	Y/N	
		A2	Adequate service clearances available	-	Y/N	
		A3	All components accessible for maintenance	-	Y/N	
		A7	Unit label visible	-	Y/N	
		B	**SENSORS AND ACTUATORS**			
		B9	tags TO CONTRLR# & CHANNEL installed	-	Y/N	
		C	**ELECTRICAL TO SENSOR / ACTUATOR**			
		C1	Supply (say 24V) is protected	-	Y/N	
		C3	Electrical connections are tight	-	Y/N	
		C4	Earthing if applicable, adequate	-	Y/N	
3	**HB-12S**	**A**	**INITAL STANDALONE STARTUP**			
		A1	Manufacturers checklist completed	-	Y/N	
		A2	Non Communication to Sensors checked	-	Y/N	
		A3	All Actuators working with controller	-		
		A4	All External Relays operating	-	Y/N	
		A6	No unusual error messages	-	Y/N	
		B	**CONTROLS STARTUP**			
		B1	Control sequence verified	-	Y/N	
		B2	Power available for commissioning	-	Y/N	
		B3	BMS Connectivity correcly established	-	Y/N	
		B4	alarms operational	-		
		B5	VFD if attached Operational (if applcbl)	-		
		C	**START UP / TAB**			
		C1	Precommissioning checks complete	-		
		C2	Check and confirm proper function of control algorithms in BMS	-		
		C10	Note PB, IAT and AT for each P&I	-		

S. No.	Appendix No.	Item No.	Description	Unit	Response	Remarks
1	HA-12 SYS	A	**PROGRAM AND FRONT-END HARDWARE**			
		A1	Manufacturer	-		
		A2	Model No.	-		
		A3	Software License	-		
		B	**PHYSICAL CHECKS**			
		B1	Computer and Display	-		
		B2	All componenets present	-		
		B5	Software manual provided	-		
		B6	Test / warranty certificate provided	-		
		B7	Unit tags affixed	-		
2	HA-12	A	**BMS AND CONTROLLERS HARDWARE**			
		A1	Each Item tagged	-		
		A2	Adequate service clearances available	-		
		A3	All componenets accessible for maintenance	-		
		A7	Unit label visible	-		
		B	**HAND-AUTO-OFF SWITCHES**			
		B1	functioning and set	-		
		C	**CONTROLLERS AND FRONT END ELECTRICAL**			
		C1	Supply (say 24V) is protected	-		
		C3	Emergency Supply if reqd working	-		
		C4	Earthing IF APPLCBL adequate	-		
3			Alarm settings on digital inputs	-		
			Alarm settings on analog inputs	-		
			History collection points	-		
			History intervals	-		
			Runtime points and alarm	-		
			Power accumulation points	-		
			Setpoints	-		
			Advisory messages	-		
			Password levels	-		
			Backups	-		
			A) Each controller configuration	-		
			B) Top-end configuration	-		
			C) All graphic displays	-		
			D) Charts and graphs	-		
			E) Dashboard if any	-		

For all "NO" responses, please fill in details in Remarks column

Annexure I (Informative)
Resolution of Concerns and Non-conformance

1.0 Any concerns and non-conformance observed during the installation and inspection phase shall be communicated to the project team for resolution.

2.0 The concerns and non-conformance shall be documented in a log format and shall be updated periodically. These are best presented in a log format and the log needs to be updated periodically.

3.0 The following items may be included as a table in the log book.

a) Serial number

b) Date

c) Brief description of issue

d) Name of person raising the issue

e) Probable cause of the issue

f) Impact the issue may have on construction or operation

g) Suggested resolution

h) Person to resolve the issue

i) Brief description of action

j) Issue closure date

k) Issue closure authorised (Name).

Annexure J (Informative)
Systems Manual

1.0 Systems manual is the collection of the following:

a) Final OPR

b) Basis of Design

c) Commissioning Plan

d) Commissioning Process report

e) Equipment and System manuals

f) Operation and maintenance manuals

g) Schematic drawings

h) Information on training

i) Test - Results and commissioning report.

j) As built drawing

k) O&M manual

2.0 Systems manual shall be put together by the commissioning team.

3.0 Systems manual is meant to provide information to the operating and maintenance staff of the building regarding design and construction and to provide comprehensively and in one document all relevant information.

4.0 Systems manual will be helpful for ongoing commissioning and for system performance improvement.

Annexure K (Informative)
Training

1.0 OPR shall address the training requirements such as training of operating staff, services that may be outsourced, scope of work of the facility management team etc. Warranty and service agreements for major equipment and system will have a bearing on the training plans.

2.0 Training needs shall depend on the nature, type and complexity of systems installed and the skill levels of the staff available to operate the systems.

3.0 Training requirements of own staff and any contractors workforce needs to be separately identified and catered for

4.0 Training may include the following:

- Purpose of the systems
- O & M Manuals
- Control drawings and schematics.
- Start up and operation of building.
- Interaction with other systems
- Optimization for energy conservation.
- Health and safety.
- Special maintenance and replacement.
- Occupant interaction.
- System response to different operating conditions.
- Emergency situations.

5.0 All training may be stored in audio video format for future reference and for facilitating subsequent training services.

Annexure L (Informative)
Commissioning Report – Final

1.0 Commissioning report – final shall contain all relevant documentation relating to the process of commissioning.

2.0 Any deviation from OPR which is accepted by the owner needs to be listed.

3.0 All construction checklists will form part of this.

4.0 The issue log and resolution details will be included.

5.0 Test procedure and data summarize.

6.0 Copies of all progress reports generated during commissioning process.

7.0 For any deferred tests, the required conditions and estimated schedule needs to be mentioned.

8.0 A preliminary report may be submitted to the owner for review and final report may include owner's comments.

9.0 The report should include a warranty review and states.

THIS PAGE IS INTENTIONALLY LEFT BLANK

THIS PAGE IS INTENTIONALLY LEFT BLANK

About ISHRAE

The Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE), was founded in 1981 at New Delhi by a group of eminent HVAC&R professionals. ISHRAE today has over 30,000 HVAC & R professionals and Student-members. ISHRAE operates from 44 Chapters and Sub-chapters spread across India with its Head Quarters in Delhi. ISHRAE is led by a team of elected officers, who are members of the Society, working on a voluntary basis, and collectively called the Board of Governors.

ISHRAE's Objectives:

- Advancement of the Arts and Sciences of Heating, Ventilation, Air Conditioning and Refrigeration Engineering and Related Services.
- Continuing education of Members and other interested persons in the said sciences through Lectures, Workshops, Product Presentations, Publications and Expositions.
- Rendition of career guidance and financial assistance to students of the said sciences.
- Encouragement of scientific research.

ISHRAE®

1103-1104, 11th Floor,
Chiranjiv Tower, 43, Nehru Place,
New Delhi - 110 019, India.

011-4163 5655
info@ishraehq.in

www.ishrae.in