Cambridge Refrigeration Technology

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EN 23953-2:2005 Test to ECA Requirements

Carter FD 3DR 234E
Remote Refrigerated Display Cabinet

Rev 2
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Confidential Technical Report for AEA Technology Ltd

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Refrigerated Display Cabinet

1.0 Introduction

Cambridge Refrigeration Technology is an independent research and test organisation. CRT provides expertise for industry within the area of environmental testing, refrigerated systems, insulated structures, refrigerated transport and perishable cargo storage.

The European standard BS EN 23953 specifies test procedures used to form the basis of this report and fulfil the requirements set out in the ECA Energy Technology Criteria List for Refrigerated Equipment.

CRT was commissioned to compare measured figures with those published by the ECA technology list. The ECA technology list has published the following figures for this refrigerated display cabinet.

Table 1 - Carter Retail Equipment Ltd FD 3DR 234E Published Results

Product Features	Value
Total Energy Consumption (TEC)	44.57kWh/day
Direct Energy Consumption (DEC)	15.88kWh
Total Display Area (TDA)	2.25m^2
Energy Efficiency Index (EEI)	19.81kWh/day/m^2
EN 23953-1 5 Digit Code (Annex A)	RVF4S

On the 1st August 2012 a Carter Retail Equipment Ltd FD 3DR 234E refrigerated display cabinet was delivered to CRT. Its details are given below.

Table 2 - Carter Retail Equipment Ltd FD 3DR 234E Details

Description	Value
Unit Supply (Voltage)	230
Unit Supply (Frequency)	50
Serial Number	33169
EN 23953-1 5 Digit Classification (Annex A)	RVF4S
Control Setpoint	-30°C
Refrigerant	R404a
Defrost	Automatic

Total Display Area

	L_{oh} =	0	H_o	0
T_{gh} = 81%	L_{gh} =	4.11	H_g	0.68
	L_{ov} =	0	V_o	0
T_{gv} = 0%	L_{gv} =	0	V_g	0
T_{gw} = 81%	W_{ov} =	0	W_{gd}	0

Total Display Area (TDA) in accordance with BS EN23953:

TDA $= (H_o \times L_{oh}) + (H_g \times T_{gh} \times L_{gh}) + (V_o \times L_{ov}) + (V_g \times T_{gv} \times L_{gv}) + (T_{gw} \times V_{gw} \times D_{gw})$

$= 0 + (0.68 \times 0.81 \times 4.11) + 0 + 0 + 0$

$= 2.26m^2$

2.0 Test Setup

The cabinet was installed in CRT environmental test chamber number 4, which conforms to BS EN 23956. The cabinet was switched on and left to stabilise with no product loaded. The test chamber was stable at 25°C, 60% relative humidity.

The cabinet was loaded with 972kg of test packages, consisting of 48 known as “M-packs”. The M-packs were located on four of the six shelves. The load profile was such that spacings between M-packages ran from front to back to align them with the evaporator airflow.

The cabinet was run for 24 hours to stabilise the packs as prescribed by the test standard.

The testing period was 24 hours in total during which there was a door-opening phase that was conducted for 12 hours. In section 5.3.3.2 of the standard it states that the door or lid of the cabinet shall be opened six times per hour and beyond an angle of 60°. The door or lid shall be opened for a total of 6 seconds and during this period the door shall be kept beyond the angle of 60° for 4 seconds. At the start of the opening cycle, each door or lid shall be opened for 3 minutes.

CRT Setup Engineer: Adrian Heaven
CRT Approval Officer: Tobias Mynott

Figure 1 below shows a photograph of the M-pack layout in test chamber 4.

Figure 1 - M-Pack Layout and Cabinet Plate

Type “T” thermocouples were used to measure temperatures inside the cabinet the table below shows the locations of all thermocouples used during this test.

Table 3 - Thermocouple Locations

Logger Channel Number	Location	Units
0	Ambient	°C
1001	Relative Humidity	%
1-48	M-Packs	°C

3.0 Test Chamber

The test chamber dimensions are 5.45m long, 3.8m wide by 2.75m high. Circulation fans are employed with a plenum with evenly spaced holes across it; this creates a uniform airflow along the length of the chamber. Return holes at the opposite end of the chamber guide the air back to the circulation fans, heaters and evaporator (located in the ceiling and not in the chamber) where the air is re-conditioned ready for the next cycle.

CAL 9400 controllers were used to control the chamber’s temperature and the remote condensing unit’s fan.

The cabinet was placed in the centre of the chamber and the airflow across the front of the cabinet and adequate spacing around the cabinet checked to ensure it complied with BS EN 23953.

3.1 Measurement Equipment

Temperature measurements of the M-packages used type “T” thermocouples, which were inserted into the centre of each M-package. The thermocouples are accurate to within ±0.5°C, in accordance with ASHRAE Fundamentals section 14.8 for special grade type “T” thermocouples.

Relative humidity (rh) was measured using a HIH4000-001 Honeywell sensor. It is controlled by taking the measured output from the Honeywell sensor and monitored by a 9400 CAL controller that is connected to a combined water and compressed air spray nozzle, which cycles on and off under PID control (proportional integral and derivative) to maintain the desired rh. The nozzle is located in the chamber, by the plenum, facing away from the cabinet and sensors.

The temperature and humidity were logged by a Fluke 2280b datalogger every 60 seconds, the refrigerant mass flow and system pressures were measured every 20 seconds in accordance with the standard. Power was recorded by a Northern Design PM390 power meter.

3.2 Remote Refrigeration Unit Setup

The remote condensing unit comprises a 10hp compressor, a liquid receiver; air cooled condenser, oil separators, mass flow meter and associated valves. The compressor and condenser fans are both driven by frequency inverters to control their speed. In this case the compressor was manually set up to run at 25Hz to limit its capacity. The condenser fan was set to operate automatically and to regulate the condensed liquid refrigerant temperature to 30°C.

The CRT system operates on demand from the cabinet. The cabinet has a solenoid valve which, when open, allows the flow of refrigerant, after passing through the mass flow meter, to the cabinet via the expansion valve. Two regulating valves control the flow back from the cabinet to the condensing unit: an EPR (evaporator pressure regulator) and a CPR (crankcase pressure regulator). The EPR prevents the temperature within the cabinet from becoming too low by holding back the refrigerant flow; the CPR protects the compressor against excessive pressure.

The cabinet's solenoid valve is connected to an electronic controller, which monitors the temperature and enables defrosting. When the solenoid valve closes, the reducing pressure in the suction line is detected by the compressor's low-pressure cutout, which slows the compressor preventing the suction going below 0.1bar. Once the cabinet's solenoid valve opens again, the pressure increases and the system starts up again. This cycle is repeated each time the solenoid valve closes.

3.3 Uncertainty Calculations

The final EEI figure quoted for a cooler is subject to uncertainty propagation inherent in the measuring systems. The following table details where uncertainty, and its extent, occurs.

Table 4 - Uncertainty Calculation Table

Source	Uncertainty Value	Standard Uncertainty
TDA measurements	Combined Panel Measurement	0.104
Power Input	1.00%	0.174
Time	1 second per day	0.0003
DEC measurement	kWh	0.1564

Uncertainty in TDA arises from the measured dimensions of each panel, which are subsequently multiplied and then added together in the TDA calculation. The standard uncertainty value in the table above accounts for this.

$U_{EEI} = \sqrt{0.104^2 + 0.174^2 + 0.0003^2}$

$U_{EEI} = 0.203 kWh/day/m^2$

4.0 Cabinet Classification ECA Criteria

In the tables below are the current classifications for cabinets.

All classifications are tested to EN 23953-2:2005 in climate class 3.

Climate class 3 specifies the following conditions:

- Dry Bulb Temperature 25°C
- Relative Humidity 60%

Table 5 - Classification Table as According to Temperature

M-Package Temperature Classes (EN 23953-2:2005)			
Class	**Highest temperature of the warmest M-package equal to or lower than °C**	**Lowest temperature of the coldest M-package equal to or greater than °C**	**Lowest temperature of the warmest M-package equal to or lower than °C**
L1	-15	-	-18

Table 6 - Performance Criteria

Classification	**EEI Performance Threshold (kWh/day/m^2)**
	Frozen (L1 – Remote Type)
L1	≤23.50

5.0 Results

The cabinet was set up and tested in accordance to BS EN ISO 23953-2:2005 successfully.

The M-package temperatures are summarised below in table 7 during the test period and detailed in the graphs in figures 2 to 4, which can be found appended to this report. Appendix 1 shows the cabinet prior to testing.

Table 7 - Temperature Results

Parameter	Temperature °C
Highest temperature of the warmest M-package	-15.4
Lowest temperature of the warmest M-package	-27.4
Lowest temperature of the coldest M-package	-29
Arithmetic mean temperature	-25.3

During the first 12 hours the unit lighting was switched off; for the last 12 hours the lighting was switched on. In total the test lasted for 24 hours and this data was used for the heat extraction calculation. The REC calculation was taken in accordance with EN ISO 23953, figure 30.

The direct energy consumption is show below in table 8.

Table 8 - Direct Energy Consumption (DEC) Data

	Logged
Energy consumed - First 12 hours lights on	8.21kWh
Energy consumed - Second 12 hours lights off	7.52kWh
Total energy consumed over 24 hours	15.64kWh

The heat extraction parameters are shown in table 9 below, followed by the total energy consumption calculation.

Table 9 - Mean Overall Data t_{run75}, Period L, 16-hours

Evaporator pressure, $_{p7}$ (bara)	1.86
Saturated evaporating temp, θ_{mrun}, ref: period C, (°C)	-29.25
Evaporating temperature, θ_{min}, ref: period F, (°C)	-22.1
Liquid temperature (°C), 75% runtime	29.9
Discharge pressure (bara)	15.7

Running Time, t_{run} (hours) = 22.56

Evaporator Saturated Vapour Temperature,

θ_{mrun} = -29.25°C

T_{mrun} = θ_{mrun} + 273.2 = 243.9K

Arithmetic mean of instant rates of heat extraction, Φ_{run75} = 1.33kW

$\Phi_{run75} = \frac{Q_{75}}{0.75.t_{run}} \Rightarrow \frac{Q_{75}}{0.75.(24 - t_{deft})}$ for constant evaporator pressure tests.

Refrigeration Energy Consumption for remote compression type systems:

$REC_{RC} = (24 - t_{deft})$ x $\Phi_{24\text{-}tdeft}$ x $\frac{(T_C - T_{mrun})}{(0.34.T_{mrun})}$ = Q_{tot} x $\frac{(T_C - T_{mrun})}{(0.34.T_{mrun})}$

$\Rightarrow$ t_{run} x Φ_{run75} x $\frac{(T_C - T_{mrun})}{(0.34.T_{mrun})}$

$\Rightarrow$ = 22.56 x 1.33 x $\frac{(308.15 - 243.9)}{(0.34x243.9)}$

= 23.25kWh

Direct Energy Consumption:

DEC = 12 hours with lights on + 12 hours with lights off

= 8.12 + 7.52

= 15.64kWh

Total Energy Consumption:

TEC = DEC+ REC_{RC}

= 15.64 + 23.25kWh

= 38.89kWh

$$EEI = \frac{TEC}{TDA} = \frac{38.89\,kWh}{2.26\,m^2} = \mathbf{17.21\ kWh/day/m^2}$$

6.0 Conclusions

The Carter FD 3DR 234E unit arrived well packaged and setup proved to be simple. The unit operated without problems during the test.

The table below contains a summary of the results of both tests.

Table 10 - Summary of Results

Test	CRT Result
Highest temperature of the warmest M-package	-15.4
Lowest temperature of the warmest M-package	-27.4
Lowest temperature of the coldest M-package	-29
Arithmetic mean temperature	-25.3
Total Energy Consumption (TEC)	39.89kWh/day
Total Display Area (TDA)	2.26m^2
Energy Efficiency Index (EEI)	17.21kWh/day/m^2

When comparing the measured values with the values published on the ECA website we found the following:

Table 11 - Verification of Results

Test	Published Values	CRT Measured Values	Difference %
Total Energy Consumption (TEC)	44.57kWh/day	38.89kWh/day ±0.174	13
Direct Energy Consumption (DEC)	15.88kWh	15.64kWh ±0.1564	2
Total Display Area (TDA)	2.25m^2	2.26m^2 ±0.104	0
Energy Efficiency Index (EEI)	19.81kWh/day/m^2	17.21kWh/day/m^2 ±0.203	13
EN 23953-1 5 Digit Classification (Annex A)	RVF4S	RVF4S	-

Figure 2 - M-Package Temperature Trend Lines

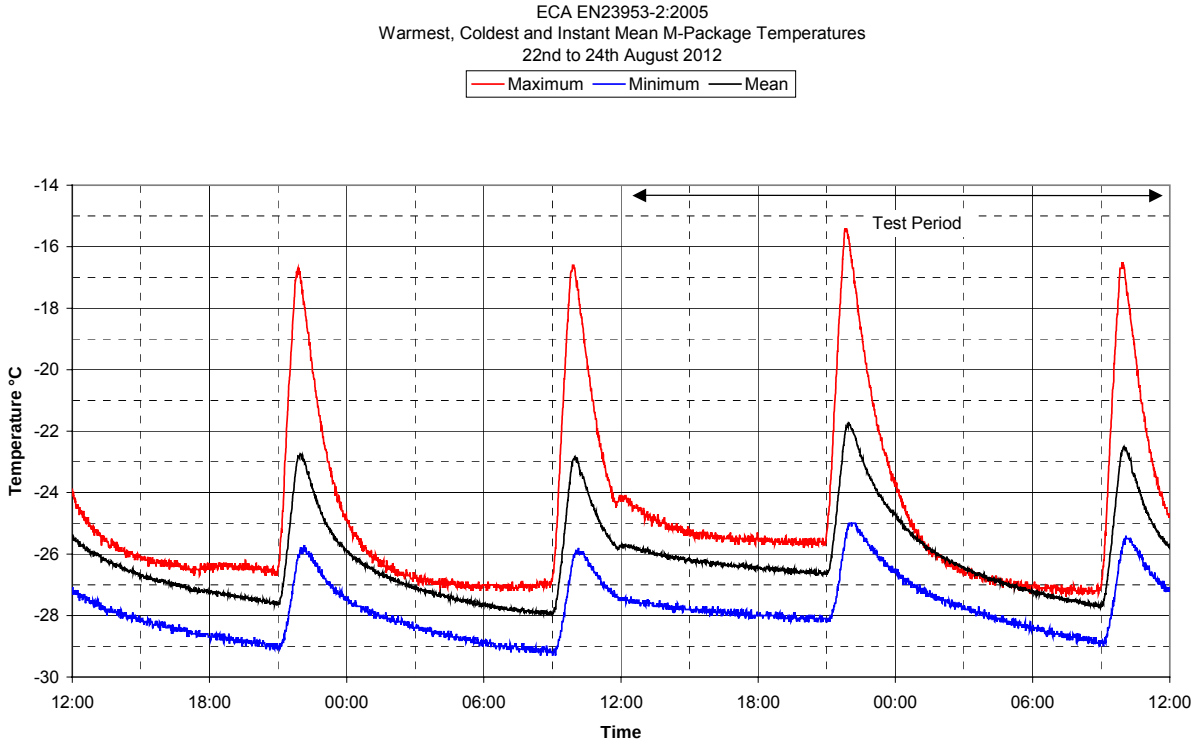


Figure 3 - All M-Package Temperatures

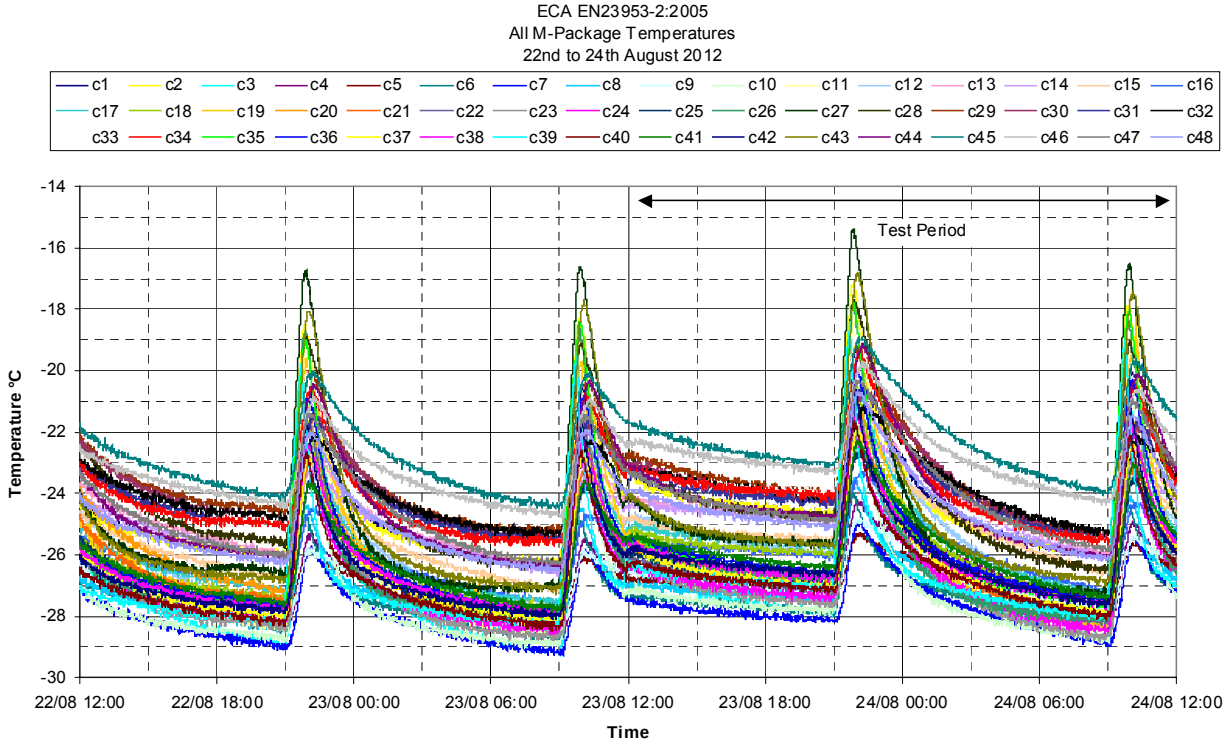
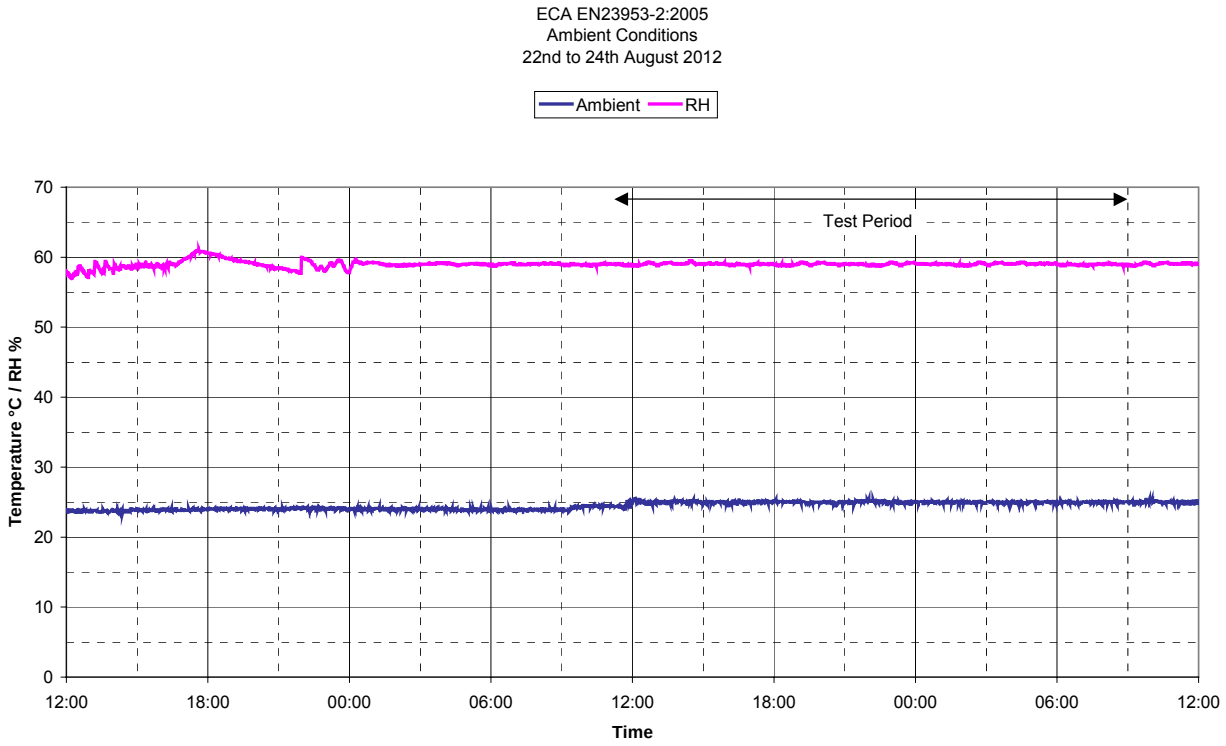


Figure 4 - Summary of Ambient and Relative Humidity



Appendix 1 - Pictures

Appendix 2 - Test Chamber Calibration Certificate

CERTIFICATE OF CALIBRATION

Completion Date: 14/02/2012
Certificate Number: 2012-CET-093-A

CAMBRIDGE REFRIGERATION TECHNOLOGY
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Telephone: (01223) 365101, Fax: (01223) 461522
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Environmental Chamber No. Four

Equipment / Ref	Reference Range	Maximum Error	Limit
Datalogger			
Fluke / 2280B / 391500	-25 to 100 °C	0.3	0.3°C
Power Meters			
Northern Design / Multicube / 55241	500 to 3080 W	0.6%	1.0%
Pressure Transducers			
Daikin LP (P=(318.04*Vdc) -179.34	100 to 550 kPa	1.0%	1.0%
Daikin HP (P=951.54*Vdc) -516.78	500 to 2000 kPa	0.2%	1.0%
Light Measurement			
ISO-TECH LUX-1335 / 060700569	600 to 600 LUX	9.1%	16.5%
Airflow Measurment			
HOT WIRE ANEMOMETER / 012705	0.1 to 0.2 m/s	0.0%	0.1%

Certified by: Tobias Mynott

Signature:

Approved by: Richard Lawton

Signature:

The uncertainty of the above temperature measurements is < $^{+}/_{-}$0.5°C.
The uncertainty of the above power measurements is < $^{+}$/-1%.
The uncertainty of the above pressure measurements is < $^{+}/_{-}$1%.

Appendix 3 - Test Chamber No 4 Details

Name	Supermarket Cabinet Test Chamber (EN441/ BS EB ISO 23953-2:2005)
Size	3.8W x 5.45L x 2.75H metres
Door size	2.7H x 2.1W metres
Floor	150mm concrete
Insulation	80mm polyurethane
Drainage	2x 150mm drains
Refrigeration	5hp recip l compressor
Remote condensing Unit	15kw @-5.0°C +30°C
Heating	10kw Electrical
Defrost system	Automatic timed electrical
Temperature range	+50 to 0°C
Temperature control	Omron IMO Jaguar inverter drive &unloading valves
Air circulation	0.1 – 0.2 m/s
Relative humidity	50-100% rh
Power supply	110/ 240V/415V 50Hz main 110/230/ 440V 60Hz converters
Water supply	15mm supply
Compressed air	20 m^3/hr 100 psi
Fixed instrumentation	Fluke data logger. Temperature, pressure, humidity