Verification Report
Danfoss AK-CC Controllers

DTI Refrigeration and Heat Pump Technology
J.no. 1001
Test no. 1 – Reduced energy consumption

Version 1.1

1. Table of Contents

2. Introduction

Environmental technology verification (ETV) is an independent (third party) assessment of the performance of a technology or a product for a specified application, under defined conditions and quality assurance.

DANETV is a Danish centre for verification of environmental technology.

The verification is conducted under the verification protocol for the specific technology tested in accordance with the test plan.

2.1. Name of product

The product is the Danfoss AK-CC Controller series.

2.2. Name and contact of vendor

Danfoss A/S, Nordborgvej 81, 6430 Nordborg, Denmark
Contacts:

Frede Schmidt (R&D Engineer) +45 7488 1553,
e-mail: frs@danfoss.com
Peter Eriksen (R&D Director) +45 7488 4191,
e-mail: peter_eriksen@danfoss.com

2.3. Name of centre/verification responsible

Danish Technological Institute, Verification Centre, Refrigeration and heat pump technology, Kongsvang Allé 29, DK-8000 Aarhus C, Denmark.

Verification responsible: Bjarke Paaske (BJPA), phone: +45 7220 2037,
e-mail: bjpa@teknologisk.dk

Internal reviewer: Anders Mønsted (ANMD), phone: +45 7220 2273,
e-mail: anmd@teknologisk.dk

2.4. Verification and test organization

The verification was conducted by Danish Technological Institute.

The test organization is shown in Figure 1.

The verification was planned and conducted to satisfy the requirements of the ETV scheme currently being established by the European Union (EU ETV).

Verification and tests was performed by Danish Technological Institute under DANETV under contract with Danfoss A/S.

The day to day operations of the verification and tests was coordinated and supervised by TI personnel, with the participation of the vendor, Danfoss A/S.

The Subbody at TI test centre performed all testing during the verification.

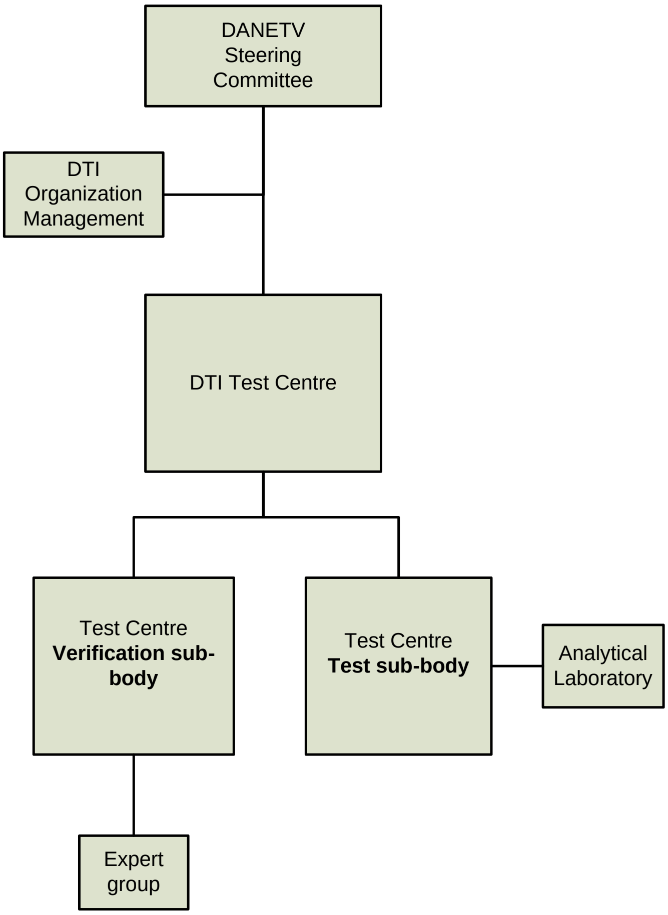

Figure 1 Verification organization

Table 1 Responsible personnel in test organization

Unit in test organization	Responsible
DTI Dan ETV steering committee member	Lars Jøker
DTI organization management Life science division	Claus S. Poulsen
DTI Life science division Test Centre, Verification subbody	Bjarke Paaske
DTI Life science division Test Centre, Test subbody	Klaus Frederiksen

2.5. Expert group

The expert group assigned to this verification and responsible for review of the verification plan and report documents includes:

Brian Elmegaard (BE), DTU, phone: +45 4525 4169, e-mail: be@mek.dtu.dk

2.6. Verification process

Verification and tests were conducted in two separate steps, by the Verification sub body and the Test sub-body respectively.

The verification sub-body is responsible for preparation and compilation of the Verification protocol and the Verification report.

The Test sub-body is responsible for the test plan and the test report.

A DANETV verification is issued after completion of the verification report.

The steps in the verification are shown in Figure 2.

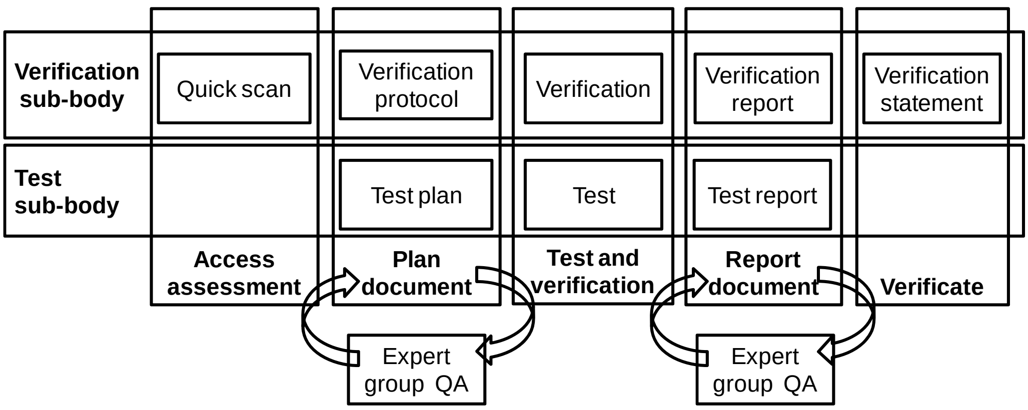

Figure 2 - Verification steps

3. Description of the technology

The technology verified are two energy reducing features in Danfoss AK-CC controllers. One feature is automatic adaptation of rail heat. The other is adaptation of defrost sessions. The necessity of both rail heat and defrost depends on the current humidity level of the surrounding air.

4. Description of the product

AK-CC controllers are complete refrigeration appliance controllers for a great number of different refrigeration appliances and cold store rooms.
The controller is an electronic unit that controls different functions in cooling applications. In applications with cooling and freezing cabinets the main functions of the controller are: liquid

injection of refrigerant in the evaporators, monitoring of superheat, defrosting of evaporators, rail heat, control of compressors, control of night blinds and control of lights.

5. Application and performance parameter definitions

5.1. Matrix/matrices

The matrix is the type of material the product is intended for

The matrix of the application is freezing/cooling cabinets in retail stores.

5.2. Target(s)

A target is defined as the property affected by the product

The target of the product is:

- Optimized control of both rail heat and defrost
- The power supplied to the rail heat system will adapt automatically according to the temperature and relative humidity of the surrounding air
- Frost formations are monitored and the controller will only initiate defrost sessions when necessary

5.3. Effects

The effects are described as the way the target is affected

The effects of this application are:

- Reduced energy consumption – both directly at the heaters and indirectly at the cooling system
- Reduced mean temperature of the cooled products

5.4. Performance parameters for verification

The ranges of performance relevant for the application, as derived in Appendix 3, are presented below. These ranges are used for planning the verification and testing only.

Concerning energy consumption of both heaters and cooling system the following parameters are measured:

- Overall energy consumption of the freezing cabinet
- Energy consumption of rail heat
- Energy consumption of defrost
- Mass flow of refrigerant at the evaporator
- Temperature of the refrigerant liquid line
- Temperature of the refrigerant at evaporator outlet
- Pressure at evaporator outlet

Other performance parameters measured includes:

- Temperature in test packages
- Visual inspection of water vapour condensation during the test

All parameters are measured according to ISO 23953

5.5. Additional parameters

Besides the performance parameters that are part of test result, compilation of parameters describing, and occupational health & safety issues of the product and user manual were evaluated as part of the verification.

6. Existing data

6.1. Summary of existing data

Previous work has shown great potential of adaptive rail heat and defrosts systems. Throughout experiments, energy consumption and temperature of systems using default and manually adapted settings have been compared. Both energy consumption and mean temperature of the products is significantly improved by adjusting the rail heat according to demand. It is also clear that the temperature during defrost will rise dramatically, and optimized defrost sessions will reduce both energy consumption and mean temperature of the products.

So far, adaptive control systems have not been tested. All experiments are carried out by manually adjusting the heat according to demand. The previous experiments proof the benefits of only applying the amount of heat necessary and show the importance of automatic adaptive controllers.

6.2. Quality of existing data

Documentation of previous experiments exists, but the experiments were not executed using adequate equipment or ambient conditions.

6.3. Accepted existing data

Data from previous experiments is not usable for this verification process.

7. Test plan requirements

7.1. Test design

The performance test will consist of two similar test series showing the performance of a standard freezing cabinet. One test series will be carried out using default settings on rail heat and defrost. The other series will be carried out the adaptive functions of the controller. The effect of the adaptive function is verified by comparing the results.

The performance test is based on the existing European Standard ISO 23953 /5/, with some exceptions. ISO 23953 is the standard performance test for freezing cabinets, showing both power consumption and cooling ability of different types of freezing and cooling cabinets. It is important to notice that ISO 23953 is a performance test of the cabinet – not the controller. By performing several performance tests using both adaptive and standard control settings, the effect of adaptive control will show through the performance of the cabinet. The standard control settings used, must correspond to typical settings of the specific type of cabinet and ambient conditions (test matrix) as tested in the verification process. The standard settings used, are stated in the Test Plan and Test Report chapter 3.5.5.

Ambient temperature and humidity during the tests will not follow the climate classes given by ISO 23953. The performance will be measured using a test matrix of 24 hour tests, using different ambient settings to reflect actual conditions in retail stores in Denmark. The matrix is based on Danish DRY-data (dimensional reference year) /6/ and ISO 13788 – Annex A (internal humidity loads) /7/.

As the effect of the product will vary significant dependent on ambient conditions, it is important to do several tests and hereby calculate the average annual effect.

The total electrical energy consumption (TEC) of the display cabinet is divided into direct electrical energy consumption (DEC) and refrigeration electrical energy consumption (REC).

DEC is the consumption of all electrical components in the cabinet – ventilation, rail heat, defrost etc. DEC is measured at the power supply and reported in kWh per 24-hour test period.

REC is the electrical energy consumption due to cooling of the cabinet. Because the refrigerant is supplied by remote condensing systems, it is not possible to measure the REC directly on the power supply. REC is determined by measuring the heat extraction in the cabinet, and recalculating into electrical energy consumption.

Heat extraction is measured through mass flow and enthalpy increase in the refrigerant. Enthalpy increase of the refrigerant is determined via pressures and temperatures of the refrigerant. The specific enthalpy of the refrigerant entering the evaporator is determined from the pressure and temperature of the liquid supply line. The specific enthalpy of the refrigerant exiting the evaporator is determined via pressure and temperature of the suction line. The enthalpy increase equals the difference in specific enthalpy of evaporator inlet and outlet. Mass flow rate multiplied by enthalpy increase equals heat extraction:

$$Q_{ref} = m_{ref} \cdot \Delta h_{ref}$$

The heat extraction is then converted to electrical energy consumption using the formula below:

$$REC = Q_{tot} * \frac{(308{,}15 - T_{mrun})}{(0{,}34 * T_{mrun})}$$

Qtot is the total heat extracted during the period. Tmrun is the evaporation temperature.

The total electrical energy consumption is determined by adding DEC and REC.

Rail heat and defrost cause temperature increase both in cooled products and air of the cabinet. An extra benefit of the adaptive control is lower mean temperature of the products.

During the performance test, temperatures in the cabinet will be measured according to ISO 23953. The cabinet will be equipped with temperature sensors measuring both test packages and air temperature of the cabinet. Data from these sensors will verify the reduced mean temperature of the products.

7.2. Reference analysis

No references are used for this verification process.

7.3. Data management

Data storage, transfer and control must be done in accordance with the requirements of the ETV Quality manual enabling full control and retrieval of documents and records.

7.4. Quality assurance

The quality assurance of the tests includes control of the test system and control of the data quality and integrity.
The test plan and the test report were subjected to review by the review group, see figure 2.

7.5. Test report

The test report follows the template of the TI Verification Centre Quality Manual /2/ with data and records from the tests presented.

8. Evaluation

8.1. Performance parameter summary

The figures of performance parameters are shown in Table 2.

Table 2 Target and measured values of tested parameters.

Parameters	Target	Measured value	Method
Overall performance			
Total electrical energy reduction	15 %	15,1 %	TI-DOP
Average temperature levels	< 0 K	-0,35 K	TI-DOP
Peak temperature levels	< 0 K	< 0 K	TI-DOP
Water vapor condensation (running water)	Non	Non	Visual inspection

The Danfoss Controller was working correctly throughout the test period. The registered dew point temperatures of the controller was slightly off (1 K higher) when comparing to calibrated equipment. Offset was the same at all dew point temperatures and once the controller is adjusted to a specific cabinet the offset will have no influence on operation. No adjustment or correction was needed during the performance tests

The purpose of the present verification was not a complete functional test of an AK-CC controller, but a verification of the energy savings potential using the adaptive functions of the controller.

The freezing cabinet used for the verification was not able to function properly at the most humid conditions. Because of this, energy and temperature reduction representing this period are regarded as 0 when determining the overall effect.
The overall test results are summarized in table 3 below. Results from sample five are neglected because of improper functioning of the freezing cabinet.

Table 3 Average and maximum temperature of the measuring packages, total electrical energy consumption (24h period) and the effect of the product in the specific samples. On the right is the average annual temperature and energy reduction (effect).

		Temperature [° C]		Energy	Results			Average	
Sample	Run no.	Package avg.	Package max	Total [kWh]	Temp. diff. [K]	Energy red.	Factor	Temp. red. [K]	Energy red.
1	1	-17,15	-11,44	29,1	-0,45	29 %	0,09	**-0,35**	**15,1 %**
	2	-17,60	-12,32	20,7					
2	3	-17,21	-11,25	29,2	-0,39	26 %	0,17		
	4	-17,61	-12,45	21,6					
3	5	-17,10	-10,90	30,1	-0,32	16 %	0,39		
	6	-17,42	-11,32	25,2					
4	7	-16,81	-9,64	31,6	-0,52	7 %	0,23		
	8	-17,33	-10,73	29,3					
5	9	-	-	-	0,00	0 %	0,12		
	10	-	-	-					

It is concluded for Danfoss AK-CC Controllers:

- Using the adaptive control method means an annual reduction in electrical energy consumption of 15,1 % for this type of application.
- Using the adaptive control method means an annual average temperature reduction of 0,35 K of the cooled products for this type of cabinet.
- Using the adaptive control method means reduced water vapor condensation for this type of cabinet (running water was only present in run 7).
- The result of this verification process is very dependent on the type of cabinet used as well as geographical location, settings, opening hours etc. It is likely that the adaptive control method will have a different influence on other types of cabinets in different applications.

8.2. Evaluation of test data quality

The data quality is evaluated to be at scientific level using measuring equipment with high accuracy, thorough quality assurance procedures and adequate running-in periods.
The test matrix is however based on certain conditions, settings, cabinet etc. Because of this the test result will not be comparable to all cabinets in real conditions in retail stores.

8.2.1. Control data

The procedure of data processing is repeated independently once by the test sub-body and once by the internal reviewer. This provides three independent results that are matched in order to secure correct results.

8.2.2. Audits

No audits were performed.

8.2.3. Deviations

It was not possible to complete test runs 9 and 10, because of ice blocking in the cabinet.

The high humidity level means that a large amount of ice is created in the bottom of the cabinet. Defrost sessions melts ice at the evaporators, but under these circumstances the water from defrost sessions, freezes at the bottom before exiting the cabinet. Ice formations reduce ventilation air at the evaporators and at some point the cooling capacity is inadequate to keep the temperature at the correct level.
The ice formations were removed and the test runs were repeated several times with the same result.

Because of this run no. 9 and 10 are not comparable with the other test runs. Results of run no. 9 and 10 are not used for the verification process. Energy and temperature reduction at annual periods representing these runs are regarded as 0, when determining the overall annual effect.

According to experienced service technicians, the specific type of cabinet used for the performance test is known of having severe ice blocking problems in real installations during humid periods.

On all other points there have been no deviations from the test plan.

8.3. Additional parameters summary

8.3.1. User manual

The manuals for use and technical manuals for the Danfoss AK-CC Controller (version 10-2008) were read thoroughly and the description of the following topics was found sufficient:

- Operation of the system
- Installation
- Troubleshooting
- Occupational health and safety issues
- Service and maintenance
- Surveillance of the installation

8.3.2. Occupational health and environment

The use of this product does not imply special health, safety or waste issues.

Recommendations for verification statement
It is recommended to issue a verification statement exclusively on controllers for appliance controls and emphasize, that the adaptive functions of the Danfoss AK-CC Controller series have positive effect on electrical energy consumption and temperature levels of the cooled products.

It can only be verified that the adaptive functions reduce the annual electrical energy consumption by 15 %, while lowering the average and maximum temperature of the products. It is assumed that similar reductions will be possible in other applications, but no guarantees can be given. Therefore the following liability exclusions should be included in the verifications statement.

9. Liability exclusion

ETV verifications are based on an evaluation of technology performance under specific, predetermined operational conditions and parameters and the appropriate quality assurance procedures. DTI makes no expressed or implied warranties as to the performance of the technology and do not certify that the technology will always operate as verified.
The end user is solely responsible for complying with any applicable regulatory requirements.

10. Quality assurance

The test protocol, test plan, test report and verification report was reviewed by internal and external experts according to the Quality plan for the verification, see table 4.

Table 4 QA plan for the verification

Reviewers	TI	Experts
Plan document with application definition, verification protocol and test plan	ANMD	BE
Report document with test report and verification report	ANMD	BE

Reviews were done using the TI review report template.

Appendix 1 Terms and definitions used in the verification protocol

Terms and definitions used in the protocol are explained in table 1:

Table 1 - Terms and definitions used by the DANETV test centers

Word	DANETV	Comments on the DANETV approach
Analytical laboratory	Independent analytical laboratory used to analyse test samples	The test center may use an analytical laboratory as subcontractor
Application	The use of a product specified with respect to matrix, target, effect and limitations	The application must be defined with a precision that allows the user of a product verification to judge whether his needs are comparable to the verification conditions
DANETV	Danish center for verification of environmental technologies	None
(DANETV) test center	Preliminary name for the verification bodies in DANETV with a verification and a test sub-body	Name will be changed, when the final nomenclature in the EU ETV has been set.
Effect	The way the target is affected	The effect could be reduced energy consumption, better cooling performance etc.
(Environmental) product	Ready to market or prototype stage product, process, system or service based upon an environmental technology	The product is the item produced and sold and thus the item that a vendor submit for verification
Environmental technology	The practical application of knowledge in the environmental area	The term technology is covering a variety of products, processes, systems and services.
Evaluation	Evaluation of test data for a technology product for performance and data quality	None
Experts	Independent persons qualified on a technology in verification	These experts may be technical experts, QA experts for other ETV systems or regulatory

Word	DANETV	Comments on the DANETV approach
		experts
Matrix	The type of material that the product is intended for	Matrices could be cooling systems, cabinets, heat exchangers etc.
Method	Generic document that provides rules, guidelines or characteristics for tests or analysis	An in-house method may be used in the absence of a standard, if prepared in compliance with the format and contents required for standards.
Performance claim	The effects foreseen by the vendor on the target (s) in the matrix of intended use	None
Performance parameters	Parameters that can be documented quantitatively in tests and that provide the relevant information on the performance of an environmental technology product	The performance parameters must be established considering the application(s) of the product, the requirements of society (regulations), customers (needs) and vendor claims
Procedure	Detailed description of the use of a standard or a method within one body	The procedure specifies implementing a standard or a method in terms of e.g.: equipment used
Producer	The party producing the product	None
Standard	Generic document established by consensus and approved by a recognized standardization body that provides rules, guidelines or characteristics for tests or analysis	None
Target	The property that is affected by the product	Targets could be temperature [° C], energy [kWh] etc.
Test center, test sub-body	Sub-body of the test center that plans and performs test	None
Test center, verification sub-body	Sub-body of the test center that plans and performs the verification	None

Word	DANETV	Comments on the DANETV approach
Test/testing	Determination of the performance of a product for parameters defined for the application	None
Vendor	The party delivering the product to the customer	Can be the producer
Verification	Evaluation of product performance parameters for a specified application under defined conditions and adequate quality assurance	None

Appendix 2 **References (verification protocols, requirement documents, standards, methods)**

1. DANETV. Center Quality Manual, 2008

2. European Parliament and Council. Directive 2006/42/EC of the 17th May 2006 on machinery and amending Directive 95/16/EC (recast).

3. European Council: Directive 89/655/EEC of 30 November 1989 concerning the minimum safety and health requirements for the use of work equipment by workers at work (amended 2007/30/EC).

4. ISO 12100-2:2003: Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles

5. European Standard EN ISO 23953 – Refrigerated display cabinets

6. Danish “Design reference year” DRY-data, 1995

7. ISO 13788 – Hygrothermal performance of building components and building elements (Internal humidity loads)

8. Measurement protocol for energy reductions in Refrigerated display cabinets for ETV tests at DANETV

Appendix 3 Application and performance parameter definitions

This appendix defines the application and the relevant performance parameters application as input for verification and test of an environmental technology following the DANETV method.

A3.1 Applications

A3.1.1 Matrix/matrices

- The matrix of the application is freezing/cooling cabinets in retail stores.

A3.1.2 Target(s)

- The target of the product is:
    - Optimized control of rail heat and defrost sessions
    - The power of the rail heat system will adapt according to the surrounding air temperature and humidity and keep the rail temperature a few degrees above the dew point at all time.
    - Frost formations are monitored and the system will only initiate defrost sessions when needed.

A3.1.3 Effects

- The effects claimed by the vendor are presented in table 2:

Table 2 - Performance parameters and vendor claims

Performance parameter	**Vendor claim of performance**
Reduction of energy consumption	15 % reduction of overall energy consumption
No increase in temperature of cooled products	Mean and maximum temperature of cooled are not increased as a side effect of the product
No increase in water vapor condensation	Water vapor condensation is not increased as a side effect of the product

Appendix 7 Test data report

Test

The test was performed as described in the test plan apart from the deviations described in chapter 7.4 of the test report.

Operational data
Ambient conditions during the test runs are shown in figure 7.1 below.

Sample no.	Run no.	Ambient conditions		
		Temp. avg.	Day RH avg.	Night RH avg.
1	1	19,6	33,1	29,9
	2	19,6	32,9	30,8
2	3	19,7	40,5	32,5
	4	19,6	40,5	30,2
3	5	19,9	49,0	35,9
	6	19,9	49,0	35,5
4	7	20,3	59,4	52,4
	8	20,2	59,4	52,4
5	9	20,5	71,8	66,4
	10	20,7	71,8	66,4

Figure 7.1 - Average ambient conditions during the test runs.

Following the test matrix, relative humidity ratios during night time settings of sample 1 and 2 should have been lower. It was not possible to reach these low levels of humidity in the climate chamber used and the test runs were executed with the lowest humidity possible.
The result of the verification however is not affected by the higher humidity ratios in sample 1 and 2. A lower humidity ratio would have increased the effect of the product and result in a verification of the effect by a larger margin.

The temperature in the climate chamber is slightly higher during the last test runs, than during the first. This has no influence, as the temperature only differs very little between the two runs of each sample.

All temperatures and relative humidity ratios (except during night time settings of sample 1 and 2) are within the tolerances specified.

Analysis results

Reduction of electrical energy consumption

The electrical energy consumption of the cabinet in each of the 24h test periods is shown in table 7.2 below.

		Energy consumption [kWh]						Results		
Sample	Run no.	Rail	Def.	Aux	Ref.	Total	Diff.	Energy red.	Factor	Overall
1	1	7,6	1,6	2,0	18,0	29,1	-8,4	29%	0,09	15,1%
	2	2,2	0,9	2,0	15,6	20,7				
2	3	7,6	1,6	2,0	18,0	29,2	-7,6	26%	0,17	
	4	3,0	0,9	2,0	15,7	21,6				
3	5	7,6	1,7	2,0	18,9	30,1	-4,9	16%	0,39	
	6	4,8	1,0	2,0	17,4	25,2				
4	7	7,5	1,8	1,9	20,4	31,6	-2,3	7%	0,23	
	8	7,5	1,1	2,0	18,7	29,3				
5	9	7,6	1,7	2,0	19,3	30,6	2,6	0%	0,12	
	10	10,1	1,0	2,0	20,2	33,3				

Figure 7.2 – Electrical energy consumption during the test runs.

As mentioned earlier the results of sample 5 are neglected due to large amounts of ice formation.

Electrical energy consumption is measured individually for rail heat, defrost, auxiliary (primarily fans) and the refrigeration system. The total electrical energy consumption of run no. 1 is 29,1 kWh. The total of run 2 is 20,7 kWh and the difference is a reduction of 8,4 kWh.
The electrical energy consumption of the refrigeration system is not measured directly, but determined from the cooling capacity using the method from ISO 23953 as explained in chapter 7.1 of the verification protocol.

As expected, the reduction of electrical energy consumption is higher during low humidity ratios. The reduction is primarily caused by lower demand of rail heat and defrost sessions.

Sample 1-4 covers 88 % of the annual hours and the average reduction during this period is 17,1 %. As the energy reduction is regarded as 0 during the last 12 % of the annual hours, the overall annual energy reduction is determined to 15,1 %.

Reduced temperature of the cooled products
The temperature levels of the measuring packages are shown in table 7.3 below.

Sample	Run no.	Temperature [° C]		Results			
		Package avg.	Package max	Water vapor	Temp. diff. [K]	Factor	Overall [K]
1	1	-17,15	-11,44		-0,45	0,09	-0,35
	2	-17,60	-12,32				
2	3	-17,21	-11,25		-0,39	0,17	
	4	-17,61	-12,45				
3	5	-17,10	-10,90		-0,32	0,39	
	6	-17,42	-11,32				
4	7	-16,81	-9,64	X	-0,52	0,23	
	8	-17,33	-10,73				
5	9	-17,11	-10,36	X	0,00	0,12	
	10	-16,36	-9,22				

Figure 7.3 – Temperature levels of test packages during the test runs.

As mentioned earlier the results of sample 5 are neglected due to large amounts of ice formation.

Temperature levels are measured individually on each of the 54 measuring packages. The column “Package avg.” in the table, shows the average temperature of all measuring packages during each of the 24h test runs. The column “Package max” shows the maximum temperature reached in any measuring package.
Both average and maximum temperatures are reduced using the adaptive functions.

Sample 1-4 covers 88 % of the annual hours and the average reduction during this period is 0,4 K. As the temperature reduction is regarded as 0 during the last 12 % of the annual hours, the overall average temperature reduction is determined to 0,35 K.

Running water caused by water vapour condensation was present in runs 7 and 9. No water vapour problems were detected using the adaptive functions.

Discussion and Conclusion

The following points are important to notice considering the effect of this product in real life applications:

- The effect of the product was only verified using a single type of cabinet
  - It is expected that other cabinets are effected different by the product
- Type of super market, default settings, opening hours, behaviour etc.
  - The test matrix is based on small size supermarkets with a lot of opening hours (11 hours a day – 7 days a week), which is a typical installation of this type of cabinet
  - The default settings used, are typical for this type of cabinet but may vary dependent on the installer, behaviour etc.
  - Door openings and load of products are based on ISO 23953, but may vary dependent on store, type of product, behaviour etc.
- The ambient conditions in the test matrix are based on stores without air conditioning or special air handling units
  - The result obtained in this verification process is not expected to be comparable for cabinets placed in special environments (for instance next to humidification systems for groceries etc.)

With the above in mind, it is concluded that the performance of adaptive functions for the Danfoss AK-CC Controllers is verified through performance tests on a specific freezing cabinet. The performance tests show reduced energy consumption as well as temperature levels of the products:

- The overall electrical energy consumption of the freezing cabinet is reduced by 15 % annually using the adaptive functions
- The overall annual average temperature levels of the products are reduced 0,35 K without increasing the maximum temperature present at any time
- No problems regarding water vapour condensation was detected – water vapour condensation was reduced at high humidity levels compared to tradition control method