EUROVENT 6/11

THERMAL TEST METHOD FOR DUCTED FAN COIL UNITS

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1. PURPOSE

The purpose of this document is to describe the measurement method of the cooling (sensible and latent) and heating capacities and the various characteristics of ducted fan coil units at one selected speed with a available static pressure equal to 50 Pa at medium speed. The test results describe the performance of the FC in the real condition of build installation where, as usual, the static pressure is fixed at medium speed.

2. NORMATIVE REFERENCES

- *EN 1397:2001 - Heat Exchangers - Hydronic room fan coil units - Test procedure for establishing the performances*
- *Eurovent 6/3:1996 – Thermal test method for ducted fan coil*

3. DEFINITIONS

A **Ducted Fan Coil Unit** is a factory-made assembly which provides the functions of cooling and/or heating air using hot or chilled water with air flow to the room ensured by one or more electrically driven fans. Fan Coil Units may be of the chassis style, concealed within the building structure with ducting appropriately connected to the inlet and/or outlet of the unit.

The principal components are:

- one or more heat exchangers
- one or more fans with electric motors
- an appropriate enclosure
- condensed water collecting facilities when cooling
- air filter
- discharge plenum

- **Total Cooling Capacity**: Total heat energy removed from the air divided by the defined interval of time, expressed in Watts.
- **Sensible Cooling Capacity**: Sensible heat energy removed from the air divided by the defined interval of time, expressed in Watts.
- **Heating Capacity**: Total heat energy supplied to the air divided by the defined interval of time, expressed in Watts.
- **Fan Power Input:** Average electrical power input of the Fan Coil Unit within the defined interval of time, expressed in Watts**.**
- **Water Pressure Drop:** Difference between input and output water static pressure.
- **Available Static Pressure:** The available air static pressure at the discharge of the air way cross section of the unit.

4. TESTING REQUIREMENTS

The thermal tests shall be performed in accordance with the following specifications:

- discharge plenum installed
- air filter installed
- with static pressure of 50 Pa at medium speed. For units with more than 3 speeds, the manufacturers shall specify a medium speed (see par.6.6 for damper setting)
- the speeds of choice has to be hard wired to the fan

For cooling test, the following Standard rating conditions shall be used:

Air Inlet	Dry bulb T. (°C)	27
	Wet Bulb T. (°C)	19
Water	Water inlet T. (°C)	7
	Water outlet T. (°C)	12
Air outlet	Available static pressure at medium fan speed (Pa)	50

For heating test, the following Standard rating conditions shall be used:

Air Inlet	Dry bulb T. (°C)	20
	Wet Bulb T. (°C)	15max
Water for 2 pipes units	Water inlet T. (°C)	50
	Water outlet T. (°C)	*
Water for 4 pipes units	Water inlet T. (°C)	70
	Water outlet T. (°C)	60
Air outlet	Available static pressure at medium fan speed (Pa)	50

* Water flow rate same as for the cooling test

The nominal voltage is 230 V, 50 Hz frequency, if not specified differently by the manufacturer.

5. TEST SPECIFICATIONS

The thermal test of ducted fan coils shall be performed in a calibrated or balanced calorimeter built in compliance with the requirements ISO 5151, EN 14511 and EN 1397 standard.
The tests under heating/cooling conditions shall be carried out by keeping the water and the air rating conditions by the reconditioning equipment, whose capacity (water and air side) can be measured and controlled to balance with high precision the performances of the unit. For the cooling test an humidifier should allow to balance also the dehumidification capacity of the UUT so to maintain the rating air wet-bulb conditions.
In the surround room of the test balanced chamber, a dry bulb temperature shall be maintained equal to the test room one.

Inside surfaces of the calorimeter compartments, should be of non-porous material with all joints sealed again air and moisture leakage. Access doors should be tightly sealed against air moisture leakage by use of gaskets or other suitable means.
The size of the compartments (see table 1) should be sufficient to avoid any restriction to intake or discharge openings of the fan coil units.

Table 1 – Sizes of compartments

Maximum heating or cooling capacity of unit (*)	Suggested minimum inside dimensions of each room calorimeter		
	Width	Lenght	Depht
3 000 W	2,4 m	2,1 m	1,8 m
6 000 W	2,4 m	2,1 m	2,4 m
9 000 W	2,7 m	2,4 m	3,0 m
12 000 W	3,0 m	2,4 m	3,7 m

(*) All figures have been voluntarily rounded

5.1 Calibrated room type-calorimeter

The calibrated room-type calorimeter is shown in figure 1. Each calorimeter, including the separating partition, should be insulated to prevent heat leakage (incl. radiation) in excess of 5% of the test unit capacity. It is recommended that the air space permitting free circulation be provided under the calorimeter floor.

Heat leakage in the room side equipped for this type of tests may be determined by the following method:
a) all openings should be closed
b) the compartment may be heated by electric heaters for example to a temperature of at least 11°C above the surrounding ambient temperature
c) the ambient temperature should be mantained constant + 1°C outside all six enveloping surfaces of the compartment including the separating partition

If the construction of the partition is identical with that of the other walls, the heat leakage through the partition mat be determined on the proportional area basis.

For calibrating the heat leakage through the separating partition alone, the following procedure may be used:
a) all openings should be closed
b) the compartment may be heated by electric heaters for example to a temperature of at least 11°C above the the ambient surrounding the five enveloper surfaces without the separating partition
c) the adjoining area on the other side of the separating partition is raised to equal the temperature in the heated compartment
d) the ambient temperature should be mantained constant + 1°C outside all six enveloping surfaces of the compartment including the separating partition

The difference in heat between the first and the second test will permit determination of the leakage through the partition alone.

1. Removable panels
2. Heater
3. Cooling coil
4. Humidifier
5. Room side compartment
6. Outdoor side compartment
7. Reheat coil
8. Fan
9. Mixers
10. test unit
11. Air sampling tubes

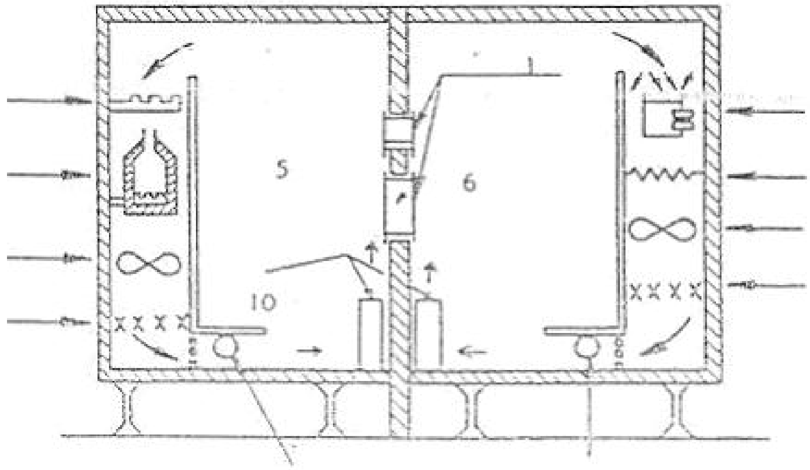

Figure 1 – Calibrated room type-calorimeter

Cool leakage in the room side equipped for this type of tests may be determined by cooling the compartment to a temperature at least 11°C below the ambient temperature (on six sedes) and carry out a similar analysis.

5.2 Balanced ambient room type-calorimeter

The balanced ambient room-type calorimeter is shown in figure 2. It operates on the principle of maintaining the dry bulb temperatures surrounding the particular compartment equal to the dry-bulb temperatures the particular compartment equal to the dry-bulb temperatures maintained within the compartment.

Controlled temperature air space
1. Room side compartment
2. Removable panels
3. Heater
4. Cooling coil
5. Humidifier
6. Outdoor side compartment
7. Reheat coil
8. Fan
9. Test unit
10. Mixers
11. Air sampling tubes

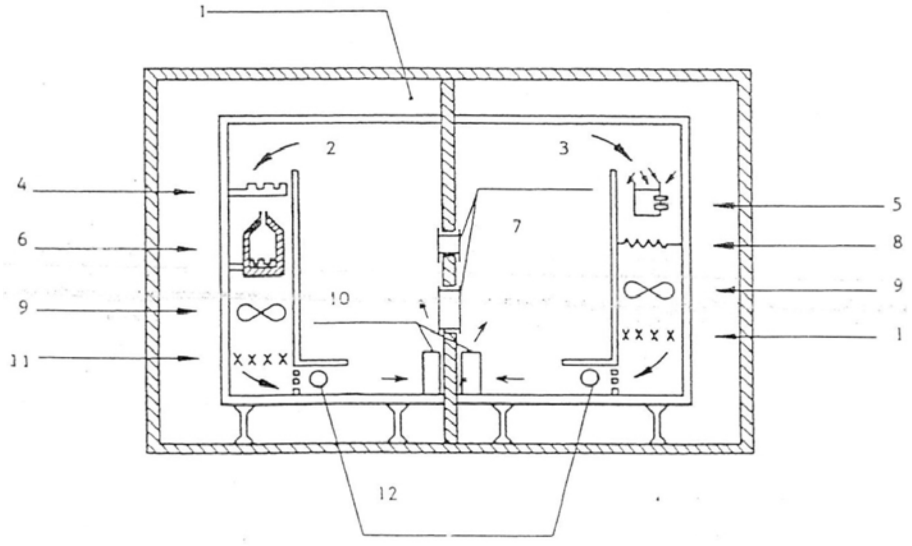

Figure 2 – Balanced room type calorimeter

If the ambient wet-bulb temperature is also maintained equal to that within the compartment, the vapour-proofing provisions, previously determined, are not required.

The floor, ceiling and walls of the calorimeter compartments should be spaced a sufficient distance from the floor, ceiling and walls of the controlled areas in which the compartments are located in order to provide uniform air temperature in the intervening space. It is recommended that the distance be at least 0,3 m. Means should provided to circulate the air within the surrounding space to prevent stratification.

Heat leakage through the separating partition should be introduced into the heat balance calculation and may be calibrated with clause 5.1, ore may be calculated.

It is recommended that the floor, ceiling and walls of the calorimeter compartments be insulated so as to limit heat leakage (including radiation) to not more than 10% of the air conditioner capacity, with a 11°C temperature difference, or 300 W for the same temperature difference, whichever is greater, as tested using the procedure given in clause 5.1.

5.3 Air and water reconditioning equipment

The room chamber equipped for ducted fan coil test should be provided with a reconditioning equipment to maintain specified air flow and water prescribed conditions. Air and water reconditioning equipment should consist respectively of the following facilities:
On the air side:

- heaters to supply sensible heat, an humidifier to supply moisture for the cooling tests
- a cooling coil with by-pass dampers and supplied with variable temperature water or variable water quantity to control the dry bulb temperature for the heating tests

On the water side:

- an essentially two energy generators respectively producing warm or cold water that permit to maintain the rating water inlet and outlet conditions. The heating or medium cooling flow can be made after the diagram of figure 3.

The test compartment should have fans of sufficient capacity to circulate not less than twice the quantity of air discharged by the fan coil unit. Perforate plates or other suitable grilles should be provided at the discharge openings from the reconditioning euipment to avoid face velocities exceeding 0,5 m/s. Sufficient space should be allowed in front of any inlet or discharge grilles of the fan coil unit to avoid interference with tha air flow.

5.4 Installation of the ducted fan coil units within the compartment

Ducted fan coil units should be located in normal operating position parallel to the floor on an appropriate holder at a distance from the side walls as equal as possible.
Fan coil should be connected to the heating or cooling medium flow (hot or cold water) by insulated pipes that pass through the compartment enclosure.
The available static pressure at the discharge air-way cross section should be set to the rating conditions by an essential system that consists of a duct and a damper.

The outlet ducts (for lateral and frontal spigot units) shall have the following characteristics:

- they shall contain all the spigots of the discharge plenum of the unit.

- the minimum distance between the lateral outlet spigot and the side plenum wall shall be 0,5 x hydraulic diameter
- the maximum discharge plenum height shall be lower than 1,25 x the unit height
- the angle of the restriction between the discharge plenum and the damper must lower than 15°
- the discharge plenum length must be longer than two hydraulic diameters (of the rectangular plenum section) defined in the ISO 5801 standard
- they shall be acoustically insulated
- to avoid set-up problems, the flexible pipes installation could be used for big units only

N.B. see 6.2 paragraph of Eurovent 6/10 document figures

There should not be any additional resistance on the UUT air suction except the normal operating filters included by the manufacturer.

5.5 Air dry-bulb and wet-bulb temperatures measurement points

It is recognised that in both the room-side and outdoor-side compartments, temperature gradients and air-flow patterns result from the interaction of the reconditioning equipment and the fan coil unit being tested. Therefore, the resultant conditions are peculiar to, and dependent upon, a given combination of compartment size, arrangement and size of reconditioning equipment, and the fan of unit air-discharge characteristics.
Accordingly, no single location for the measurement of dry and wet-bulb temperatures can be specified which will be acceptable for all combinations of calorimeter facilities and fan coil units which may be tested.

It is intended that the specified test temperatures surrounding the unit being tested should simulate as nearly as possible the normal conditions of use of such a unit.

The point of measurement of specified test temperatures should be such that the following conditions are fulfilled:
- the measured temperatures should be representative of the temperature surrounding the unit, and simulate the conditions encountered in an actual application
- at the point of measurement of specified test temperatures of air should not be affected by air discharged from the test unit. This makes it mandatory that the temperatures are measured upstream of any recirculation produced by the test unit.

Note :
- If the conditions of air movement and airflow patterns in the calorimeter compartments are favourable, the temperatures may be measured at the outlet of the reconditioning equipment.
- If it has been established that the unit being tested does not produce any bypassed air from discharge to intake opening, the specified temperatures may be measured immediately upstream of such intake opening.

5.6 Water inlet and outlet pressure and temperature measurement points

The water inlet and outlet temperature should be measured with a sensor dipped in the insulated pipe connection so to avoid any risk of uncorrect measurement caused by stratification and medium flow course. The inlet and outlet temperature sensors should be as close as possible to the UUT so to have an high precision measurement. If the distance between the unit and the T sensors couldn't be reduced too much due to the particular set-up, the pipes insulation could be improved so to avoid any thermal dispersion.
The water pressure sample points should be located in the middle of a rectilinear peace of insulated pipe with the following characteristics:

- constant diameter equal to the UUT ones
- a minimum lenght of ten times the UUT connection diameter
- located between the temperature measurement points indicated above and the UUT connections

The available static pressure should be measured at the discharge air way cross section of the unit by a series of pressure tapping in compliance with the indications of ISO 5801 in accordance with the following specifications:

- at zero heat load
- at 20 ± 2 °C in isotherm conditions

6.7 Condensate measurements

During a cooling capacity test, the condensate produced by the UUT should be drained and collected to measure the water condensate mass flow-rate by dividing the mass for the test scan time. Also the water supplied to the humidifier should be checked so to control the precision of the condensate mass flow rate measurement. The difference between the two measures should be less of 10 %.

6. UNCERTAINTY OF MEASUREMENTS

The uncertainties of measurement shall not exceed the values specified in table 2.

Measured quantity		*Uncertainty of measurement*
Liquid	*Temperature*	± 0,1 K
	Flow rate	± 1 %
	Static pressure difference	± 5 % (DP > 100 Pa)
		± 5 Pa (DP < 100 Pa)
Air	*Dry bulb temperature*	± 0,2 K
	Wet bulb temperature	± 0,2 K
	Static pressure difference	± 5 % (DP > 100 Pa)
		± 5 Pa (DP < 100 Pa)
Electrical quantities	*Power*	± 1 %
	Voltage	± 0,5 %
	Current	± 0,5 %
	Frequency	± 0,5 %

Table 2 – Uncertainties of measurement for indicated values

8. TEST PROCEDURE

8.1 Nomenclature and calculations

a) The total cooling capacity is calculated by the following formula:

$$\phi_{fd} = q_l (h_{lout} - h_{lin}) \qquad [W]$$

where:

ϕ_{fd} is the total cooling capacity (W)

q_l is the unit water mass flow-rate (g/s)

h_{lout} is the unit water outlet specific enthalpy (kJ/kg)

h_{lin} is the unit water inlet specific enthalpy (kJ/kg)

b) The heating capacity is calculated by the following formula:

$$\phi_{hd} = q_l (h_{lin} - h_{lout}) + P_t \qquad [W]$$

where:

ϕ_{hd} is the heating capacity (W)

q_l is the unit water mass flow-rate (g/s)

h_{lin} is the unit water inlet specific enthalpy (kJ/kg)

h_{lout} is the unit water outlet specific enthalpy (kJ/kg)

P_t is the power input of the UUT (W)

c) The dehumidification capacity is calculated by the following formula:

$$\phi_{ld} = q_{mc} * h_w \qquad [W]$$

where:

ϕ_{ld} is the dehumidification capacity (W)

q_{mc} is the water mass flow-rate condensed by the unit (g/s)

h_w is the water latent heat of vaporisation (2500,4 kJ/kg)

d) The sensible cooling capacity is calculated by the following formula:

$$\phi_{sd} = \phi_{fd} - \phi_{ld} \qquad [W]$$

where:

ϕ_{sd} is the sensible cooling capacity (W)

ϕ_{fd} is the total cooling capacity (W)

ϕ_{ld} is the dehumidification capacity (W)

e) The air-side performance (balanced calorimeter method) should be calculated by the following formulas:

$$\phi_{fi} = q_w (h_{win} - h_{wout}) + q_{mc} * (c_{pw1} * T_{whu} - c_{pw2} * T_{wb}) + \phi_{lp} + P_{in} + P_t \qquad [W]$$

$$\phi_{hi} = q_w (h_{wout} - h_{win}) + \phi_{lp} - P_{in} \qquad [W]$$

where:

ϕ_{fi}	is the total cooling capacity – air side (W)
ϕ_{hi}	is the heating capacity – air side (W)
q_w	is the brine mass flow-rate through the cooling/heating coil (g/s)
h_{win}	is the brine inlet specific enthalpy (kJ/kg)
h_{wout}	is the brine outlet specific enthalpy (kJ/kg)
q_{mc}	is the water mass flow-rate condensed by the unit (g/s)
c_{pw1}	is the water specific heat at T_{whu} temperature (kJ/kg°C)
T_{whu}	is the humidifier inlet water temperature (°C)
c_{pw2}	is the water specific heat at T_{wb} temperature (kJ/kg°C)
T_{wb}	is the unit condensate temperature (°C)
ϕ_{lp}	is the heat leakage through the test chambers (W)
P_{in}	is the total power input of the test chamber (W)
P_t	is the unit power input (W)

The two simultaneous determinations on water and air side should agree within 5 % to validate the thermal test.

8.2 Procedure of testing

The procedure of testing is the following:

1) the unit shall be tested at medium speed;

2) with an anemometer shall be verified that the air velocity in the surround of the UUT is less of 0,5 m/s

3) the damper shall be set to have a static pressure of 50 Pa at the discharge air way cross section of the UUT in the conditions specified at point 6.6

4) the water flow rate and the set points shall be set to have the water inlet and outlet temperatures (7/12°C)

5) the air conditions of the indoor balanced chamber, measured by the sampling device, shall be set to the dry and wet bulb temperatures (27/19°C)

6) the steady state conditions are achieved when all the measured quantities remain constant for a minimum duration of 1 hour within to the tolerances given in the *Eurovent 6/3 -1996 standard*

7) when the steady state conditions are achieved, the test could start and it shall be extended for almost 30 minutes and all the relevant data shall be stored continuously for all the duration of the test

8) in the heating mode for a 4 pipes model the water flow rate and the set points shall be set to have the water inlet and outlet temperatures at 70/60°C.

9) in the heating mode for a 2 pipes model the water mass flow-rate shall be set equal to the cooling mode while the water inlet temperature shall be 50°C. The outlet water temperature will be consequence of the flow-rate fixed in the cooling mode

10) the air conditions of the indoor balanced chamber, measured by the sampling device, shall be set to the dry/wet bulb temperature (20/15max °C)

11) the steady state conditions are achieved when all the measured quantities remain constant for a minimum duration of 1 hour within to the tolerances given in the *Eurovent 6/3 -1996 standard*

12) when the steady state conditions are achieved, the test could start and it shall be extended for almost 30 minutes and all the relevant data shall be stored continuously for all the duration of the test

8.3 Test results

The cooling and heating test data are indicated respectively in the following tables:

Table 3 – Data to be recorded for a cooling test

Electrical quantities	Unit
Voltage	V
Current	A
Total power input	W
Frequency	Hz

Air inlet conditions	Unit
Atmospheric pressure	kPa
Dry bulb temperature, air inlet	°C
Wet bulb temperature, air inlet	°C
Wet bulb temperature, air leaving	°C
Outer space dry bulb temperature	°C

Water side	Unit
Water temperature, inlet	°C
Water temperature, outlet	°C
Water flow-rate	l/h
Water pressure drop	kPa
Cp water, inlet	kJ/kg°C
Cp water, outlet	kJ/kg°C
Water density, inlet	Kg/dm^3
Total Cooling capacity	W
Condensate mass flow-rate	g/s
Latent Capacity	W
Sensible capacity	W

Air side	Unit
Brine coil capacity	W
Power input to the compartment	W
Power input to the UUT	W
Water humidifier-condensate balance	W
Dispersion between center wall	W
Total Cooling capacity	W

Humidifier flow-rate	g/s
Latent capacity	W
Sensible capacity	W
Balance direct/indirect	%

Table 4 – Data to be recorded for an heating test

Electrical quantities	Unit
Voltage	V
Current	A
Total power input	W
Frequency	Hz

Air inlet conditions	Unit
Atmospheric pressure	kPa
Dry bulb temperature, air inlet	°C
Wet bulb temperature, air inlet	°C
Outer space dry bulb temperature	°C

Water side	Unit
Water temperature, inlet	°C
Water temperature, outlet	°C
Water flow-rate	l/h
Water pressure drop	kPa
Cp water, inlet	kJ/kg°C
Cp water, outlet	kJ/kg°C
Water density, inlet	Kg/dm^3
Heating capacity	W

Air side	Unit
Brine coil capacity	W
Power input to the compartment	W
Power input to the UUT	W
Dispersion between center wall	W
Heating capacity	W
Balance direct/indirect	%