DRAFT STANDARD FOR AIR HANDLING UNITS – GENERAL REQUIREMENTS, PERFORMANCE TESTING AND RATING

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Foreword

This DRAFT standard is an initiative of ISHRAE (Indian Society of Heating Refrigerating and Air conditioning Engineers) and RAMA (Refrigeration and Air conditioning Manufacturers Association) to introduce standards for testing of equipment in the field of HVAC&R applicable for Indian industry & environment. This work of preparing DRAFT standard is carried out through a joint technical committee set up by ISHRAE and RAMA. The Technical committee comprised of representatives from Consultants, user Industry, manufacturers, ~~and~~ International organizations, as well as the governmental and non-governmental bodies in liaison with ISHRAE-RAMA standards core committee. ISHRAE-RAMA standards core committee collaborates and proposes to Bureau of Indian Standards (BIS) and / or Bureau of Energy Efficiency (BEE) on matters of performance standardization.

While drafting this standard considerable amount of support has been drawn from the following standards.

ISO 9614 – 1	Acoustics - Determination of Sound Power Levels of Noise Sources Using Sound Intensity - Part 1: Measurement at Discrete Points
ISO 9614 – 2	Acoustics - Determination of Sound Power Levels of Noise Sources Using Sound Intensity - Part 2: Measurement by Scanning
ISO 7235	Acoustics — Laboratory measurement procedures for ducted silencers and air-terminal units — Insertion loss, flow noise and total pressure loss
ISO 5221,	Air distribution and air diffusion — Rules to methods of measuring air flow rate in an air handling duct
EN 1886	Ventilation for buildings – Air handling units – Mechanical performance
EN 13053	Ventilation for buildings - Air handling units - Rating and performance for units, components and sections
EN 308	Heat exchangers — Test procedures for establishing performance of air to air and flue gases heat recovery devices
EN 779	Particulate air filters for general ventilation — Determination of the filtration performance
EN 1216	Heat exchangers — Forced circulation air-cooling and air-heating coils — Test procedures for establishing the performance
AHRI 1351	Mechanical Performance Rating of Central Station Air-handling Unit Casings
AHRI 410	Forced-Circulation Air-Cooling and Air-Heating Coils
AHRI 1061	Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation Equipment
AHRI 431	Performance Rating of Central Station Air-handling Unit Supply Fans
UL 1995	Standard for safety of heating and cooling equipment

This standard has been developed with adherence to Quality Council of India's SDO recognition program requirement and as per ISO Guide 59 guidelines to a large extent.

This DRAFT standard after wide circulation amongst the member bodies of ISHRAE-RAMA and industry at large shall be published as ISHRAE – RAMA standard for India.

1.0 Scope

a) This standard covers the mechanical as well as thermal performance, general requirements and the method of testing to measure the performance of factory-made air handling units,

b) Requirements, recommendations, classification, and testing of specific components and sections of air handling units designed for individual operation and combined operation

c) Both to standardized designs, which may be in a range of sizes having common construction concepts, and also to custom-design

d) With and without heat recovery devices

e) Units producing ventilation air including Dedicated Outdoor Air System (DOAS)

f) to work with rated voltage up to and including 250 V, 50 Hz AC, single phase and up to and including 415 V, 50 Hz AC for three phase input power supply

1.1 This standard does not cover

a) Fan coil units

b) Control system

c) Application in explosive environment

d) Health and hygiene application

e) Site assembled AHUs

Note: This standard recommends factory built AHUs only, considering the conformance to mechanical performance, thermal performance and general safety requirements.

2.0 REFERENCES

The following Standards contain provisions which through reference in this text, constitute provisions of the standards. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the Standards indicated below:

IS Number	*Title*
101 (Part 6 : Sec 1)	Methods of sampling and test for paints, varnishes and related products – Part 6 : Durability tests – Section 1 : Resistance to humidity under conditions of condensation
IS 101 (Part 6 : Sec 5)	Method of sampling and test for paints, varnishes and related products Part 6 Durability test on Paint films section 5 Accelerated weathering test
IS 101 (Part 7 : Sec 1)	Methods of Sampling and Test for Paints, Varnishes and Related Products – Part 7 : Environmental Tests on Paint Films – Section 1 : Resistance to water
IS 101 (Part 7 : Sec 2)	Methods of sampling and test for paints, varnishes and related products part 7 Environmental tests on paint films Sec 2 Resistance to liquids
IS 101 (Part 7 : Sec 3)	Methods of sampling and test for paints, varnishes and related products Part 7 Environmental tests on paint films Sec 3 Resistance to heat
IS 196	Atmospheric conditions for testing
IS 325	Three phase induction motors
IS 7613	Method of testing panel type air filters for air-conditioning and ventilation purposes

IS 2360	Voltage bands for electrical installations including preferred voltages and frequency
IS 3615	Glossary Of Terms Used In Refrigeration And Air Conditioning
IS/ISO 5149 – 1	Refrigerating systems and heat pumps – Safety and environmental requirements – Part 1: Definitions, classification and selection criteria
IS/ISO 5149 – 2	Refrigerating systems and heat pumps – Safety and environmental requirements – Part 2: Design, construction, testing, marking and documentation
IS/ISO 5149 – 3	Refrigerating systems and heat pumps – Safety and environmental requirements – Part 3: Installation site.
IS/ISO 5149 – 4	Refrigerating systems and heat pumps – Safety and environmental requirements – Part 4: Operation, maintenance, repair and recovery
IS / ISO 817	Organic refrigerants – Number designation
ISO 3741	Acoustics — Determination of sound power levels of noise sources using sound pressure — Precision methods for reverberation rooms
ISO 3744	Acoustics -- Determination of sound power levels and sound energy levels of noise sources using sound pressure -- Engineering methods for an essentially free field over a reflecting plane

AHRI 1351	Mechanical Performance Rating of Central Station Air-handling Unit Casings
AHRI 410	Forced-Circulation Air-Cooling and Air-Heating Coils
AHRI 1061	Performance Rating of Air-to-Air Exchangers for Energy Recovery Ventilation Equipment
AHRI 431	Performance Rating of Central Station Air-handling Unit Supply Fans

3.0 Terms and definitions

For the purpos~~es~~ of this standard, the terms given in IS 3615 – "*Glossary of terms used in Refrigeration and Air conditioning*", and in addition following definitions listed below shall apply.

3.1 Standard air

Dry air at 20 °C and at a standard barometric pressure of 101.325 kPa, having a mass density of 1.204 kg/m^3

3.2 Air handling unit

Is an encased assembly of fan or fans with other necessary equipments to perform any one or more functions of circulating, filtering, cooling, heating, heat recovery, dehumidifying, humidifying and mixing air.

3.2.1 Air handling unit – Real unit

Is a factory built enclosed unit serving as a prime mover of air conditioning installation where outdoor air, recirculated air or extracted air is treated or ventilation, consisting of a fan section with a filter section and heat exchanger connected. In addition the unit may consist of an inlet section (with one or more louvers and dampers), ~~a~~ mixing section, heat recovery section, one or more cooling and heating coils, humidifiers, sound attenuators and additional equipment such as controls, measuring sections etc.

3.2.2 Air handling unit – Model unit

Is a unit specially built for general testing and measurement for general classification, comparison or categorization of series or individual casings (as defined in clause 6.0).

3.3 Section of air handling unit

The functional element of an air handling unit consisting of one or more components in a single casing

3.4 Casing of an air handling unit

Is the enclosure of unit within which the components to perform any of the functions of circulating, filtering, cooling, heating, heat recovery, dehumidifying, humidifying ~~and~~ or mixing air.

3.5 Different Functions of air handling unit

3.5.1 Cooling

Removal of sensible heat and / or latent heat from air. Can we add conditioned or unconditioned

3.5.2 Heating

Adding heat from a body to air.

3.5.3 Dehumidification

Controlled removal of water vapor from air.

3.5.4 Humidification

Controlled addition of water vapor in to air.

3.5.5 Filtration

Removal of particulate matter from air.

3.5.6 Heat recovery

Recovering heat from one airstream and transferring it to another ~~into another~~, either directly or using an intermediary heat transfer medium.

3.5.7 Mixing air

Controlled way of mixing outdoor air ~~flow~~ and the recirculation air ~~flow~~.

3.6 Casing surface area

The total area of all the exterior surfaces ~~area~~ of the AHU casing (calculated from the nominal external dimensions), excluding the area of the unit inlet and outlet airflow openings. Casing surface area is expressed in m^2

Note: The area of components which are not the part of the unit casing shall be excluded. These exclusions can include, both are not limited to: casing attachments such as base rails and/or ceiling mount structures, externally mounted devices such as dampers, louvers, hoods, and the area of the block-off plates on openings of separately tested unit sections

3.7 Airflow rate

Volume of air passing through a plane of unit area in unit time

3.7.1 Air leakage rate

Leakage of the air from air handling unit, at maximum rated air pressure

The air leaking through the casing of an air handling unit per square meters of casing surface area, $L. s^{-1}. m^{-2}$. It is the ratio of the total air leaking through the casing measured at the maximum rated pressure to the casing Surface Area (per 1 m^2).

Note: Where a casing at design conditions has portions of the AHU operating in both positive and negative pressures, the Air Leakage Rate shall be determined separately for casing sections applied under positive pressure from those applied under negative pressure.

3.7.2 By-pass leakage

Uncontrolled and non-desirable mixing of untreated air into the treated air between the components within the AHU casing. It is measured as ratio of the diverted air flow to the total air flow (sum of the main air flow and the diverted air flow)

3.8 Casing deflection

The deformation of the external surface of the casing, measured perpendicular to reference plane to the maximum point of deflection of the casing surface, when the unit is subjected to a positive or negative internal air pressure. Casing deflection is expressed in mm.

3.9 Thermal bridging factor

Ratio of ~~between~~ the lowest temperature difference between any point on the external surface and the mean internal air temperature to ~~and~~ the mean air to air temperature difference.

3.10 Thermal transmittance

Is the heat flow per unit ~~of~~ area ~~and~~ per unit temperature difference expressed as ($W.m^{-2}. K^{-1}$), determined at steady state temperature difference of 20 K. The classification of Thermal transmittance is defined in Table 9.

Note: The casing surface area shall be used for the purposes of calculating the U value.

3.11 Published rating

A statement of the assigned values of the ~~those~~ performance characteristics, under stated Rating Conditions, by which a unit may be chosen to fit for its application. For Casing Air Leakage Rate and Casing Deflection, these values apply to all units of similar casing construction and type (identification) produced by the same manufacturer. For thermal performance ratings, these values only apply to the casing construction of the Standard Rating Unit. The term Published Rating includes the rating of all performance characteristics shown on the unit or published in specifications, advertising or other literature controlled by the manufacturer, at stated Rating Conditions.

3.12 Casing mechanical strength class

The casing mechanical strength class designation shall be defined by the casing deflection at the corresponding test pressure specified in Table 4

3.13 Casing air leakage class

The casing air leakage class designation shall be defined by the maximum leakage rate at the test pressure as specified in Table 5 and Table 6

4.0 Construction

4.1 The unit shall at least have ~~minimum of~~ fan, filter and heat exchanger enclosed in a thermally insulation casing with sufficient mechanical strength to meet the requirements as specified by this standard. The enclosure casing shall be constructed of corrosion resistant material or coated with corrosion resistance paint conforming to relevant Indian standard. In addition the unit may consist of an inlet section with one or more louvers and dampers, a mixing section, heat recovery section, one or more cooling and heating coils, humidifiers, sound attenuators and additional equipment such as controls, measuring sections etc.

4.2 The unit shall be provided with means for mounting in the intended manner. Any special fitting~~s~~ necessary for intended mounting shall be supplied with the unit. A free-standing, floor-supported unit need not be provided with mounting means. The unit shall be supplied with instruction for transportation, site preparation for installation, installation manual and commissioning manual. The instructions shall ~~should~~ provide specification regarding the space required for maintenance, mounting and supports etc., with drawings and/or technical data. The drawing shall also include water connections, drain connection, electrical supply connection and control settings. The unit shall ~~should~~ be easy to connect to water, electrical and other connections and easy to disconnect for service or repair as needed.

4.3 Air handling unit ~~construction~~ shall be provided with suitable provision for lifting through devices such as crane eyes, ~~wood or~~ pallets and for transportation by crane or forklift.

4.4 The safety devices for protection against damage to components ~~risk~~, like fans, vibration isolator springs, during transportation shall be identified clearly by label stating that such devices shall be removed prior to installation.

4.5 An electrical part within the outer cabinet need not be individually enclosed if the assembly complies with all of the following:

i. The construction and location of the part is such that there is no possibility of emission of flame or molten metal through openings in the outer cabinet, or malfunction of the component does not result in a risk of fire.
ii. The part is not in the vicinity of flammable material other than electrical insulation.
iii. Sheet metal thickness of the enclosure casing is enough to prevent from spreading of fire.
iv. The electrical supply part is not located in an air-handling section.
v. The electrical current carrying part is not accessible to unintended contact by personnel.

4.6 Electrical connection diagram shall be provided with clear instructions for field wiring of AHUs supplied with pre-wired electrical starter and controller panel.

4.7 All the labels shall be clearly legible and durable. Compliance is checked by inspection and by rubbing the marking by hand for 15 s with a piece of cloth soaked with water and again for 15 s with a piece of cloth soaked with petroleum spirit. After all the tests of this standard, the marking shall be clearly legible. It shall not be easily possible to remove marking plates nor shall they show curling.

Note:

a) In considering the durability of the marking, the effect of normal use is taken into account.
b) The petroleum spirit to be used for the test is aliphatic solvent hexane having a maximum aromatics content of 0.1 % by volume, a kauri-butanol value of 29, an initial boiling point of approximately 65 °C, a dry point of approximately 69 °C and a specific mass of approximately 0.66 kg/l.

4.8 For ~~all~~ parts (for example, controls, filters, oiling of bearings, adjustment of belts) required normal servicing or adjustment in the AHU in installed condition shall have sufficient and reasonable accessibility. Covers or access panels giving access to such parts that are required to be removed for routine maintenance shall not expose uninsulated hazardous voltage live parts.

4.9 The overcurrent protective device that can be replaced or reset by the user as required shall be accessible without removal of parts other than the service covers or panels.

4.10 The reset button or lever of manual resettable devices (for example, the operating handle of a circuit breaker, the reset button of a motor protector, the adjusting screw or knob of an adjustable temperature or pressure control) shall be accessible without the use of a tool, providing that the resetting of the device does not result in exposure to uninsulated live hazardous voltage parts or moving parts. Outdoor units shall be provided with suitable ingress protection.

4.11 A cover or door shall not depend solely upon screws or other similar means to hold it closed, but shall be provided with an automatic latch or the equivalent. A spring latch, a magnetic latch, a dimple, or any other mechanical arrangement that will hold the door in place and would require some effort on the user's part to open is considered to be acceptable for holding the door closed. An access door with interlocking mechanism, such as

i. Secures the door in the closed position when engaged;
ii. Must be engaged before any moving parts and hazardous voltage circuit can be energized; and
iii. Is located so that unintentional operation is unlikely during normal servicing.

The interlock that is required to reduce risk of electric shock or injury to persons shall withstand 1000 cycles with a load not less than that controlled in the equipment, and 5,000 cycles without a load.

4.12 The typical construction of the AHU can be as shown in figure 1, 2, 3 and 4

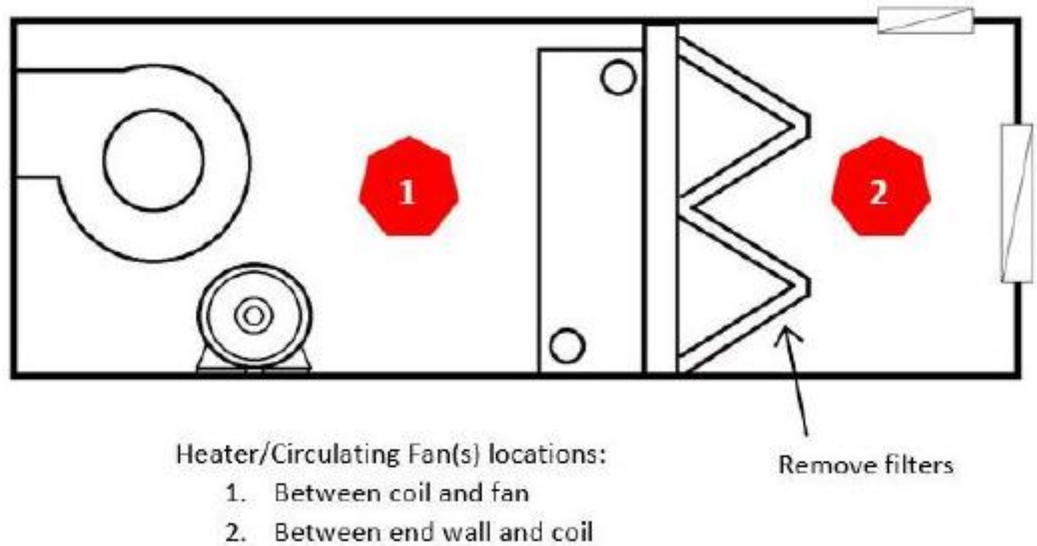


Figure 1: Air Handling Unit with no pressure change wall

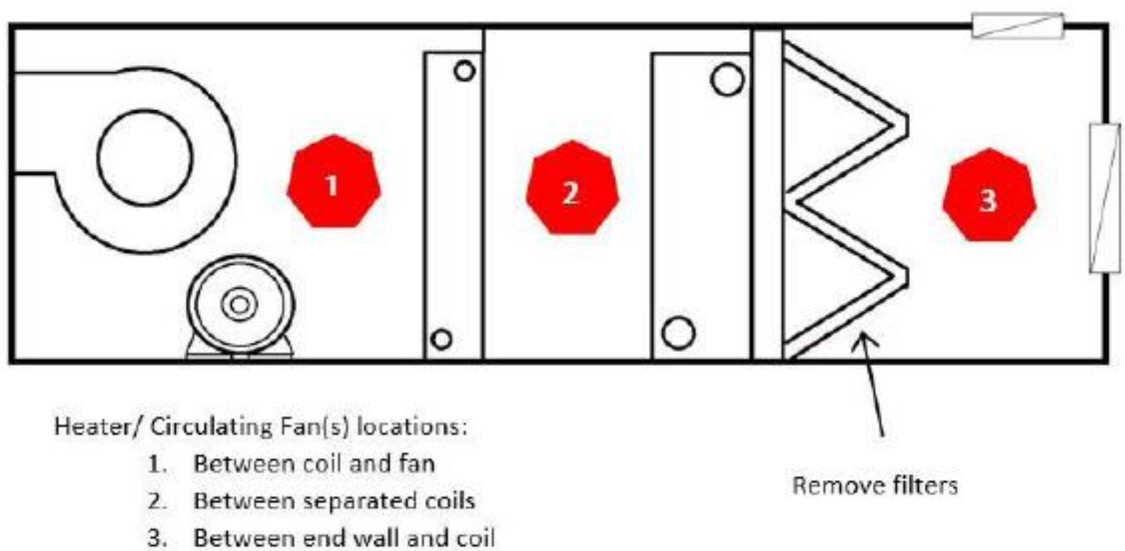


Figure 2: Air Handling Unit with no pressure change wall and separate coils

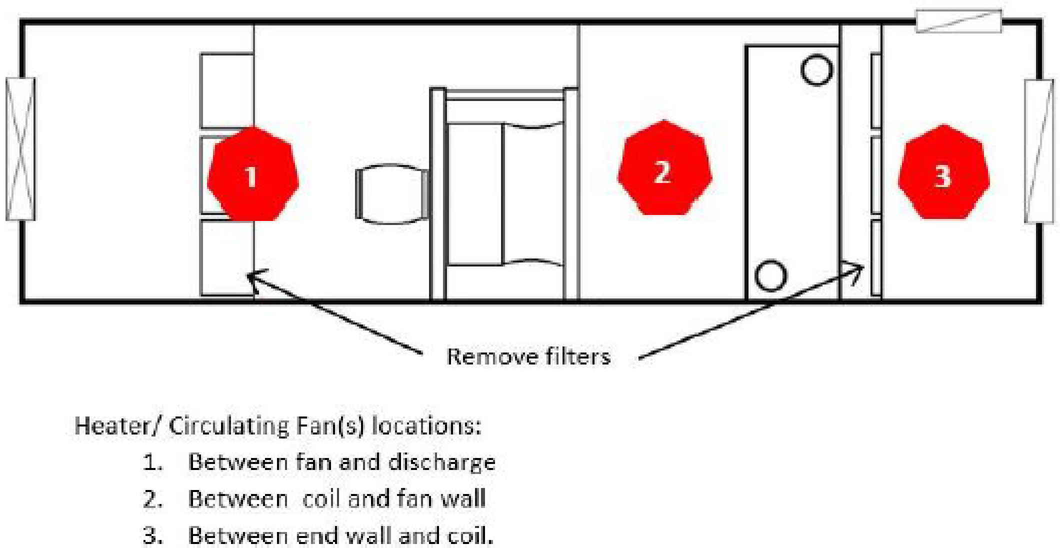


Figure 3: Air Handling Unit with pressure change wall

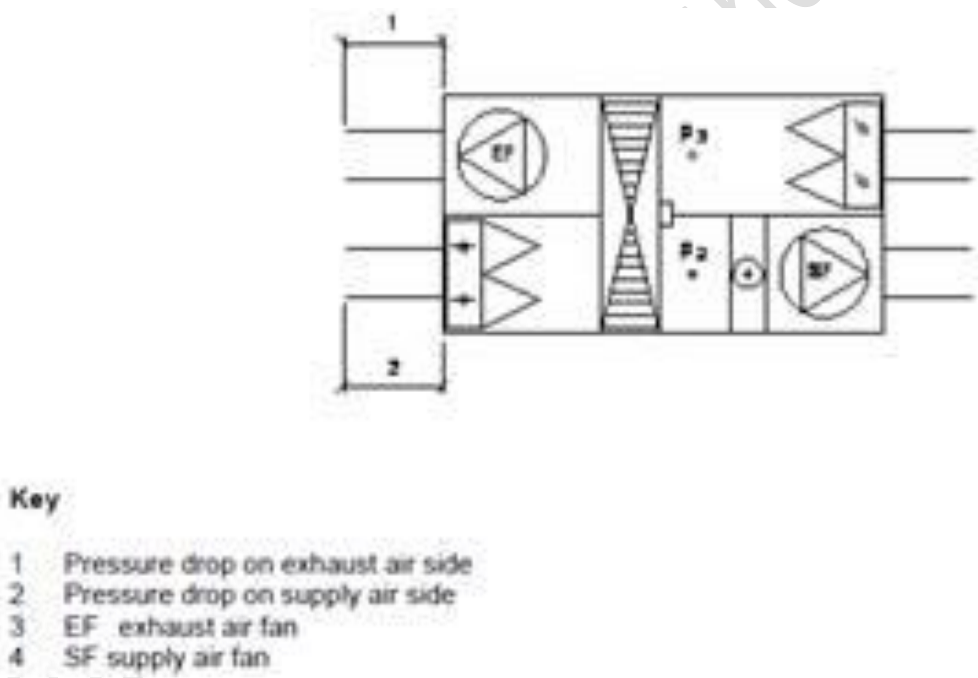


Figure 4: Air Handling Unit with heat recovery wheel

5.0 Symbols

Table 1:

Symbol	Description	Unit
qv_{nom}	Nominal air flow rate of the filter section	$L.\ s^{-1}$
Ql	Leakage rate	$L.m^{-2}.s^{-1}$
Ql_m	Measured leakage rate at the actual test pressure	$L.m^{-2}.s^{-1}$
qL	Sum of leakage through casing	L
qL_f	Sum of leakages through joints between filter cell, frames and casing	L
qv_a	Filter bypass leakage rate	$L.m^{-2}.s^{-1}$
qL_t	Total leakage	L
kb	Thermal bridging factor	--
k	Filter bypass leakage rate in percent of nominal volume flow rate	--
U	Thermal transmittance	$W.m^{-2}K^{-1}$
P_{el}	Electrical input to heaters and circulating fans	W
A	External surface area	m^2
ρ	Density of air	$kg.\ m^{-3}$
pa	Atmospheric pressure	Pa
pv	Partial pressure of water vapor in air	Pa
ta	Dry bulb temperature	℃
P_{tu}	External total pressure difference	Pa
A	External surface area	m^2

6.0 **Classification**

Classification of AHU shall be done based following parameters.

a) Mechanical strength of casing
b) Casing air leakage
c) Filter bypass leakage
d) Thermal performance of casing
e) Mechanical safety

The test for the classification parameters shall be done as per the test matrix in Table 2

Table 2: Test matrix for Model unit and Real unit

Test criteria	Unit type	
	Model unit (M)	Real unit (R)
Mechanical strength	General classification of casing construction	Particular classification of casing construction and individual evaluation
Air leakage		
Filter bypass leakage		
Thermal transmittance		--
Thermal bridging		--

7.0 Mechanical Strength of Casing:

7.1 General

The mechanical strength tests shall be conducted on the model unit for general classification and on the real unit for particular classification of casing and individual evaluation. The construction of model unit for testing of mechanical strength of casing shall be as per 7.1.1.

7.1.1 Construction of Model unit:

The model unit shall be manufactured from the type of design and method of assembly as used by the manufacturer in normal production. Every/ each design shall be manufactured separately. If more than one type of construction or assembly method is available, the construction adopted for each test shall be clearly stated by the manufacturer. The ~~assembly~~ manufacturing process and process controls (example: the torque applied to fixings), shall be in accordance with normal manufacturing procedures and standards for the product range. The enclosure shall be designed taking account of the following specifications:

a) Height and width shall have external dimensions of between 0.9 m and 1.4 m.
b) Total external surface area shall be between 10 m^2 and 30 m^2.

For the air handling unit under test, the enclosure shall reproduce an assembly of at least two sections of a unit joined in accordance with the normal methods of manufacturing.

The operating side of each section shall have at least one access door (with hinges and standard closures, but with no window), and shall include at least one fixed panel. Every/each construction detail of the real unit shall be included in the model box (e.g. doors, mullions, panels). Screws shall be tightened as in normal production.

A filter frame (without the filter medium) shall be installed while all measurements are taken, allowing filter bypass leakage to be measured. The filter frame shall be placed away from the section joints so that negative pressure impinges on the joint during the casing leakage test. This enables the effect of the joint on casing air leakage to be taken into account. If the test is executed/conducted without a filter frame, this is to be noted separately in the test report.

Weatherproof units shall not be covered (e.g. with a roof or roofing membrane) when the thermodynamic values are determined.

If an air handling unit enclosure is used, any internal fittings, such as filters or coils~~,~~ shall be removed, except for the filter holder. The assembly shall be supported by insulating blocks, at ~~with~~ the bottom or the base frame of the enclosure 0.3 m to 0.4 m~~m~~ above the floor of a draught-free room (air flow velocity less than 0.1 $m.s^{-1}$). The total area of the insulating blocks shall be not be greater than 5 % of the air handling unit base area. No radiant heat shall enter the test environment.

The following shall be mounted inside the enclosure:

a) One or more externally controllable electric heating elements;

b) One or more circulating fans with a total free air volume performance equivalent to 100 air changes per hour to 110 air changes per hour, allowing the internal air temperature difference across the measurement points ~~to~~ not to be greater than 2.0K. The test equipment assembly inside the unit shall not influence the heat transmission of the casing. Annex XX gives examples of these arrangements.

The enclosure shall be divided ~~equally lengthwise~~ into three equal measurement sections along the longest side.

16 temperature sensing ~~measuring~~ devices shall be installed inside the enclosure; one in each corner and at the corners of each section division, each 0.1 m from the side panels as shown in the figure 5.

All air temperature sensing ~~measuring~~ devices used inside and outside of the enclosure, shall be protected against thermal radiation. The accuracy of the air temperature measuring devices used shall be ± 0.1 K and the accuracy of the surface temperature measuring devices used shall be ± 0.2 K.

The external air temperature shall be measured at points 0.25 m from the center of the top, bottom and all four vertical sides of the enclosure.

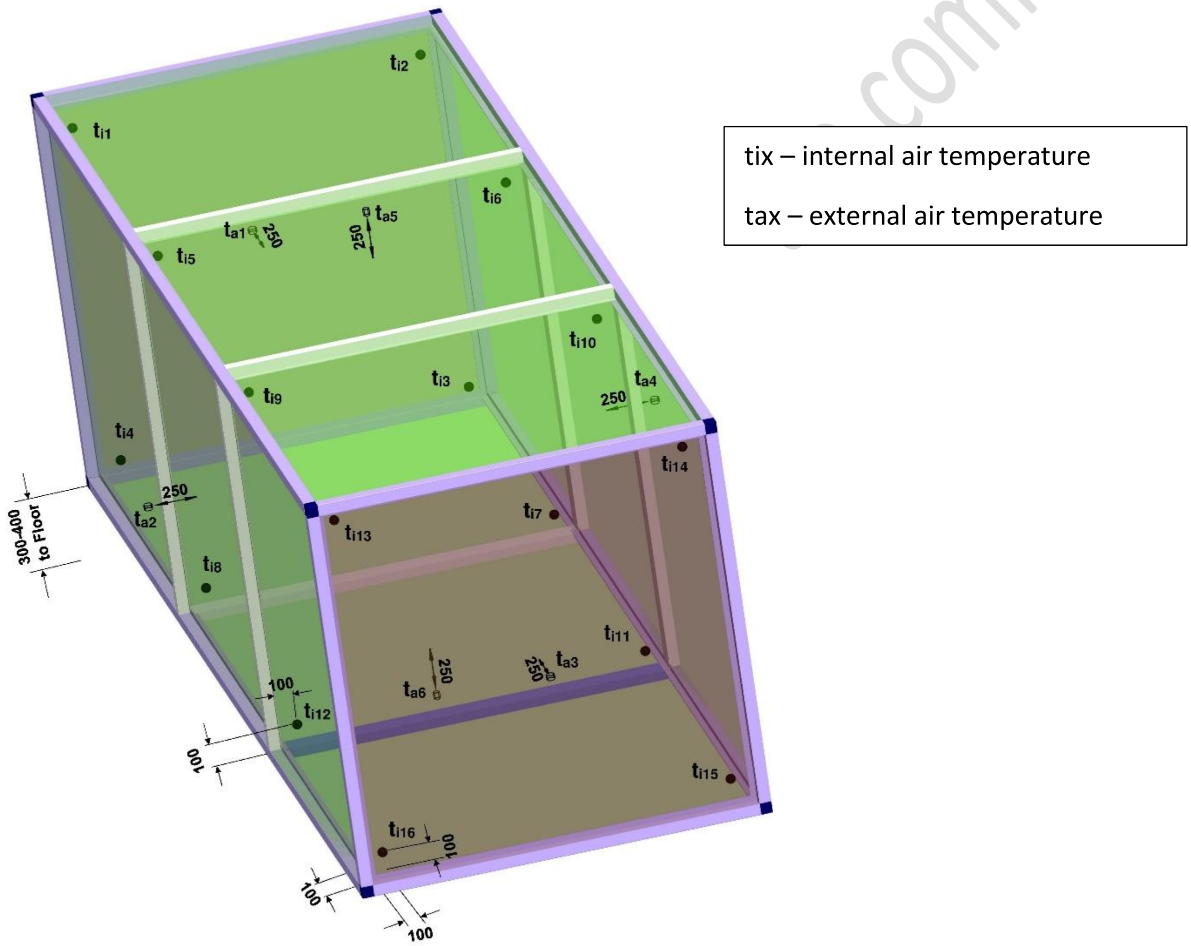


Figure 5: Test model preparation - Zoning and temperature sensing device installation (dimensions in millimetres)

7.1.2 Testing for Mechanical Strength of casing:

The test pressure as per table 3 shall be applied on the model unit or real unit.

Parts of the Real unit, which are running under positive pressure, shall be tested under positive pressure.

Parts of the Real unit, which are running under negative pressure, shall be tested under negative pressure.

Table 3: Test pressure

Test Criteria	Casing type	
	Model (R)	Real (A)
Deflection	± 1000 Pa	Normal Pressure at design fan speed
Maximum withstand fan pressure	± 2500 Pa	Maximum Pressure at design fan speed

7.1.3 Measurement

The panel deflection shall be measured on span A shown in figure 6 and frame deflection shall be measured on span B as shown in figure 6.

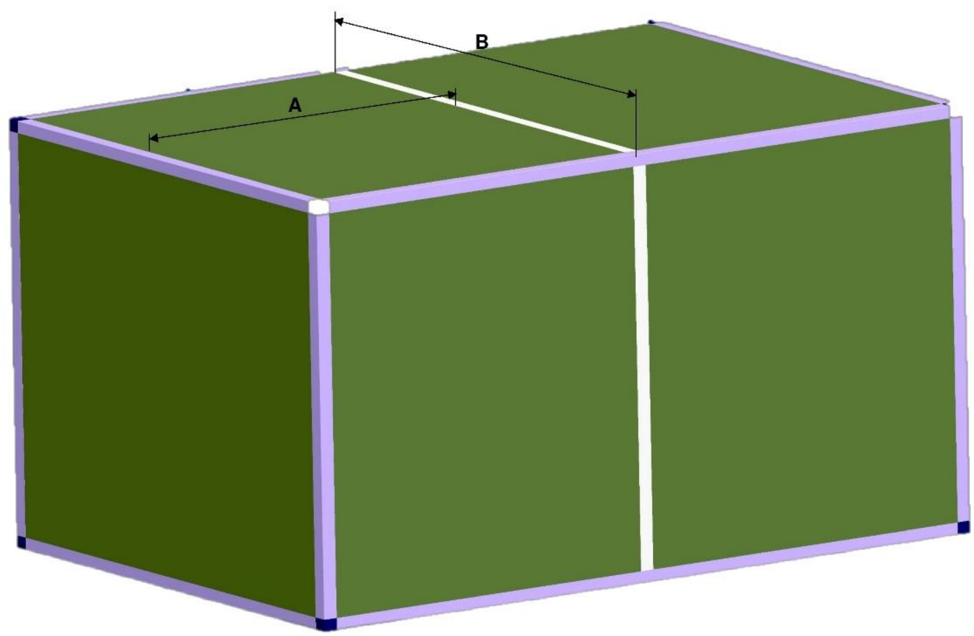


Figure 6 — Illustration of panel and frame spans of air handling units

Deflection shall be measured within an accuracy of ± 0.5 mm whilst the air handling unit is operating under test conditions. For example, referring to Figure 7, deflection X'X" is measured for span R'S', deflection XX" is measured for span PQ.

Deflection X'X" is a function of panel stiffness. Deflection XX" is a function of both frame and panel stiffness. Frame deflection is RR' and SS'.

Example:

PQ = 2m

R'S' = RS = 1 m

Measured deflection XX" = 8 mm

Measured deflection X'X" = 5 mm

Hence, the deflection of span R'S' is 5 mm / m and that of span PQ is 4 mm / m. The class is determined by the highest value of the measured relative deflections.
In this example the deflection of R'S' (the shortest span) determines that class M2 is met.

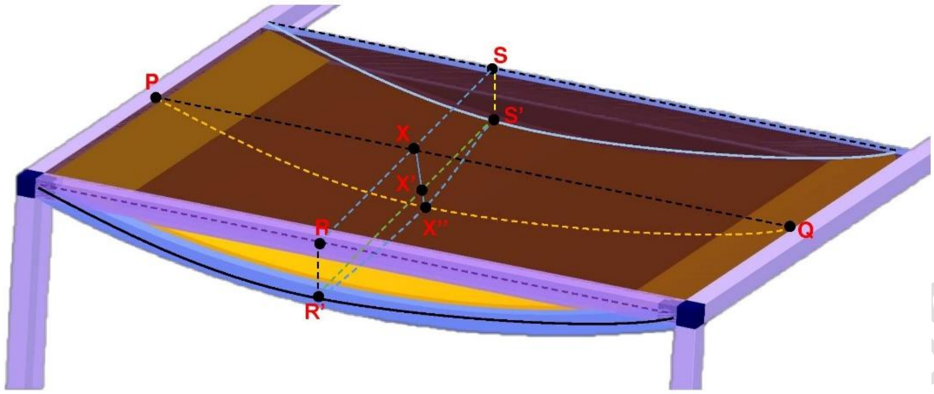


Figure 7 — Deflection of panels and frames of air handling units

7.1.4 Performance requirement - mechanical strength test:

The casings shall have to withstand the maximum fan pressure (not shock pressure) at the selected design fan speed. No permanent deformation (hysteresis maximum ± 2.0 mm per meter of frame/panel span is allowed) of the structural parts (structures and supports) or damage of the casing may occur.

Note:

i. The ability of the real unit to withstand the maximum designed fan pressure may be demonstrated by prior agreement between the supplier and buyer, by blanking off the inlets to the unit and running the fan up to its design operating speed. Downstream sections of blow-through units shall be proved by blanking off the air handling unit's outlets.
ii. Any special requirements, for example the ability to survive shock loading caused by sudden closure of fire dampers, shall ~~should~~ be clearly specified
iii. The measurement made on the Real unit shall be presented with a suffix “A” – example M1 (A) and for the measurement made on the model test model unit by using letter “R” - example M1 (R)
iv. Class M1 and Class M2 casings shall be designed and selected so that the maximum deflection of any span of the panels and/or frames does not exceed the limits given in Table 4 as demonstrated in the Figure 7.
v. Deviating test pressures shall be as mutually agreed between the supplier and buyer.

The classification of air handling unit based on their mechanical strength is given in table 4

Table 4

Casing class	Maximum relative Deflection (mm/m)	Casing strength weightage factor W_{CS}
M1	4	1.00
M2	10	0.67
M3	Above 10	0.33

Note:
The casing leakage test (clause 8.0)shall be done after the mechanical strength is completed.
Casing strength weightage shall be used for overall performance calculation as in Clause 11.

8.0 Casing air leakage

8.1 General

The leakage test shall be done after the strength test as specified in clause 7.0. The casing air leakage tests shall be conducted on the model test unit ~~model~~ for general classification and on the real unit for particular classification of casing and individual evaluation. The construction of Model unit for testing shall be as per 7.1.1.

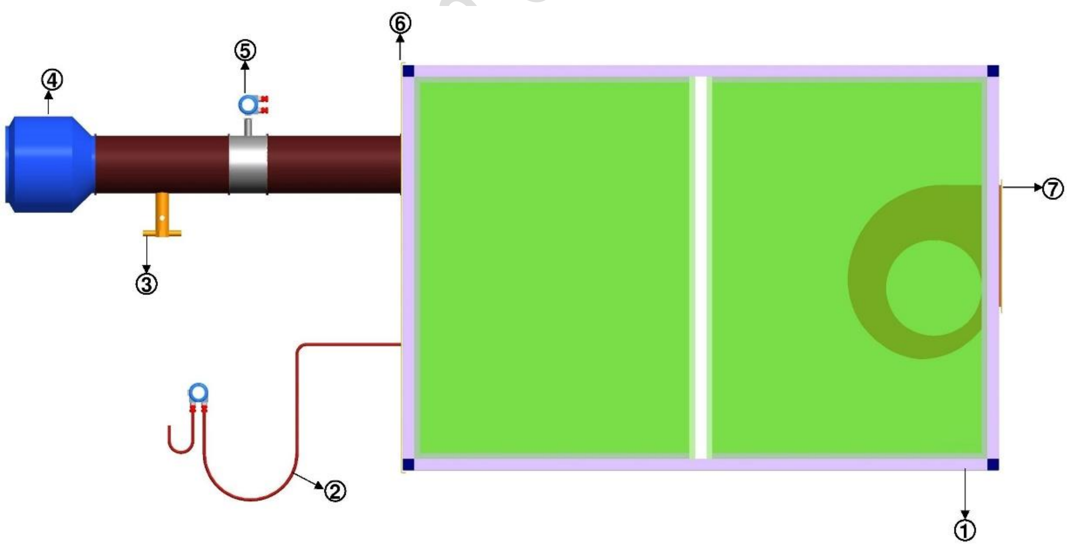
8.2 Testing

8.2.1 Test apparatus

The test apparatus shall be as shown in Figure 8, using a fan with a duty at least capable of meeting the anticipated leakage rate at the respective test pressure(s).

If the air handling unit is too large for the capacity of the leakage test apparatus (accuracy ± 3.0 %), or a restriction of access for delivery requires that the unit should be tested in sections or subassemblies, the breakdown should be agreed by the supplier and customer prior to the test date.

Whenever heat recovery devices are installed, the supply and extract sections shall be tested together as a single unit.



Key:
① AHU under test; ② AHU test pressure gauge; ③ Bleed valve as alternative variable speed fan;
④ Variable speed fan; ⑤ Flow measurement device; ⑥ Inlet plate; ⑦ Outlet plate

Figure 8— Apparatus for testing the casing air leakage (negative pressure test). Typical example

8.3 Test condition

The unit shall be installed in the intended operation conditions with its sections joined by the method as specified by the manufacturer in the installation instructions.

Blanking plates shall be fixed wherever necessary by following similar method of joining in the installation.

All opening for electrical, air or water services shall be closed prior to testing. Dampers shall be removed before testing or fitted with blanking plates if the damper is inside.

The air handling unit shall not be applied with any additional sealing other than the standard design unless agreed by the buyer and supplier on any additional sealing.

8.4 Test procedure

Turn on the test apparatus fan unit and adjust the pressure until the static test pressure inside the test unit is within 5 % of the specified value.

The pressure shall be maintained constant for 5 minutes, and readings shall be recorded after ~~only once~~ the pressure is stabilized.

Leakage flow rate and the test pressure shall be recorded.

8.5 Units operating under negative pressure only

The air leakage of the assembled air handling unit shall be tested at 400 Pa negative pressure and it shall not exceed the applicable rate given in Table 5.

Table 5 — Casing air leakage classes of air handling units, 400 Pa negative test pressure

Casing leakage class	Maximum leakage rate (Ql_{400}) l / m^2. s	Filter class (As per EN 779)	Casing leakage weightage factor W_{LS}
CL’ 1	0.15	Superior to F9	1.00
CL’ 2	0.44	F8 to F9	0.75
CL‘ 3	1.32	G1 to F7	0.50
CL’ 4	1.50	G1 to F7 (MERV 1 to 13)	0.25

NOTE:

i. *Class CL’1 for special application units only. Example: cleanrooms.*
ii. *For special applications by agreement with buyer, leakage class may be chosen independent from the filter class.*
iii. *For the units not equipped with filters, class CL’4 is recommended.*
iv. *Casing leakage shall be used for calculation of overall performance as in clause 11*

In the case of units tested at a pressure deviating from 400 Pa the measured leakage rate shall be converted into a value at reference pressure, using the following formula.

$$Ql_{400} = Ql_m \left[\frac{400}{Test\ \ pressure}\right]^{0.65}$$

Where Ql_m is – The measured leakage rate at the actual test pressure

Ql_{400} is the derived leakage rate at 400 Pa

Unless otherwise specified, the applicable rate shall be a function of the efficiency of the air filters within the air handling unit. Where there is more than one stage of air filtration, the classification shall be based on the efficiency of the highest grade of filter.

8.6 Units operating under both negative and positive pressure

Air handling units with sections operating under positive pressure shall, in all cases, have the positive pressure sections tested separately from the rest of the unit where the operating pressure immediately downstream of the fan exceeds 250 Pa positive pressure. If the positive pressure does not exceed 250 Pa, a negative pressure test shall be sufficient. The test pressure applied to the positive pressure sections shall be 700 Pa positive pressure or the air handling unit's maximum positive operating pressure, whichever is the greater. The remainder of the unit shall be tested in accordance with 8.5, with the applicable leakage rate being governed by the efficiency of the filter immediately upstream of the fan. It is also allowed to test the entire unit under positive and negative pressure.

The air leakage from the sections subjected to 700 Pa positive pressure shall be in accordance with Table 6**.**

Table 6 — Casing air leakage classes of air handling units, 700 Pa positive test pressure

Casing leakage class	Maximum leakage rate (Ql_{700}) L. m^{-2}. s^{-1}-	Casing leakage weightage factor W_{LS}
CL 1	0.22	1.00
CL 2	0.63	0.75
CL 3	1.90	0.50
CL 4	NA	0.25

Note:

Casing leakage shall be used for calculation of overall performance as in clause 11.

In the case of units tested at a pressure deviating from 700 Pa the measured leakage rate shall be converted into a value at reference pressure, using the following formula:

$$Ql_{700} = Ql_m \left[\frac{700}{Test\ \ pressure}\right]^{0.65}$$

Where Ql_m is – The measured leakage rate at the actual test pressure

Ql_{700} is the derived leakage rate at 700 Pa

Air leakage tests on model units ~~boxes~~ shall be performed at both 400 Pa negative pressure and 700 Pa positive pressure.

8.7 Performance requirement – Casing air leakage rates

Calculate the casing surface area from the nominal external dimensions, including the area of the blanked inlet and outlet airflow aperture. The area of components which does not form part of the airtight casing shall be excluded, as well as the area of blanking plates on openings of separately tested unit sections.

Leakage results obtained from test pressures deviating from the specified standard test pressure (maximum deviation ± 5 %), shall be converted into leakage rates in accordance with the test pressure classifying the leakage class in Table 5 and/or 6.

Determine the maximum allowable leakage from Tables 5 and 6, as appropriate, and relate it to the casing area of the unit under test.

The ~~unit recorded~~ measured leakage rate shall be lesser than the allowable leakage rate. If the unit is tested in sections, the ~~total~~ sum of the ~~recorded~~ measured leakage rates for all sections shall be the less than allowable leakage rate as specified in Table 5 and / or 6.

9.0 Filter bypass leakage

9.1 Requirements

9.1.1 General

Air bypass around filter will decrease the effective efficiency of the filter, especially a high efficiency one, because the bypass air is not filtered. In addition, any inward leakage through the casing downstream of the filter has the same effect. Therefore, for filters located upstream of the fan, the air tightness and area of the casing between the filter and the fan are factors that can affect the filter bypass leakage rate.

9.1.2 Acceptable filter bypass leakage rates

Table 7 gives the acceptable filter bypass leakage rate, related to different filter classes, as percentages of the specified or nominal air flow rate of the air handling unit to be tested. If the filter is upstream of the fan, leakages of the sections between the filter and fan are deemed to be included in the specified values. In the case of downstream filters, the specified values are for the bypass around the filter only

The acceptable filter bypass leakage rate q_{va} shall be calculated by the formula:

$$q_{va} = \frac{k \times q_{vnom}}{100}$$

Where

q_{vnom} is the airflow rate of the filter section, as given in table 7.

k is the filter bypass leakage rate, in percent of nominal volume flow rate, as given in 8.

Table 7 – Airflow rate of the filter section q_{vnom} subject to the type of test unit

Test criteria	Type of test unit	
	Model test unit	Real unit
Volume flow rate	Corresponds to a filter face velocity of 2.5 m/s	Normal operating conditions at selected design fan speed

Table 8 – Acceptable filter bypass leakage, at test pressure of 400 Pa

Filter class	G1 to F5 / (MERV 1 to 10)	F6 / (MERV 11 & 12)	F7 / MERV 13	F8 / MERV 14	F9 / MERV 15

Maximum filter bypass leakage rate k in % of the volume flow rate	6	4	2	1	0.5
Filter bypass leakage weightage W_{FB}	0.20	0.40	0.60	0.80	1.00

Note:

The values in table 8 are percentage leakage of unfiltered air.

Filter bypass leakage shall be used for calculation of overall performance as in clause 11

For filters located in upstream of the fan, bypass leakage shall be the sum of leakage around filter cells and the casing air leakage of the sections between the filter and the fan.

For filters located in downstream of the fan, bypass leakage shall be around the filter cells only.

The unit shall be deemed to pass if the specified value for the filter bypass leakage rate, determined in 9.1.2, is no greater than the acceptable filter bypass leakage rate q_{va}

7.1.3 Two or more filter sections in the same unit

If two or more filter sections are provided within the air handling unit, the filter bypass leakage shall be tested separately for each filter.

9.2 Testing

9.2.1 General

The specified test requirements refer to the complete air handling unit.

The filter shall be removed and replaced with blanking plates, e.g. as shown in Figure 9. These plates shall have exactly the same shape, dimensions and surface finish as the filter in the area relevant to air tightness.

Alternatively, the inlet face of every individual filter may be covered with a plate or a foil. The joints between the filter and frames shall not be covered and any additional fastenings of plates, foils shall not have any influence on the air tightness of the joints. Openings for electrical, air or water services shall be closed prior to testing. The accuracy of the measuring device for the leakage airflow shall be ± 3.0 %.

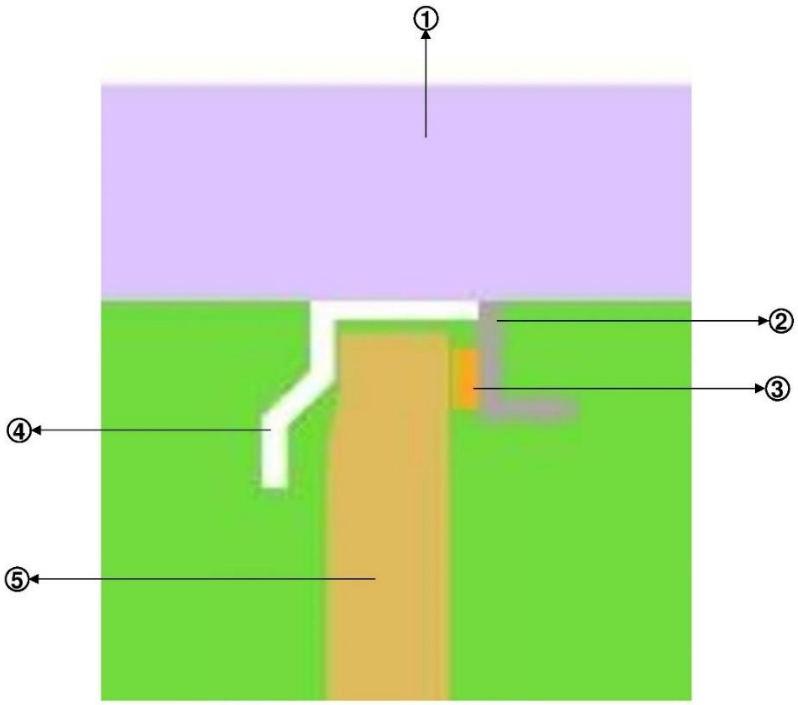


Figure 9: Method of blanking off filter cells

Key: ① Casing wall; ② Frame: ③ Seating; ④ Fastener of filter cell; ⑤ Plate

9.2.2 Filters downstream of the fan (positive pressure)

For testing, the inlet opening of the test filter section shall be covered with an airtight plate. A leakage test apparatus shall be connected as shown in Figures 6 and 7. The outlet for the test filter shall be open.

The test shall be carried out in two stages at a positive test pressure of 400 Pa.

Stage 1: Determination of the total leakage q_{Lt}

The total leakage shall be calculated by the formula:

$$q_{Lt} = q_L + q_{Lf}$$

Where
q_{Lt} is the total leakage
q_L is the sum of leakages through casing
q_{Lf} is the sum of leakages through the joints between the filter cell, the frame and the casing

Measurement of the total leakage shall be carried out with blanking plates, replacing or covering each individual filter cell in the filter section; as described in 7.2.1.

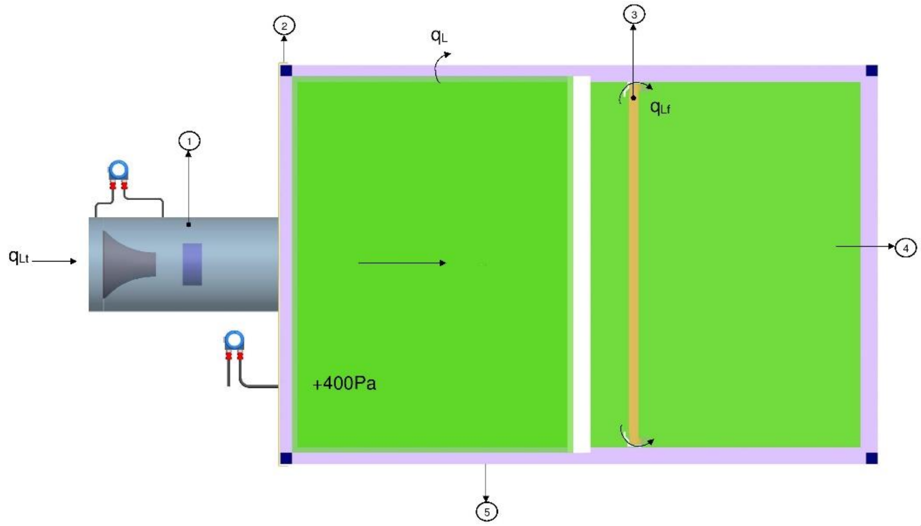


Figure 10: Test apparatus for testing filter sections downstream of the fan – Stage 1

Key: ① Leakage test apparatus; ② Inlet plate: ③ Filter cells replaced by blanking plate or with blanking foil; ④ Filter Section; ⑤ Casing

Stage 2: Determination of the leakage through the casing q_L

Air leakage through the casing shall be determined by eliminating all possible bypass leakage through the framework around the filter cells. Therefore the entire frontal face area of filter frames and filter cells shall be blanked off, including the filter frames adjoining the casing panels

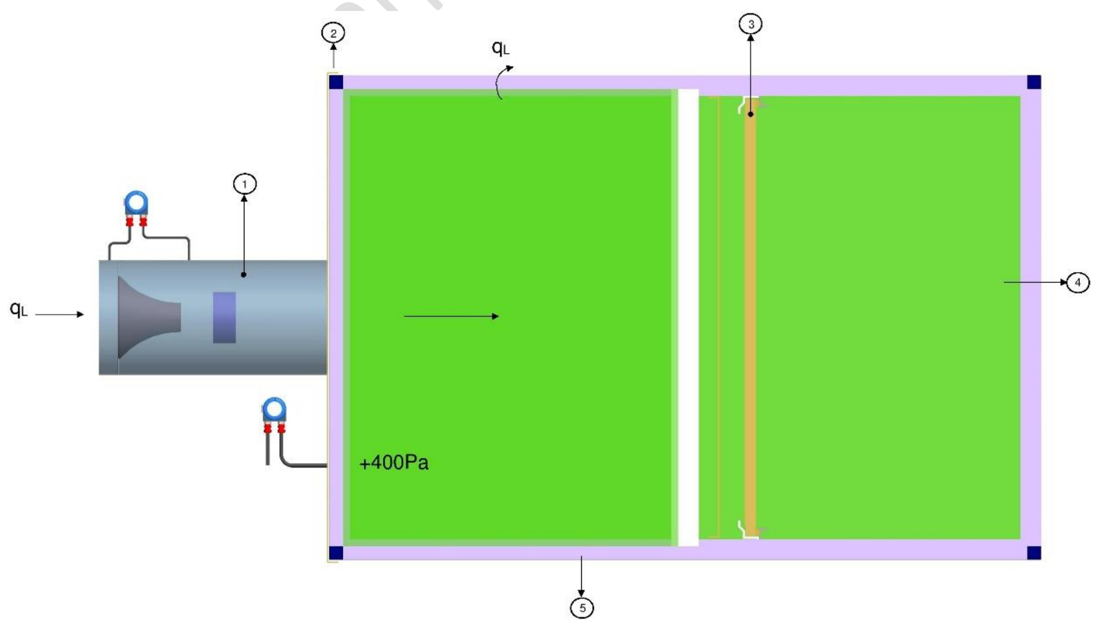


Figure 10 — Test apparatus for testing filter sections downstream of the fan – second stage
Key: ① Leakage test apparatus; ② Inlet plate: ③ Filter cells replaced by blanking plate or with blanking foil; ④ Filter Section; ⑤ Casing

The value used to calculate the leakage is specified by the formula:

$$q_{Lf} = q_{Lt} - q_L$$

Where
q_{Lt} is the total leakage
q_L is the sum of leakages through casing
q_{Lf} is the sum of leakages through the joints between the filter cell, the frame and the casing

9.2.3 Filters upstream of the fan (negative pressure)

For testing, the outlet opening of the section, which is downstream of the filter under negative pressure, shall be covered with an airtight plate.

A leakage test apparatus shall be connected as shown in Figure 11. The inlet opening of the test filter section shall be open.

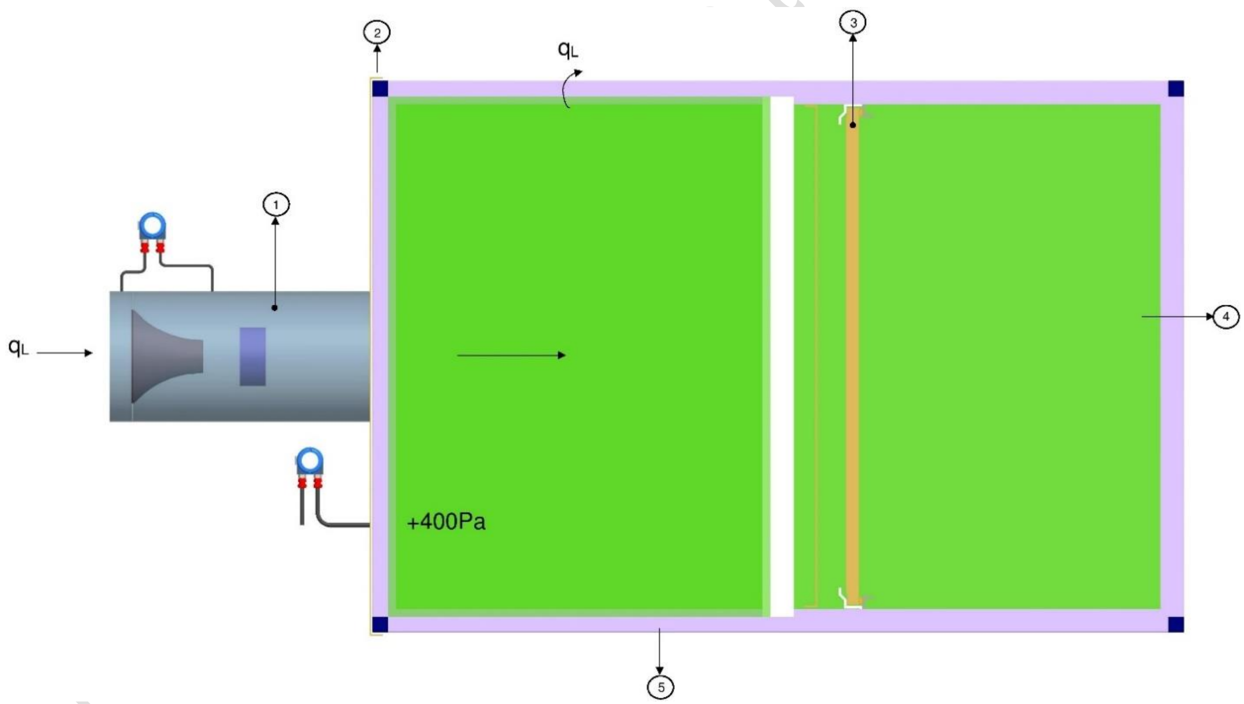


Figure 11 — Test apparatus for testing filter sections upstream of the fan
Key: ① Leakage test apparatus; ② Outlet plate: ③ Filter cells replaced by blanking plate or with blanking foil; ④ Filter Section; ⑤ Casing

The following steps shall be added if there is a heat recovery section between the filter and the fan. Connect a pressurization fan to one airside opening of the unit part which does not contain the filter to be tested and close all other openings. A second fan shall be connected on the discharge side of the part that contains the filter frame to be tested. Regulate the negative pressure downstream filter to 400 Pa and the pressure difference between the two airsides to ± 5 Pa.

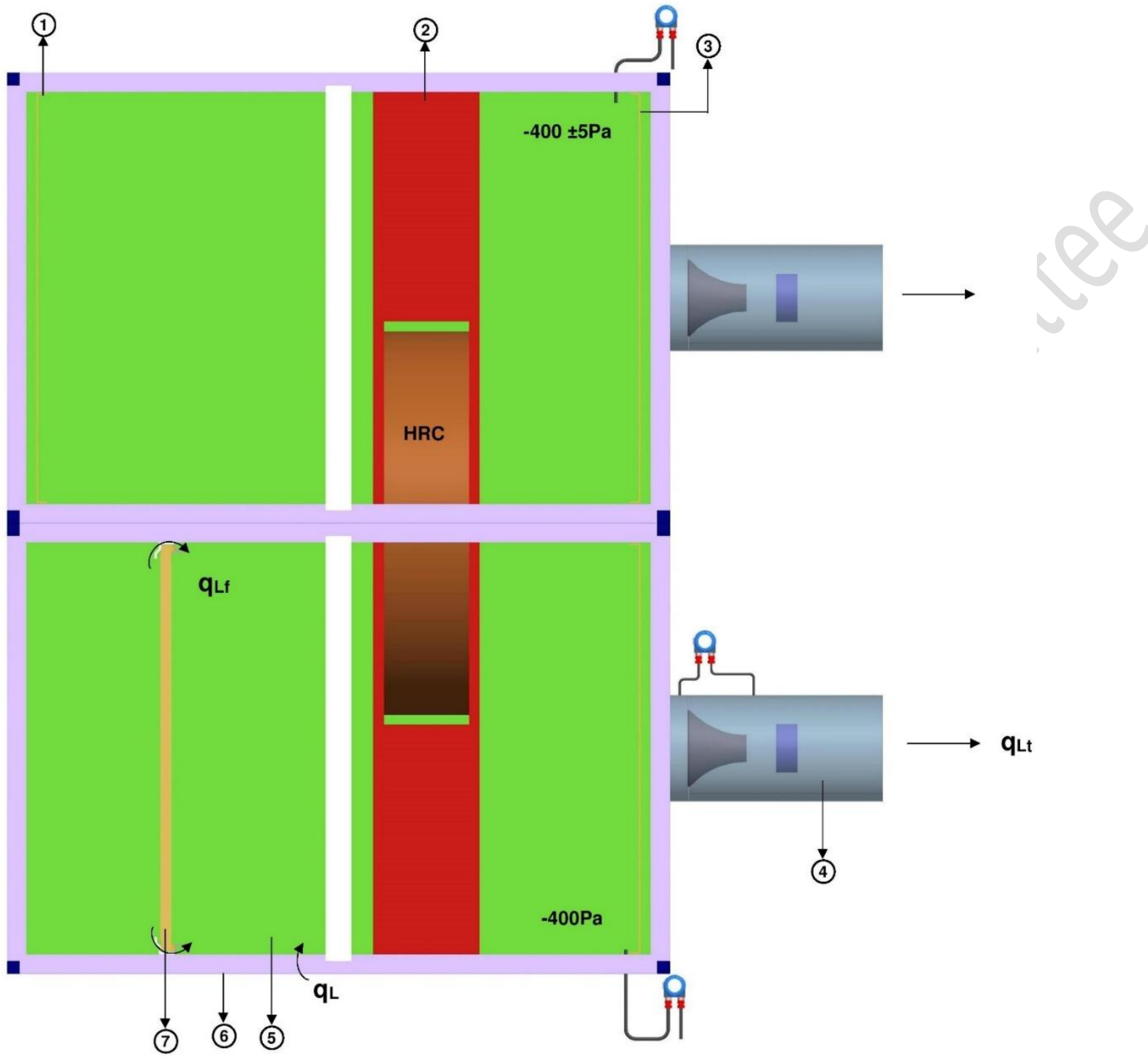


Figure 12 — Test apparatus for testing filter sections with heat recovery section

Key: ① Inlet plate; ② Heat recovery device; ③ Outlet plate; ④ Leakage test apparatus;
⑤ Filter section; ⑥ Casing ; ⑦Filter cells replaced by blanking plates or individually covered with foil

The test shall be carried out at a negative test pressure of 400 Pa.
The total leakage is specified by the formula:

$$q_{Lt} = q_L + q_{Lf}$$

Where
q_{Lt} is the total leakage
q_L is the sum of leakages through casing
q_{Lf} is the sum of leakages through the joints between the filter cell, the frame and the casing.

This is the value to calculate the filter bypass leakage rate. Filter frames in test units model boxes shall be tested both as filter sections downstream (positive pressure) and upstream (negative pressure) of the fan. The bypass test under positive pressure shall also be conducted in two stages as described in 9.2 in order to eliminate the casing leakage. For a non– ambiguous interpretation of figures, only the bypass leakage across the filter frame shall be specified.

Example:
A test was performed for a filter section with 4 filters.
Surface section area: 1.49 m^2
Face velocity: 2.5 m . s^{-1}
Air flow rate: 3.725 m^3 . s^{-1}

The following values were determined:
a) Testing filter sections downstream of the fan (positive pressure)
Total leakage q_{Lt}: 27.5 × 10^{-3} m^3 . s^{-1}
Leakage through the casing q_L: 14.5 × 10^{-3} m^3 . s^{-1}
Leakage through the filter q_{Lf}: 13.0 × 10^{-3} m^3 . s^{-1}
Filter bypass leakage rate: 0.35 %

b) Testing filter sections upstream of the fan (negative pressure)
Total leakage q_{Lt}: 24.5 × 10^{-3} m^3 . s^{-1}
Leakage of unfiltered air q_{Lf}: 24.5 × 10^{-3} m^3 . s^{-1}
Filter bypass leakage rate: 0.66 %
Usable filter class: F8 (MERV 14)

10.0 Thermal performance of casing

10.1 General

Thermal performance of the AHU shall be measured by Thermal Transmittance as defined in ~~Clause~~ 10.2 and thermal bridging as defined in ~~clause~~ 10.3. The test shall be conducted on Model test unit ~~model~~ constructed as defined in 7.1.1.

10.2 Thermal transmittance

Mean heat loss coefficient (thermal transmittance “U”) is only measured on model box and is calculated as defined in 10.4.1.

Note:
Thermal transmittance is the rate of transfer of heat through the matter. The thermal transmittance of a material or an assembly is expressed as a U- value.

Table 9 Thermal transmittance

Class	Thermal transmittance (U) (W/ m² K)	Casing thermal transmittance weightage factor W_{TT}
T1	U ≤ 0.5	1.0
T2	0.5 <U ≤ 1.0	0.8
T3	1.0 <U ≤ 1.4	0.6
T4	1.4 <U ≤ 2.0	0.4
T5	No requirements	0.2

Note:

W_{TT} = Weightage on basis of Thermal Transmittance class used for calculating mechanical performance of the AHU as defined in clause 11

10.3 Thermal bridging

Shall be tested on Model test model and measurements are taken under steady state condition. Under steady state condition, when the mean temperature difference between internal air and external air temperatures is stabilized at 20 K, the lowest value of temperature difference between any point on the external surface and the mean internal air temperature shall be established. The ratio between the lowest temperature difference and the mean air-to-air temperature difference determines the thermal bridging factor.

Note: Thermal bridging is an area or component of an object which has higher thermal conductivity than the surrounding materials, creating a path of least resistance for heat transfer. Performance of unit can be compared by defining a thermal bridging factor

Table 10 Thermal bridging

Class	Thermal bridging factor (k_b)	Casing thermal bridging weightage factor W_{TB}
TB1	$0.75 \le k_b \le 1.00$	1
TB2	$0.60 \le k_b < 0.75$	0.8
TB3	$0.45 \le k_b < 0.60$	0.6
TB4	$0.30 \le k_b < 0.45$	0.4
TB5	No requirements	0.2

Note:

W_{TB} = Weightage on basis of Thermal Bridging class used for calculating mechanical performance of the AHU as defined in clause 11

10.4 Testing

The electrical heaters and fans are energized from a stable power source with constant voltage till steady state conditions are achieved. The conditions are said to be steady state when the standard deviation of readings of difference between mean external temperature and mean internal temperature is less than or equal to 1.0 K for a period of 30 minutes.

During measurement, the temperature difference ~~across~~ among the measurement points inside the unit shall not exceed 2.0K nor shall the difference between the three consecutive mean temperature measurements in the inner zones exceed 0.5 K. The difference between the outside air temperature at measuring points shall not exceed 0.5K.

The power input to heaters and fans is measured when the difference between the mean internal and mean external temperatures ~~are~~ is at least 20 K shall be used to determine thermal transmittance U.

Note: The instrument with an accuracy of ± 1 % of the measured value shall be used for power measurement.

To thermal bridging factor shall be calculated by the measurement of mean internal temperature at the eight points limiting each section, together with the maximum outside temperature, measured under steady state conditions. The thermal bridging factor, k_b, shall be calculated by taking the lowest value for the three sections for defining the temperature class.

Note:

The diameter of surface temperature measuring instrument shall be 7mm to 9mm, and the maximum uncertainty of temperature measurement shall be ± 0.2 K.

Infrared imaging can assist in locating the maximum external surface temperatures.

10.5 Calculations

Thermal transmittance shall be calculated by using equation below.

$$\mathrm{U} = \frac{\mathrm{P_{el}}}{\mathrm{A} \times \Delta \mathrm{t_{air}}}$$

Where

U = thermal transmittance [W/ m^2 K]

$\mathrm{P_{el}}$ = electrical power input for heater(s) and circulating fans [W]

A = external surface area [m^2]

$\Delta \mathrm{t_{air}}$ = air to air differential temperature [K]

Thermal bridging factor k_b, shall be calculated by using the equation below.

$$k_b = \frac{\Delta t_{min}}{\Delta t_{air}} = \frac{t_i - t_{s-max}}{t_i - t_a}$$

k_b = Thermal bridging factor

Δt_{min} = least differential temperature (internal air – casing) [K]

Δt_{air} = air to air differential temperature [K]

t_i = mean internal air temperature [°C]

t_{s-max} = measured maximum external surface temperature [°C]

t_a = mean external air temperature [°C]

Terms in the applicable equations (either measured or calculated) shall be rounded off ~~(final figure less than 5 is eliminated and a final figure of 5 or greater increases the preceding figure to its next highest value)~~ to the number of decimal places as specified below:

$\mathrm{P_{el}}$, Δt_{air}, Δt_{min}, t_i and t_a shall be rounded off to 1 decimal place and A shall be rounded off to 2 decimal places.

To calculate an average temperature, readings with more decimal~~s~~ places may be used. Rounded off terms shall be used in the relevant formulas to calculate the U value and kb factors.

Calculated ~~figures~~ values for thermal transmittance and thermal bridging factors shall be rounded off to two decimal places.

11.0 Overall Mechanical Performance

To determine the overall Mechanical Performance weightages are assigned to each performance criteria and these weightages are assigned on basis of its importance in Energy consumption. As shown in the below table 6, 5% Weightage is ~~are~~ assigned to casing strength class and filter bypass class, 15% weightage is ~~are~~ assigned to casing leakage class and 30% weightages is ~~are~~ assigned to Thermal transmittance class and Thermal bridging class.

Table 11 – Overall Mechanical Performance Value

Weightages For Overall Mechanical Performance Value (MPV)	
Casing Strength class	5% (W_{CS})
Casing Leakage class – Positive pressure	15% (W_{CL+})
Casing Leakage class – Negative Pressure	15% (W_{CL-})
Filter bypass class	5% (W_{FB})
Thermal transmittance class	30% (W_{TT})
Thermal bridging class	30% (W_{TB})
Overall Mechanical Performance Value (MPV)	(5%)W_{CS}+(15%)W_{CL+}+(15%) W_{CL-}+(5%)W_{FB}+(30%)W_{TT}+ (30%)W_{TB}

11.1 Acoustic performance level:

The sound power level shall be measured as per ISO 3744 and should be 80 dB or less.

12.0 Energy Efficiency Class

In this method the impacts of the various factors are weighted together to establish the final energy class.

Energy to Air Handling Units (AHUs) is divided into two main groups:

- Thermal energy (For cooling)
- Electrical energy for fans

Note: Different levels for thermal energy consumption for cooling are covered by the consideration of the Heat Recovery System (HRS) efficiency. The climate dependency for the thermal energy consumption is considered and the difference in primary energy between thermal energy and electrical energy is taken into account to evaluate the impact of the pressure drops across the HRS.

13.0 Rating and performance of Air Handling Unit

13.1 Testing of aerodynamic performance

The test as defined in this section shall determine the performance of entire AHU.

13.1.1 Characteristics

13.1.1a. External total pressure difference of the unit: The difference in total pressure between outlet and inlet of the air handling unit related to the air volume flow at the measurement plane.

13.1.1b. Electrical motor input power: The power input to the fan motor related to the air volume flow.

Note: If a speed adjustment device is needed, e.g. frequency inverter, the electrical motor input power shall include the power of speed control devices.

13.1.2 Quantities

13.1.2a. Air volume flow rate (q_v) shall be measured by any method which is in accordance with ISO 5801, e.g. a nozzle, an orifice plate or a pitot-static tube.

13.1.2b External total pressure difference of the unit ($\mathrm{P_{tu}}$) shall be calculated from the pressure measurements defined in 13.1.4 and is the difference between the total pressure at the outlet of the air handling unit and the total pressure at the inlet.

Note: The transition duct sizes shall be as defined by the manufacturer.

The external total pressure difference of the unit is:

$$\mathrm{P_{tu}} = \mathrm{P_{tu2}} - \mathrm{P_{tu1}}$$

where

$\mathrm{P_{tu2}}$ sum of the static and dynamic pressure at outlet (~~in~~ Pa)

$\mathrm{P_{tu1}}$ sum of the static and the dynamic pressure at inlet (~~in~~ Pa)

13.1.2c Density of air (ρ) shall be calculated as below.

$$\rho = \frac{P_a - 0.378 P_v}{287(278 + t_a)} \text{ kg x m}^{-3}$$

where

P_a is the atmospheric pressure, expressed in Pa;
P_v is the partial pressure of water vapor in the air, expressed in Pa;
287 is the gas constant of dry air, expressed in J x kg^{-1} x K^{-1}
t_a is the dry-bulb temperature, expressed in °C

13.1.2d. Temperature of the air (t_a) shall be measured at the point of flow measurement.

13.1.2e. Rotational speed of the fan (n_F) shall be measured at each test point.

13.1.2f. Electrical motor input power (P_E), the power to the fan motor, shall be measured at each test point. The applied voltage and the current to each phase shall also be recorded when measured.

13.2 Test method

Tests shall be carried out in accordance with one of the methods shown in ISO 5801. The testing can be either by Chamber test method or Ducted test method.

For ducted test installation type B, C or D shall be adopted as best suited to the geometry of the air-handling unit and the test facilities available.

Note: When a standardized test chamber is used it shall conform to the requirements of clause 31 of ISO 5801:1997.

The three installation types are:

a) Type B: free inlet, ducted outlet -
b) Type C: ducted inlet, free outlet
c) Type D: ducted inlet, ducted outlet

Note:

i. Free inlet or outlet means that air enters or leaves the air handling unit directly from or to the unobstructed free atmosphere.
ii. Ducted inlet or outlet signifies that air enters or leaves the unit through a duct directly connected to the unit inlet or outlet.

13.2.1 Ducted test method

The common parts of a ducted system, for Types B, C or D installations, shall conform to the requirements of clause 30 of ISO 5801:1997. The cross-sectional dimensions of the air outlet shall be used to determine the dimensions of the outlet ducting required in a Type B or Type D installation, and the inlet ducting required in a Type C or Type D installation.

13.2.2 Measurement procedure

13.2.2a Conditions for measurements

Air flow control dampers of air handling unit to be tested shall be fully open. Other dampers that form part of a different air circuit, e.g. bypass and recirculation dampers, shall be fully closed.

All elements included in the design of the air handling unit shall be fitted as intended with filters and dry coils. If there is no negative influence on the internal pressure of the unit, the average filter pressure drop shall be simulated by increasing the external total pressure difference of the unit with a value equal to the difference between rated average and initial filter pressure drop.

Where the duty specified is for an initial or final filter condition; the simulated external total pressure difference applied shall be the rated design value or shall be increased by the difference between the rated final and initial filter pressure drop (as appropriate).

13.3 Testing of unit with heat recovery

Testing shall be performed taking the leakage between the air streams into consideration.

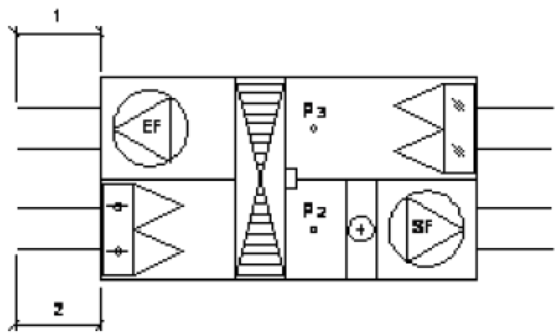


Figure 13 Testing of complete unit

Keys

① Pressure drop measurement point on exhaust air side
② Pressure drop measurement point on supply air side
EF – Exhaust air fan
SF – Supply air fan

The airflow shall be measured at the supply air side and at the extract air side. The external pressures shall be set to design pressure conditions. Unless otherwise stated, the pressure drop on the outdoor airside and exhaust airside is set to 50 Pa. The remainder of the external pressures shall be set on the supply and extract air openings. In order to avoid leakages from the extract air stream to the supply air stream, the pressure P_2 should be higher than the pressure P_3. The two pressures P_2 and P_3 shall be measured. The leakage and the extra pressure drop are the responsibility of the manufacturer.

13.4 Testing of one air stream

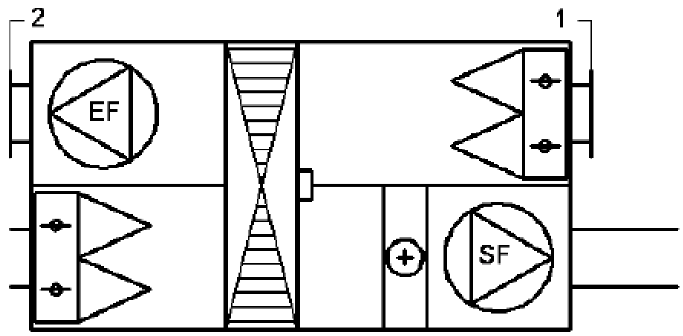


Figure 14 Testing of one air stream

Key

1 Inlet plate; 2 Outlet plate; EF exhaust air fan; SF supply air fan

If just one air stream is to be tested, then the connections of the opposite air stream shall be closed with airtight plates.

13.5 Measurements

Atmospheric pressure and temperature shall be measured at the beginning of the test.

Pressure measurements, at the locations and in the manner described in ISO 5801, shall be recorded at a sufficient number of test points enabling the characteristic curve to be plotted through the specified duty point or over the full operating range, whichever is required.

Rotational speed of the fan and the electrical input to the fan motor shall be recorded at each of the test points.

13.6 Evaluation of results

For each operating point, the external total pressure of the unit and air volume flow shall be calculated in accordance with ISO 5801. It is sufficient, in most circumstances, to adopt the simplified procedures applicable when the Mach Number is less than 0.15 and the fan pressure ratio is less than 1.02 (corresponding to a pressure rise less than 2 000 Pa in ambient air).

13.6.1 Tolerances

The air performance quoted or specified shall be the most probable, not the minimum or maximum acceptable value. The test for the specified duty shall be conducted in accordance with clause 16.7 of ISO 5801.

The tolerance should be applied to a specified duty or duties, not to every point on the air handling unit characteristic. The characteristic is drawn from the measured data and mathematically converted to the standard density 1.2 kg. m^{-3}.

The permissible deviation of the specified duty point from the operating point on the air handling unit characteristic is the sum of the tolerance range of the specified duty point and the uncertainty range of the measured data. This uncertainty range derives from the measuring uncertainty of the methods of measurement and the measuring instruments and test rig used and is to be stated for a confidence level (probability) of 95 %.

$$q_{vm} - q_{vs} = \Delta q_v \leq t \times q_{vs} + u \times q_{vm}$$

is the allowable difference in air volume flow, expressed in m^3/s

Where

t (in %)	= tolerance range of duty point
u (in %)	= uncertainty range of measured data
Δ	= admissible deviation
q_{vs} ($m^{-3} \cdot s^{-1}$)	= specified(design) air volume flow
q_{vm} ($m^3 \cdot S^{-1}$)	= measured and converted air volume flow

Table 12 Air handling unit performance tolerances

Working values	**Tolerance range**	**Remarks**
Air volume flow q_v in $m^3 \cdot s^{-1}$	± 5 %	$\Delta q_v = (t_{qv}/100\ \%) \times q_v$
External total pressure difference p_{tu} in Pa	± 5 %	$\Delta p_{tu} = (t_{\Delta p}/100\ \%) \times p_{tu}$
Electrical motor input power P_E in W	8%	$\Delta P_E = (t_P/100\ \%) \times P_E$

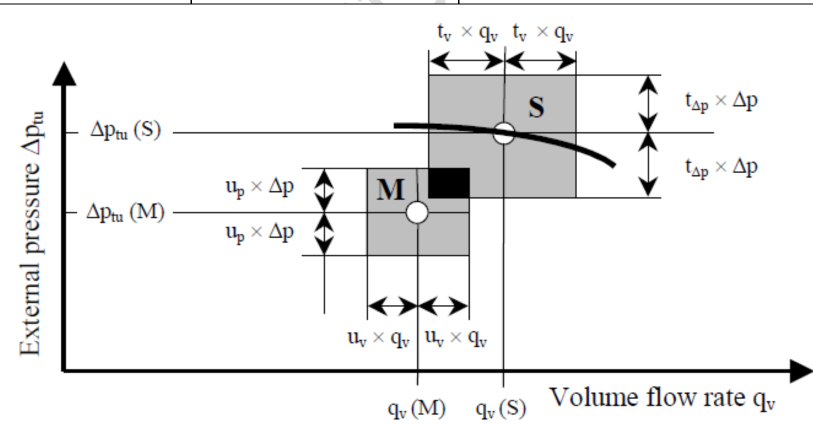


Figure 15 Admissible tolerances

Note:
Tolerance ~~ranges~~ of 5 % on air flow rate and external total pressure difference is allowed.
Tolerance ~~ranges~~ of +8 % on absorbed motor power is allowed.

14.0 Rating & performance of individual components of Air Handling Unit

14.1 Fan section

14.1.1 Air velocity class

14.1.1a General:

For hygiene reasons and to reduce maintenance expenditure, it is recommended to arrange supply air fans in such a way that the suction-side leakage air flows are minimized. The arrangement of the fan in the air handling unit casing shall ensure an even inflow and outflow of air. Additional inflow and outflow devices should be fitted for this purpose if necessary.

The air velocity in the unit has a large influence on energy consumption. The velocities are calculated for air velocity in AHU cross-section. The velocity is based on the square area of filter section of a unit, or if no filter is installed, it is based on the square area of the fan section.

Velocity class should be determined according to below table

Table 13 Classes of air velocity levels

CLASS	Air velocity (m/s)
V_f1	$v \leq 1.2$
V_f2	$1.2 < v \leq 1.4$
V_f3	$1.4 < v \leq 1.6$
V_f4	$1.6 < v \leq 1.8$
V_f5	$1.8 < v \leq 2.4$
V_f6	$2.4 < v \leq 2.8$
V_f7	$2.8 < v \leq 3.4$
V_f8	$3.4 < v \leq 4.0$
V_f9	$v > 4.0$

Fans with blades curved backwards should be provided on energy reasons. To reduce the consumption of electric power even further, energy-saving motors with increased efficiency should preferably be fitted.

14.1.2 Fan power consumption Class

$$Pm_{ref} = \left(\frac{\Delta P_{stat}}{450}\right)^{0.925} \times (q_v + 0.08)^{0.95}$$

Where

Pm_{ref} = reference value absorbed power (kW)

Δp_{stat} = available static pressure ($p_{internal} + p_{external}$) (Pa)

q_v = air flow rate of the fan (m3/s)

Table 14 Classification of power consumption fan

Class	Pm max [kW]
P1	$\leq Pm_{ref} \times 0.85$

P2	$\leq Pm_{ref}$ x 0.90
P3	$\leq Pm_{ref}$ x 0.95
P4	$\leq Pm_{ref}$ x 1.00
P5	$\leq Pm_{ref}$ x 1.06
P6	$\leq Pm_{ref}$ x 1.12
P7	$> Pm_{ref}$ x 1.12

14.2 Heat recovery section

Table 15 Energy efficiency of heat recovery system

CLASS	Temperature Efficiency (η_t)	ΔP_{HRS} [Pa]	COP(ε)	Energy Efficiency (η_e)
H1	0.75	2 x 280	19.5	0.71
H2	0.67	2 x 230	21.2	0.64
H3	0.57	2 x 170	24.2	0.55
H4	0.47	2 x 125	27.3	0.45
H5	0.37	2 x 100	26.9	0.36

To determine the HRS Energy efficiency two parameters pressure drop (ΔP) and temperature efficiency (η_t) are used.

$$\text{Temperature efficiency } (\eta_t) = \frac{t_{ODA} - t_{SUP}}{t_{ODA} - t_{ETA}}$$

$$\text{Pressure drop } (\Delta P_{HRS}) = \Delta P_{Supply} + \Delta P_{exhaust}$$

$$\text{Electric power consumption } (P_{el}) = \frac{q_v \times \Delta P_{HRS}}{\eta_{el}} + P_{aux}$$

Where

Standard value for η_{el} = 0.6

P_{aux} = Power consumption of other auxiliaries such as any moving mechanical assembly

ΔP_{HRS} = According to table 10 (Energy efficiency of heat recovery)

$$\text{HRS performance } (Q_{HRS}) = q_v \times \rho \times c_p \times \eta_t (t_{ODA} - t_{ETA})$$

$$\text{Coefficient of performance}(\varepsilon) = \frac{Q_{HRS}}{P_{el}}$$

$$\text{Energy Efficiency } (\eta_e) = \eta_t \times \left(1 - \frac{1}{\varepsilon}\right)$$

Table 16 Classes of heat recovery

Class	**η_e (min %)**
H1	≥ 71

H2	≥ 64
H3	≥ 55
H4	≥ 45
H5	≥ 36
H6	No Requirement

14.3 Mixing sections

The mixing section can have a major influence on the air flows and pressure balance within the ventilation or air conditioning system and hence the building. The quality of mixing is characterized by the temperature mixing efficiency specified Table 9

The mixing efficiency shall be measured at recirculation flow damper positions 90 % open, 50 % open, and 20 % open.

Mean temperature of mixed flow can be calculated using

$$t_M = \frac{t_H \cdot \rho_H \cdot q_{vH} + t_L \cdot \rho_L \cdot q_{vL}}{\rho_{tot} \cdot q_{vtot}}$$

Mean velocity is calculated using

$$V_M = \frac{q_v}{A_{tot}}$$

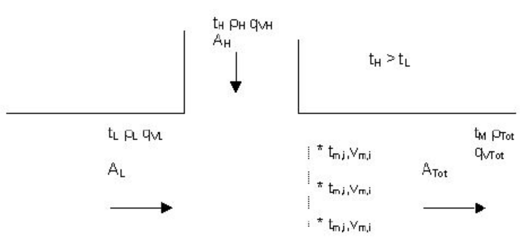


Figure 16 Quantities to define mixing efficiencies

The temperature mixing efficiency is calculated from

$$\eta_{mix} = \left[1 - \frac{t_{max} - t_{min}}{t_H - t_L}\right] \times 100\%$$

where

η_{mix} = mixing efficiency (%)

t_{max} = highest temperature in the measuring plane downstream the mixing section (°C)

t_{min} = lowest temperature in the measuring plane downstream the mixing section (°C)

t_H = higher temperature of entering air (°C)

t_L = lower temperature of entering air (°C)

Table 17 Mixing temperature efficiency

Class	Mixing efficiency [%]
M_x1	$\eta_{mix} \geq 95$
M_x2	$85 \leq \eta_{mix} < 95$
M_x3	$70 \leq \eta_{mix} < 85$
M_x4	$50 \leq \eta_{mix} < 70$
M_x5	$\eta_{mix} < 50$

14.4 Filter sections

The task of air filters in HVAC systems is not only to protect the ventilated rooms from ~~too~~ severe ~~a~~ level of contamination but also to protect the HVAC system itself. This is guaranteed by the use of fine filters of filter class F5 to F9. First filter stage is to be fitted on the intake side, as close as possible to the outer air intake aperture to keep the air treatment elements as clean as possible. Additional coarse filters G1 to G4 are also permissible

The side wall on the service side of the filter section shall be equipped with an inspection door. The width and height of the door shall be greater than the external dimensions of the replaceable filter elements.

If a single stage filter system is used, a minimum of filter class F7 shall be fitted.

If two-stage filtering is used, the supply air fan shall be arranged between the first and second filter stage

Table 18 Maximum final pressure drop for filters

Filter class as per EN 779 (MERV)	Final pressure drop
G1 - G4 (MERV 1 – 8)	150 Pa
F5 - F7 (MERV 8 – 14)	200 Pa
F8 - F9 (MERV 14 – 16)	300 Pa

15.0 Marking, labels and manuals

A name plate of corrosion-resistant material shall be affixed on the AHU with the following details:

a) Manufacturer's name and address
b) Model number designation
c) Serial number
d) Rated capacity
e) Rated voltage, phase and frequency (in accordance with IS 12360)
f) Rated air volume
g) Rated power consumption
h) Overall mechanical performance value
i) Thermal performance value

15.1 The operation and maintenance manual shall be supplied with the AHU. The operation and maintenance manual shall provide minimum of

i. Exploded view drawing of the unit with component naming.
ii. Operation and safety instructions.
iii. Installation instructions, precautions, warnings and drawings.
iv. Internal Electrical circuit diagram and field connection drawings.
v. Instructions for safe use in service and maintenance;
vi. Instructions for starting and closing down the equipment
vii. Instructions for monitoring equipment and instrumentation, periodical inspections, recommendations for inspection intervals;
viii. Description of normal operation of the unit, instructions concerning protection and control equipment, instructions for fault finding;
ix. Service and cleaning instructions including drawings; for components which require periodical servicing or changing, an estimated service schedule and a list of spare parts and accessories are required;
x. Estimated schedule for periodical inspections.
xi. For each functional section of the air-handling unit, appropriate instructions for operation and maintenance are required.

Annexure A

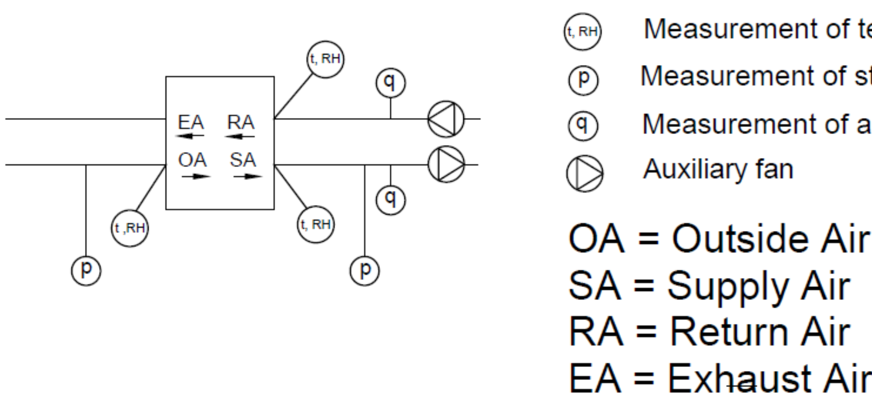
Performance evaluation method for composite air handling unit (Normative)

Test procedures for establishing Performance evaluation

This Annexure specifies methods to be used for laboratory testing of air handling unit with air-to-air heat recovery devices or those recovering heat to obtain rating data. It gives test requirements and procedures for performing such tests and specifies input criteria required for tests to verify performance data as declared. This procedure applicable to

1. Non-hygroscopic recovery device
2. Hygroscopic recovery device

This is intended to be used as a basis for testing heat recovery devices for HVAC-systems, consist of the heat exchanger itself installed in a casing having the necessary air duct connecting elements and in some cases the fans and pumps, but without any additional components of the HVAC-system.



i. Reference condition for air is air with density 1.2 kg/m^3, a dynamic viscosity if 18.2x10^{-6} (kg/m s) and an absolute pressure of 101.3 kPa
ii. Typical summer design thermal conditions shall be:
    a. DBT 27 °C
    b. WBT 19 °C
iii. Absolute pressure is used for air & fluids properties calculation

Test

- The calculations shall be made with standard air density = 1.2 kg/m^3
- In the calculations for classification evaluation, the design conditions for summer time shall be used for air flows, outdoor temperature, mixing ratio, heat recovery efficiency, etc.

- The velocities in the calculations are the air velocities in the AHU cross-section based on the inside unit area for supply, respectively extract air flow of the air handling unit. The velocity is based on the area of the filter section of the respective unit, or if no filter is installed, it is based on the area of the fan section
- The relationship between velocity in the cross section of the unit and internal static pressure drop is considered to be exponential to the power of 1.4:

$$\Delta P_{st-1} = \left(\frac{v_1}{v_0}\right) \times \Delta P_{st-0}$$

- The heat recovery dry efficiency at balanced air volume flows shall be used. If the exhaust air volume flow diverges from supply air volume flow, then for heat recovery efficiency is calculated by considering both air volume flows equal to the supply air volume flow. Here dry efficiency is temperature ratio calculated for dry air without considering condensation.
- For efficiency evaluation the supply air volume for the heat recovery section, summer time shall be taken (the supply air volume flow of the unit can be higher in case of a mixing section).
- Pressure drop increase due to condensation shall not be considered. Air pressure drop shall be considered for standard air density at 1.2 kg/m^3.

An empirical formula for the equivalence between the efficiency and the pressure drop of a heat recovery system, as a function of the outdoor climate, has been derived from numerous energy consumption calculations all over India for Enthalpy wheel and Sensible wheel separately.

$$\mathbf{f_{pe}\left(\frac{Pa}{\%}\right) = -0.0003{t_{ODA}}^2 + 0.0163t_{ODA} + 2.8792}$$

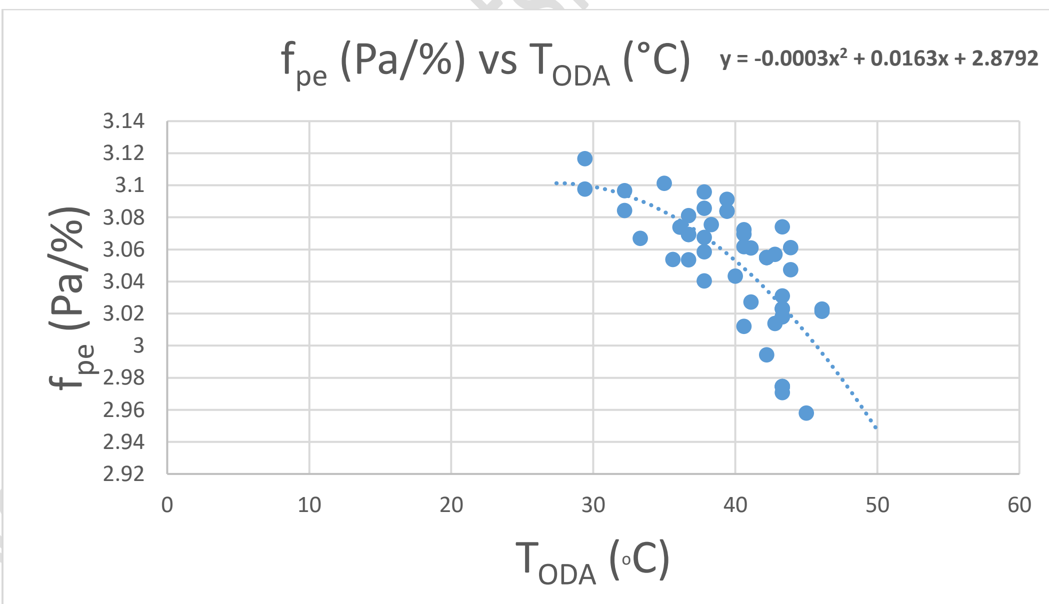


Figure 1 Equivalence Efficiency / Pressure Drop for Heat recovery wheel

These Correlation are valid for Summer condition i.e. when outdoor air temperature in range of 28°C to 50°C

$$f_{pe}\ (Pa/\%) = \frac{HRS\ Pressure\ drop\ (\Delta P)}{100 \times HRS\ Efficiency\ (\eta)}$$

Where

f_{pe} (Pa/%) = Pressure efficiency factor

T_{ODA}(°C) = Outdoor air temperature i.e. Ambient temperature

ΔP = Pressure drop across Heat recovery system

η = Efficiency of heat recovery system

Air Handling Unit subgroups:

Three subgroups, with different label signs, are defined:

1) Units for full or partial outdoor air at design summer temperature <27°C DBT / 19°C WBT

This subgroup will consider the velocity in the filter cross section, the HRS efficiency and pressure drop and the mains power consumption to the fan(s). The class signs are A+ to E. This subgroup comprises units connected to outdoor air with the design outdoor temperature, summer time > 30°C. The unit can be extract only, supply only or supply and extract unit, and can be with or without HRS. If it is a supply only unit, there shall be no consumption and no pressure drop on the extract side. If the unit doesn't have a HRS, the heat recovery efficiency shall be considered as 0.

2) Recirculation units or units with design inlet enthalpy conditions always < 27°C DBT / 19°C WBT
This subgroup will only consider the cross section velocity of the filter section and mains power consumption to the fan(s). The class signs are from A+↪ to E↪. This subgroup includes units with 85% recirculation air, units connected to outdoor air for which the design outdoor temperature during summer time <27°C DBT / 19°C WBT. If it is a supply only unit, there shall be no consumption and no pressure drop on the extract side. Even if the heat recovery efficiency is not taken into account in the calculation, the unit can be with or without HRS.

3) Stand-alone extract air units
This subgroup will only consider the cross section velocity of the filter section and mains power consumption to the fan(s). The class signs are from A+↑ to E↑. This subgroup is for pure extract air units (First reason to allocate an energy label to this kind of unit application is that they could not include heat recovery. Another reason is that the design outdoor temperature has no relevance for such units).

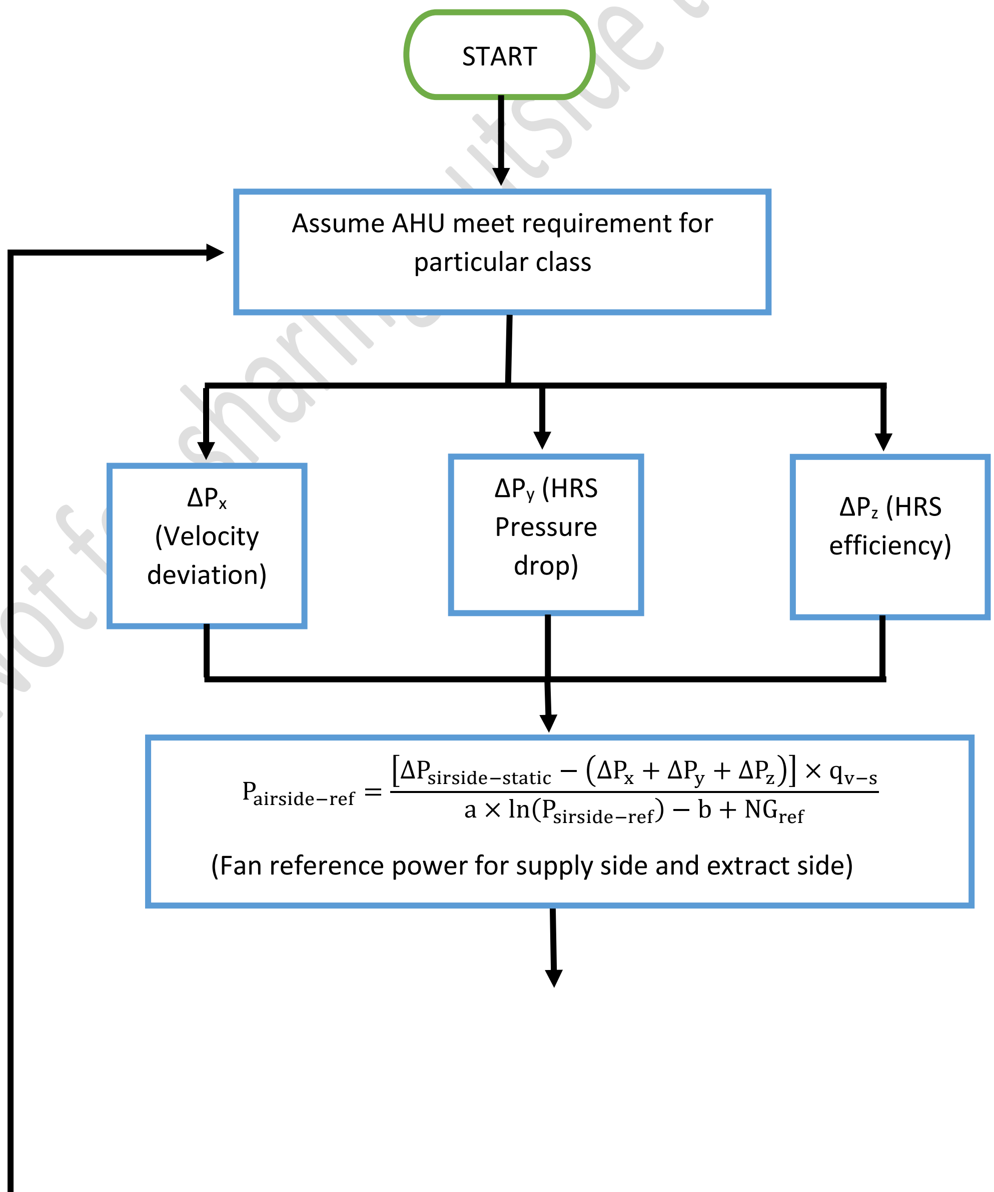
Reference table

Table 18 Reference table for energy efficiency calculations

CLASS	Velocity V_{class} [m/s]	Heat recovery system		Fan Efficiency Grade NGref-class [-]	Thermal performance value (TPV)
		ηclass [%]	Δpclass [Pa]		
A+ /A+↳/A+↑	1.4	83	250	64	1
A /A↳/A↑	1.6	78	230	62	0.8
B /B↳/B↑	1.8	73	210	60	0.6
C /C↳/C↑	2.0	68	190	57	0.4
D /D↳/D↑	2.2	63	170	52	0.2
E /E↳/E↑	No requirement				0

Note: Symbol in the table are:
+ : Units for full or partial outdoor air
↑ : Standalone extract units
↳ : Recirculation units

Methodology



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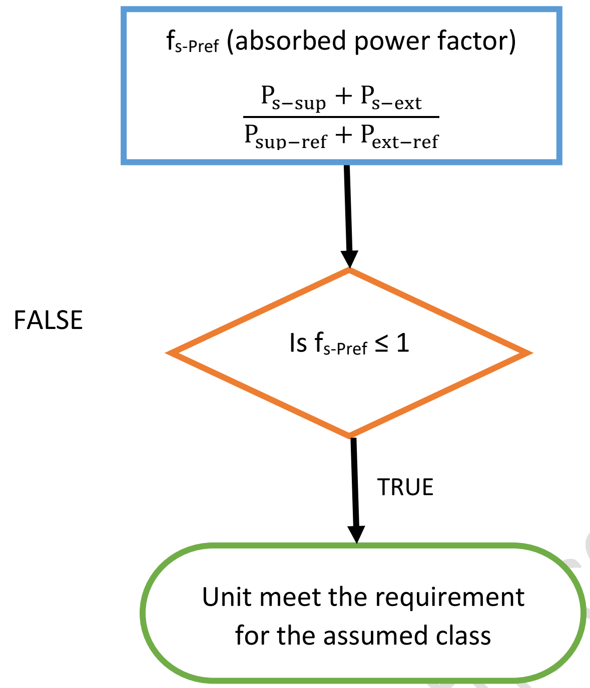

The principle is to establish whether the selected unit with different energy parameters will consume no more energy than a unit that would exactly meet the requirements for the aimed class in Table 8.

Perform the four following steps for respective air sides, supply and/or extract:

1. Assume an AHU is designed to meet the requirements for a particular class, so apply the corresponding class values (subscript "class") from Table 8:
   a. for velocity v_{class}
   b. for Fan Efficiency Grade $NG_{ref\text{-}class}$

   If subgroup 1 (units for full or partial outdoor air at design summer temperature > 30°C), apply also:
   a. heat recovery efficiency η_{class}
   b. pressure drop Δp_{class}

2. Use, for the real air handling unit to be classified at design air flow, summer time, the actual selection values (subscript "s") values:

- fan static pressure increase Δps-static
- external pressure drop $\Delta p_{s\text{-}external}$
- velocity v_s
- power supplied from mains to selected fan $P_{s\text{-}sup}$ if supply air side else $P_{s\text{-}ext}$
- If subgroup 1 use also:
  - HRS dry efficiency η_s
  - HRS pressure drop $\Delta p_{s\text{-}HRS}$

3. Calculate the pressure correction due to velocity Δp_x

- If subgroup 1, then calculate:
  - Pressure correction due to HRS pressure drop Δp_y
  - Pressure correction due to HRS efficiency Δp_z

4. Calculate fan reference power Pair side-ref for the real air handling unit side, i.e. $P_{sup\text{-}ref}$ if supply air side or $P_{ext\text{-}ref}$ if extract air side.

Final check consists in verifying whether the selected unit meets the absorbed power consumption criterion for the aimed class. So calculate the absorbed power factor; f_{s-Pref}. If the value $f_{s\text{-}Pref}$ is equal or lower than 1, the unit meets the requirements for the class. If not, the same calculation procedure shall be repeated for a lower class.

Pressure correction due to velocity: Δp_x

$$\Delta P_x = (\Delta P_{s-internal} - \Delta P_{s-HRS}) \times \left\{1 - \left(\frac{V_{class}}{V_s}\right)^{1.4}\right\}$$

Where

Δp_x = pressure correction due to velocity [Pa]

$\Delta p_{s\text{-}internal}$ = $\Delta p_{s-static}$ - $\Delta p_{s-external}$ internal pressure drop across components; exclusive system effect pressure drops [Pa]

$\Delta p_{s\text{-}static}$ = useful fan static pressure increase measured between fan Inlet and fan outlet [Pa]

$\Delta p_{s\text{-}external}$ = external (ductwork system) pressure drop [Pa]

$\Delta p_{s\text{-}HRS}$ = HRS pressure drop [Pa] (0 if no HRS or subgroup 2 or 3)

v_{class} = value from Reference table [m/s]

v_s = velocity in AHU filter (fan if no filter) cross section [m/s]

With pressure drop correction for velocity, the equivalence figures for primary energy and the corrections for heat recovery it is possible to make a conversion to static pressure surplus or deficit compared to a unit fully compliant with the energy class. A surplus of static pressure means that the real unit demands a higher static pressure; a deficit of static pressure means that the real unit needs a lower static pressure than the class compliant unit. Hence, a surplus of static pressure means higher energy consumption while a deficit of static pressure will mean lower energy consumption!

Pressure correction due to HRS pressure drop: Δp_y

$$\Delta P_y = \Delta P_{s-HRS} - \Delta P_{class}$$

Where

Δp_y = pressure correction due to HRS pressure drop [Pa]
$\Delta p_{s\text{-}HRS}$ = HRS pressure drop (0 if no HRS or subgroup 2 or 3) [Pa]
Δp_{class} = value from Table 8 [Pa] (0 if subgroup 2 or 3)

Pressure correction due to HRS efficiency: Δp_z

$$\Delta P_z = (\eta_{class} - \eta_s + 5 \times cf_{heater}) \times \left(1 - \frac{mr}{100}\right) \times f_{pe}$$

Where

Δp_z = pressure correction due to HRS efficiency [Pa]
η_s = HRS dry efficiency summer [%] (0 if no HRS or subgroup 2 or 3)
η_{class} = Value from Reference class [%] (0 if subgroup 2 or 3)
mr = Mixing ratio, summer (recirculation air / supply air; maximum), allowed range 0 to 85 [%]

f_{pe} (pressure–efficiency factor) for Enthalpy wheel
= $-0.0003*t^2_{ODA} + 0.0163*t_{ODA} + 2.8792$
t_{ODA} = Design outdoor temperature, summer [°C]
cf_{heater} = Correction for electrical heater (i.e. reheater)
= 0 when there is no electrical heater
= 1 when there is an electrical heater

Fan reference power ($P_{sup-ref}$) if supply air side or $P_{ext\text{-}ref}$

The total static pressure correction $\Delta p_x + \Delta p_y + \Delta p_z$ has a negative or positive value. A negative value means that the required static pressure for the selected unit is lower than the static pressure for the class compliant unit would be. For a positive pressure value, it is just the other way round. Now the fan reference power for a class compliant unit has to be derived from the available static pressure of the selected unit by taking into account the calculated pressure corrections.

$$P_{sup-ref} = \frac{\left[\Delta P_{s-static} - \left(\Delta P_x + \Delta P_y + \Delta P_z\right)\right] \times q_{v-s}}{a \times \ln\left(P_{sup-ref}\right) - b + NG_{ref}}$$

$$P_{ext-ref} = \frac{\left[\Delta P_{e-static} - \left(\Delta P_x + \Delta P_y + \Delta P_z\right)\right] \times q_{v-s}}{a \times \ln(P_{ext-ref}) - b + NG_{ref}}$$

Where

$P_{airside\text{-}ref}$ = fan reference power [kW] (use $P_{sup-ref}$ for supply air side or $P_{ext-ref}$ for extract air side)
$P_{sup\text{-}ref}$ = fan reference power for supply air side [kW]
$P_{ext\text{-}ref}$ = fan reference power for extract air side [kW]

$\Delta p_{s\text{-}static}$ = useful fan static pressure increase measured between fan Inlet and fan outlet in supply side [Pa]

$\Delta p_{e\text{-}static}$ = useful fan static pressure increase measured between fan Inlet and fan outlet in extract side [Pa]
qv-s = air volume flow rate [m3/s]
NGref = Fan Efficiency Grade corresponding to the class value
a, b = coefficients as per Table 9

Table 1 Coefficients for the calculation of $P_{air\ side\text{-}ref}$

$P_{air\ side\text{-}ref}$	a	b	NG_{ref}
≤ 10 kW	4.56	10.5	$N_{gref\ class}$
> 10 kW	1.1	2.6	$N_{gref\ class}$

Absorbed power factor (f_{s-Pref})

$$f_{s-Pref} = \frac{P_{s-sup} + P_{s-ext}}{P_{sup-ref} + P_{ext-ref}} \leq 1$$

Where:
$f_{s\text{-}Pref}$ = absorbed power factor
$P_{s\text{-}sup}$ = active power supplied from the mains, including any motor control equipment, to selected supply air fan [kW]
$P_{s\text{-}ext}$ = active power supplied from the mains, including any motor control equipment, to selected extract air fan [kW]
$P_{sup\text{-}ref}$ = supply air fan reference power [kW]
$P_{ext\text{-}ref}$ = extract air fan reference power [kW]

Annexure (informative)
Overall rating of AHU

Overall Rating is based on both Mechanical Performance as well as Thermal performance.

~~To determine Overall performance value weightage of 35% is given to Mechanical performance value and 65% weightage is given to thermal performance value (TPV) and~~ below formula can be used to ~~determine to~~ calculate Overall performance value (OPV).

$$Overall\ Performance\ Value\ (OPV) = 35\%\ of\ (MPV) + 65\%\ of\ (TPV)$$

Note:

MPV – Mechanical performance value calculated as in Table 11

TPV – Thermal Performance Value calculated as in Table 18

Based on the Overall Performance Value, rating is decided and below table shows the ratings such as A rating is Provided if Overall performance value is greater than 0.8. Similarly, B rating is provided if OPV is greater than and equal to 0.6 and less than 0.8 and so on.

The overall performance value that results into assignment of rating may get revised in future, taking into consideration the Enhanced energy performance and Indoor Air Quality as a Major Criteria of evaluation.

Table 19 Overall rating for Air handling unit

Rating based on Overall Performance	Overall performance value (OPV)
A	OPV ≥ 0.8
B	0.6 ≤ OPV< 0.8
C	0.4 ≤ OPV< 0.6
D	0.2 ≤ OPV< 0.4
E	OPV < 0.2