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“Chilled air” refrigerated display cabinet test methodology

July 2019

About RD&T

RD&T specialise in:

- Retail and commercial cabinet testing, development and optimisation.
- Design and optimisation of prototype refrigeration systems.
- Heat and mass transfer modelling.
- Energy reduction and optimisation of refrigeration facilities and systems.

RD&T are ISO 9001 certified.



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Statement of intent

This document was prepared by RD&T on behalf of CBES Limited and the intent is for it to be used as a performance testing methodology for air cooled refrigerated display cabinets. Feedback on the proposed methodology is welcomed to help refine and improve this document.

This report has been prepared by:

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Checked as a final copy by:

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Date of report:

1 July 2019

File reference number:

RDT1171

This report shall not be reproduced except in full without written approval from RD&T. The test report details any deviations from, additions to, or exclusions from the test method, and contains information on specific test conditions, such as environmental conditions.

Change record:

<i>Date</i>	<i>Change</i>	<i>Reason for change</i>
1/7/19	Changes to previous document of 15/3/19.	Comments from ICF.

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Scope

'Chilled air' refrigerated display cabinets that are designed to work with a ducted air system served by a remote refrigeration system where the compressor, condenser, evaporator and all parts of the refrigeration system are located at a separate location from the cabinet.

Notes:

The scope only includes 'chilled air' refrigeration with passive defrosting (off cycle). At the time of writing, no known air ducted low temperature (freezer) systems are available. The test methodology would need to be revised to consider active (electrical, hot gas etc), defrosting.

Terms, definitions, symbols and abbreviated terms

Terms and definitions

Air handling and refrigeration unit (AHRU). A device used to regulate and circulate cold air. The AHRU used for this purpose differs somewhat from a typical AHU, in that it provides air at a suitable temperature for a chilled display cabinet rather than comfort air conditioning and heating. For the purposes of testing, the AHRU unit does not have to be a self-contained unit, it can incorporate a condensing unit, remote from the evaporator and ventilation fan.

Humidity. The quantity of water vapour in the air. Can be represented as absolute humidity, relative humidity or specific humidity.

Symbols

t	Running time of the fan, in hours per day.
T_{mrun}	Arithmetic average of evaporator-saturated temperature, in K
v	Specific volume of the air passing through the fan, in m^3/kg
θ_i	Secondary refrigerant temperature at the cabinet inlet, in K.
Φ	The instantaneous heat extraction rate, in kW.
Δp	Pressure difference across the cabinet shall be measured to an accuracy, in kPa,
μ	Efficiency of the fan.

Abbreviations

CFEC	Fan electrical energy consumption, in kWh/24h.
DEC	Direct daily electrical energy consumption, in kWh/24h.
F	Factor to take into account the pressure drop of the entire system, not just the display cabinet.
h_i	Specific enthalpy of air entering the cabinet, in kJ/kg.
h_o	Specific enthalpy of the air as it exits the cabinet, in kJ/kg.
q_{mrun}	Mass flow rate of air in the duct, in kg/s.
Q_{tot}	Total heat extraction, in kW.
REC	Refrigeration daily electrical energy consumption, in kWh/24h.

REC_{RA}, Revised refrigeration daily electrical energy consumption, in kWh/24h, for chilled air refrigerating system.

RH. Relative humidity, in %.

Test method

The proposed methodology is for chilled air cabinets to be tested in accordance with BS EN ISO 23953:2015, with the suggested amendments and additional clauses outlined in Table 1. It is stated next to each of the relevant clauses whether the clause is the same as in the standard (no change) or whether it has been modified to account for the cabinet being a 'chilled air' refrigerated display cabinet.

Table 1. EN23953:2015 clauses and their status regarding air cooled cabinets.

4.2.2 Classification according to temperature (see Appendix A)	No change
4.2.5 Energy consumption	No change
4.2.6 Specific Energy Consumption	No change
5.2.2 Linear dimensions, areas and volumes	No change
5.3.1.1 Test room - General design, walls, floor and radiant heat	No change
5.3.1.2 Test room (empty) - Thermal and air flow characteristics	No change
5.3.1.3.1 Test room climate classes	No change
5.3.1.3.2 Climate measuring point	Amend
5.3.1.4 Test packages and life-time	No change
5.3.1.5 M-packages and life-time	No change
5.3.1.7 Instruments, measuring equipment and measuring accuracy	Amend
5.3.2.1 Cabinet selection, installation and positioning within the test room	Amend
5.3.2.2 Air movement	No change
5.3.2.3.1 General	No change
5.3.2.3.2 Loading heights	No change
5.3.2.3.3 M-package locations	No change
5.3.2.3.3.1 Longitudinal section	No change
5.3.2.3.3.2 Cross-section	No change
5.3.2.4 Running in	No change
5.3.2.5 Stable conditions	No change
5.3.2.6 Test period	No change
5.3.2.7 Lighting and night-covers	No change
5.3.2.8 Accessories	No change
5.3.2.9 Liquid refrigerant inlet condition	No change
5.3.2.10 Power supply	No change
5.3.3.1 Test conditions	No change
5.3.3.2 Closed refrigerated cabinets	No change
5.3.3.4 Temperature curves of M-packages	No change
5.3.3.5 Calculation of average mean temperature	No change
5.3.5.1 Test conditions	No change
5.3.5.3 Cabinets with remote condensing unit	No change
5.3.6.1.1 General	No change

5.3.6.1.4 Specific test conditions for cabinets intended for connection to air duct type refrigeration systems.	New section
5.3.6.2.3 Cabinets intended for connection to air duct type refrigeration systems.	New section
5.3.6.3.1 General	No change
5.3.6.3.2 Determination of heat extraction rates	No change
5.3.6.3.3 Calculation of REC	Modified
5.3.6.3.4 Calculation of TEC	No change
5.3.6.3.4 Calculation of SEC	No change

The following sections outline how the new clauses should be modified to allow air cooled cabinets to be tested and compared fairly with technologies which are already included in the standard.

Text to be inserted into clauses are written in *italics*.

5.3.1.3.2 Climate measuring point

If the condensing unit is in room, then the standard needs to consider that air flow from the condenser shall not affect the climate measuring point. It is suggested that that the following is inserted into this clause:

For ‘chilled air’ refrigerated display cabinets, the warm condenser air flow from the AHRU shall be prevented from influencing the temperature at the climate measuring point by placing the AHRU downstream of the cabinet in relation to the room air flow. Air deflectors or other suitable means shall be applied to prevent the influence of the AHRU on the climate measuring point if necessary.

5.3.1.7 Instruments, measuring equipment and measuring accuracy.

It is suggested that the following is inserted into this clause:

Specially for the test of ‘chilled air’ refrigerated display cabinets;

temperature of air in the duct downstream and upstream of the cabinet shall be made to an accuracy of ± 0.2 K.

wet bulb temperature of the air in the duct shall be made to an accuracy of ± 0.4 K.

mass flow rate of air through the duct shall be measured to an accuracy of ± 5 %.

pressure difference across the cabinet shall be measured to an accuracy of ± 5 Pa (if $\Delta p \leq 100$ Pa) or ± 5 % (if $\Delta p > 100$ Pa).

5.3.2.1 Cabinet selection, installation and positioning within the test room

It is suggested that that the following is inserted into this clause:

For ‘chilled air’ refrigerated display cabinets, with the condensing unit in the room, the condensing unit shall be installed downstream of the cabinet in relation to the room air flow. The condenser fan shall not blow towards the cabinet. It shall ideally be blowing perpendicular to the room air flow, in the direction from front to back of cabinet. If the condenser fan is blowing in the direction of the room air flow,

downstream of the cabinet, then measurements shall be taken to ensure that it does not create a draught that interferes with the cabinet air flow.

The air flow ducting (used for supply and return air to the cabinet) shall ideally not protrude upstream, regarding room air flow, from the leading edge of the cabinet (

Figure 1). If this is not possible due to length of ducting constraints, then the ducting which protrudes upstream of the cabinet should be kept behind a supply wall extending from the rear of the cabinet (line A). No ducting shall be placed in area B.

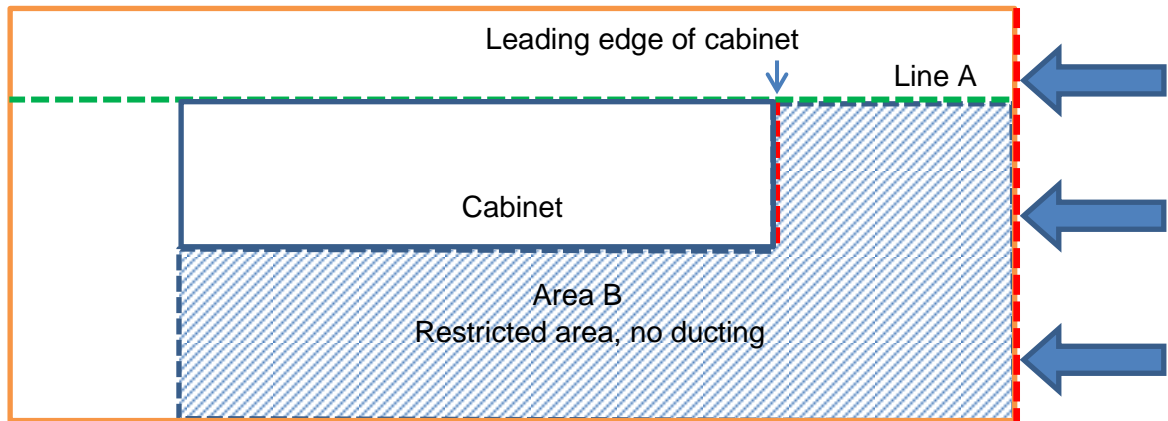


Figure 1. Layout of cabinet in room, showing direction of room air flow, marked by arrows and area where ducting cannot be located.

5.3.6.1.4 Specific test conditions for 'chilled air' refrigerated display cabinets

It is suggested that that the following be inserted into this new clause: *The 'chilled air' refrigerated display cabinet selected for the test shall be capable of operating as follows:*

- with the air temperature and flow rate supplied to the cabinet as specified by the manufacturer;
- with the air supplied liquid free (no droplets of water or ice) and less than 100% RH.

Air supply flow rate, temperature and humidity shall be stated in the test report.

Temperature, humidity and pressure of the air entering and exiting the cabinet inside the ducts shall be measured. The ducts shall be insulated between the cabinet and the sensors and beyond for at least 150 mm, or a length equal to the internal width of the duct, whichever is the larger. The sensors (temperature, pressure and humidity) will ideally be located within 150 mm of the cabinet or the internal width of the duct, whichever is the larger. If this is not possible, heat leakage through the ducting should be taken into account in the uncertainty of the measurement of the heat extraction rate.

Temperature measuring points shall be arranged in order to obtain mean temperature within the uncertainties given in 5.3.1.7. It is suggested a minimum of 3 measurements upstream and downstream are made, however, more may be required, if the temperature profile is non uniform.

A flow meter shall be installed in either the discharge or return duct. The duct must be leak free (no air leakage into or out of duct) between the flow meter and the cabinet.

During defrost and cycling, the air from the supply duct should continue to flow through the cabinet.

The heat extraction rate necessary for the cabinet shall be determined from temperature, pressure and flow rate readings which allow a resultant accuracy of $\pm 5\%$.

5.3.6.2.3 Cabinets intended for connection to air duct type refrigeration systems.

It is suggested that that the following is inserted into this new clause:

The

rate, Φ is determined below;

$$\Phi = q_{mrun}(h_o - h_i)$$

Where

q_{mrun} is the mass flow rate of air in the duct

h_o is the enthalpy of the air as it exits the cabinet

h_i is the enthalpy of air entering the cabinet.

The enthalpy is a function of the temperature, relative humidity and pressure of the air.

5.3.6.3.3 Calculation of REC

The calculation of REC for a 'chilled air' refrigerated display cabinet is based on the methodology used for a cabinet intended for an indirect type refrigerating system, where, CFEC is adapted from CPEC and REC_{RA} is based on REC_{RI} .

Compared to liquid (e.g. water), gas (e.g. air) is a poor conductor of heat and therefore for the same size evaporator, the air ducted system will require a lower evaporating temperature than a conventional indirect type refrigerating system. For an indirect type refrigerating system in EN23953:2015:

$$T_{mrun} = \theta_i - 4K$$

Where θ_i is the secondary refrigerant temperature at the cabinet inlet, in K

Therefore, it would appear appropriate for 'chilled air' refrigerated display cabinets that T_{mrun} should be reduced by a greater degree (>4 K). We feel that it would not be appropriate to suggest an alternative value without seeing measured data for an air cooled system. At the moment that has not been possible. It is possible that other stakeholders may have an opinion on what the evaporating temperature should be.

It is suggested that that the following is inserted into this clause:

Electrical energy is consumed by the fan(s) necessary for circulating the air in the duct. This consumption is not measured and is dependent on the practical design of the ducting circuit. The fan daily energy consumption (CFEC) in kilowatt hours per 24-h period is calculated using the following equation;

$$CFEC = v \cdot q_{mrun} t \frac{(F \cdot \Delta P)}{\mu}$$

Where;

v is specific volume of the air passing through the fan in cubic metres per kilogram.

q_{mrun} is the average of the air duct mass flow during t_{run} , in kilograms per second.

t is the running time of the fan in hours per day. This would be expected to be 24, as air ducted systems would likely be running the fan all the time. However, this may need alteration, if this is not the case.

ΔP is the pressure drop across the cabinet in kPa,

μ is the efficiency of the fan. A value of 0.5 shall be used. Alternative values may be used with appropriate justification.

F is a factor to take into account the pressure drop of the entire system, not just the cabinet. A value of 2.5 shall be used. Alternative values may be used with appropriate justification.

The value of CFEC as above defined shall be added to the cabinet Direct Cabinet Consumption DEC.

In EN 23953, it is assumed that for a remote indirect refrigerating system, the heat resulting from the pump (not work created for pumping) does not impact the refrigeration energy consumption and is therefore not included in the REC calculation. This is because the pump motor (where most of the heat is created), dissipates the heat to the ambient, not the fluid. This is not necessarily the case with the fan of an air ducted system as the fan motor is likely to be inside the duct. Therefore, all the CFEC should be included in the REC if the fan motor is inside the duct and only the fan work should be included if the fan motor is external to the duct (see equations below).

It is suggested that that the following is inserted into this clause:

The refrigeration daily electrical energy consumption for a cabinet intended for an air ducted refrigerating system, REC_{RA} , in kilowatt hours per 24-h period is calculated from the following formula for the fan motor inside the duct:

$$REC_{RA} = [Q_{tot} + CFEC] \cdot \frac{(T_c - T_{mrun})}{(0.34 \cdot T_{mrun})}$$

And where the fan motor is outside the duct

$$REC_{RA} = [Q_{tot} + \mu \cdot CFEC] \cdot \frac{(T_c - T_{mrun})}{(0.34 \cdot T_{mrun})}$$

Where

Q_{tot} is the heat extracted during in in kilowatt hours per 24-h period;

with a constant condensing temperature of $T_c = 308,15 \text{ K}$ (35 °C).

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