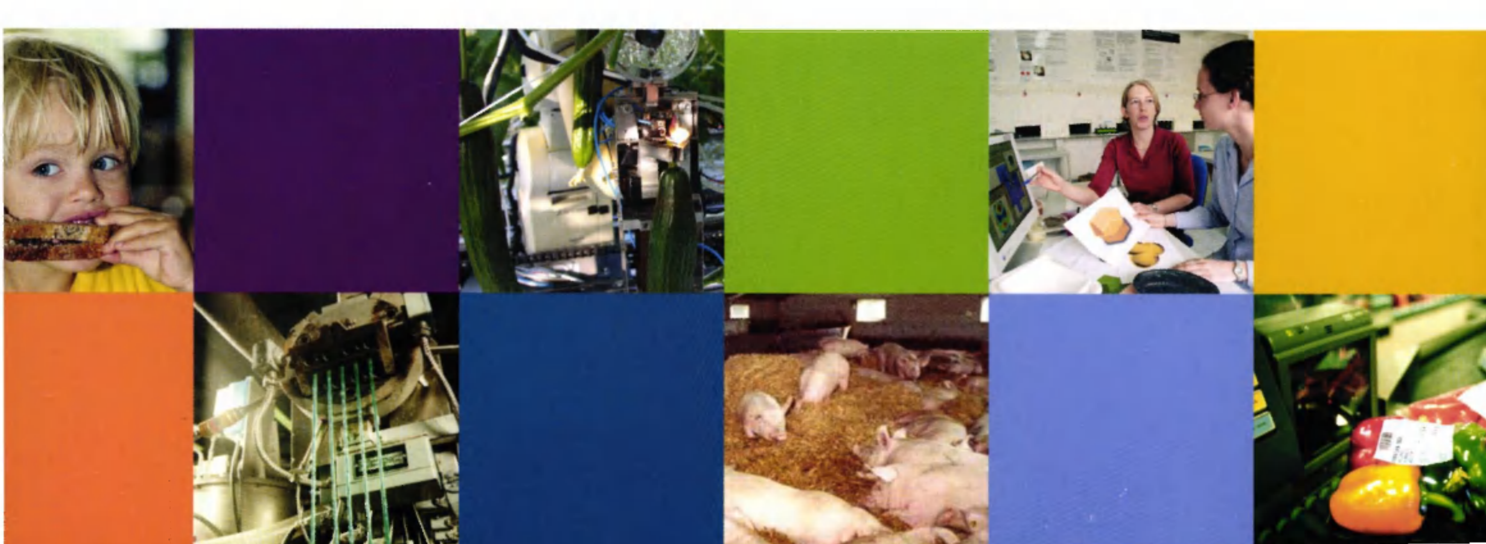
AGROTECHNOLOGY & FOOD INNOVATIONS
WAGENINGEN UR

First Quest Regular Trial Shipment

Mangoes from Brazil to the Netherlands

J.E. de Kramer-Cuppen
H.A.M. Boerrigter

Report 627



First Quest Regular Trial Shipment

Mangoes from Brazil to the Netherlands

J.E. de Kramer-Cuppen
H.A.M. Boerrigter

Report 627

Colophon

Title	First Quest Regular Trial Shipment
Author(s)	J.E. de Kramer-Cuppen, H.A.M. Boerrigter
AFSG number	627
ISBN-number	-
Date of publication	February 16th 2006
Confidentiality	Yes
OPD code	-
Approved by	H. Maas

Agrotechnology and Food Sciences Group
P.O. Box 17
NL-6700 AA Wageningen
Tel: +31 (0)317 475 024
E-mail: info.afsg@wur.nl
Internet: www.afsg.wur.nl

Abstract

The Quest Regular concept and corresponding CCPC software was tested in a real-life shipment of mangoes from Brazil to the Netherlands in December 2005. Power usage, temperature distribution and product quality of the Quest test container were compared to a reference container, which was shipped simultaneously at original settings.

A 41% power saving was achieved over the whole trip. This includes a period in which CCPC mode was mistakably turned off for approximately 5 days during the first part of the trip. The second part of the trip, during which CCPC Mode was on, (29-12-05 to 05-01-06, the second Quest Regular period) showed a mean power saving of 52%.

Carton temperatures in the Quest container were satisfactory and quite close to the setpoint and the temperatures in the reference container. An unbiased quantitative comparison can not be made, because of the different loading temperatures and the period that CCPC was turned off.

Due to the fact that not all the test samples consisted of product coming from one grower only general conclusions with respect to quality and ripening behavior are possible and valid. Chilling effects did not occur in both containers. The ripening of all mangoes was regular and normal. External rot incidence in both containers was the same. There is no indication that the Quest Regular control mode has a negative effect on the quality maintenance of mangoes. The test is valuable because it is demonstrates that the power consumption of mango shipping in Reefer containers can be reduced to a high extend without any negative effect on product quality.

Acknowledgements

This first real-life Quest trial was largely organized and performed by Maersk Sealand. Most of the data and information in this report was provided by Maersk employees. We especially would like to thank Mr. Lindhardt and Mr. Nielsen of Maersk's Centre Reefer Management as well as Mr. Barfod and Mr. de Castro Alves of Maersk's Reefer Operations - South America.

We also thank Carrier Transicold for providing the necessary CCPC software for the trial and the unit data-files that were made from the unit downloads. We especially would like to thank Mr. Griffin, Mr. Dudly, Mr. McIntosh and Mr. Hofsdal.

Quality inspections at arrival and power and temperature data logging were supported by MMS. We would like to thank Mr. Meyers and Mr. Pailes for sharing their data files, findings and reports with us, part of which were used for this report.

We are indebted to our A&F colleagues Mr. van den Boogaard, Mr. Harkema and Mr. Zegveld for their help during the organisation of the trial and its preparations as well as the product quality assessments.

Finally, our thanks go to Bocchi Fruit Trade, whose fruit was transported and who made quality inspection possible at and after arrival.

Contents

1 Introduction

The "Quest regular" system developed to reduce power consumption of reefer containers has been tested in a real life situation in December 2005. In order to exactly determine the amount of power reduction, a comparison was made with a standard controlled reefer container. Both 40 ft. containers were loaded with mangoes and put beside each other on the same vessel (Lexa Maersk). The shipment was from Brazil (Pecem) to The Netherlands (Rotterdam). The transport time was 12 days.

The test container (MWCU 6739457: nr. 3) was equipped with and controlled by the "Quest Regular" software, also referred to as CCPC (Compressor-Cycle Perishable Cooling). The second container (MWCU 6775222: nr. 4) served as a reference container. During the shipment power consumption of both containers was measured using externally added KWH-meters. Temperature distribution in both containers was measured extensively using 30 sensors per container and logging the actual temperature every 30 minutes. Fruit samples for quality evaluation were placed on several fixed positions (27 cartons) in each container (see scheme and location of the temperature sensors). All test cartons[1] contained a temperature sensor (Tiny Tag) to be able to compare the temperature distributions of both containers. With these readings it would be possible to determine correlations between local temperatures and quality development of the fruits. At the moment of stripping of the containers at Bocchi's premises in Bleiswijk, The Netherlands, a first quality inspection of the mango fruit was carried out. The quality evaluation was extended by a ripening treatment of the test samples using the experimental facilities of A&F in Wageningen, The Netherlands.

A precise quality evaluation was necessary as the Quest Regular mode operation allows the supply air to have a low value during specific interval times. This value is lower than the value that is commonly considered a chilling temperature. The idea behind this is that chilling will be avoided by cycling, as the supplied air is only on this low level for short periods. Product temperature and internal metabolic processes do not follow these quick changes of the temperature settings i.e. chilling will not occur. This hypothesis was tested successfully for several commodities before but not with mangoes. The energy saving method is only of value when product i.e. mango quality is not harmed by it.

---

[1] *Except one carton in middle of the reference container which sensor was placed in its kWh meter to get a measure of the ambient temperature.*

2 Material and methods

2.1 Product

The packed mango variety was Tommy Atkins in different sizes. This the largest and least sensitive mango variety. The product originated from various growers and was pre-cooled at 9°C, product temperatures lying between 9 and 11°C.

2.2 Packaging and stowage

The mangoes were packed in corrugated open cardboard packages with holes in the bottom and front ends. Dimensions: 33*27*10cm. In total, two times 5544 cartons were packed, placed on 22 container pallets per container. The size of the pallets (100*110cm) is adapted to container dimensions resulting in the same orientation of the pallet stacks on both sides in the container. The stack contains 12 cartons per layer and 21 layers (column stacking) per pallet.

2.3 Unit settings

The settings of the reference container were the normal settings for Bocchi mango shipments. The intention was to maintain the same average temperature in the Quest container, but with an allowed band width, which enables energy savings. To this end, so called CCPC software was installed on the Quest container, which contains both normal operation as well as the possibility to set the unit in CCPC mode.

The reference container settings were:

• Supply setpoint	8.9 °C = 48 F
• Fan setting	High
• Vent setting	40 m3/h

The CCPC settings were:

• Supply setpoint	6.9 °C = 44.4 F
• Return Air Pulldown Low Limit	8.9 °C = 48 F
• Return Air Low Limit	8.9 °C = 48 F
• Return Air High Limit	9.9 °C = 49.8 F
• Fan setting	Alternating
• Vent setting	40 m3/h

MMS surveyor Philip Meyers reported that at arrival the vent setting for the Quest container was 15 m3/h. Unfortunately, it is unclear when this setting was changed.

2.4 Voyage schedule

On December 22nd the containers were loaded with mangoes. Subsequently, the containers were taken to the harbor of Pecem and loaded to the vessel on December 24th (out stack starboard side, bottom tier on deck). The containers arrived in Rotterdam in the morning of January 5th.

The next day, January 6th, the containers arrived at Bocchi in Bleiswijk, where the mangoes were unloaded. Figure 6 and Figure 7 in the appendix depict the mean temperature and relative humidity in December for such a trip.

2.5 Unit and climate measurements

External KWh meters were attached to both units. The CCPC software installed on the Quest container included additional data logging, storing elaborate unit information every hour. Temperatures were measured by 4 USDA probes and 27 Tiny Tags per container. MMS reports:

"Within MWCU 6739457 (Quest) there were 27 TinyTag data loggers; TK-0014 range G (-40°C to 85°C) conforming to EN500081 pt1: 1992, EN50082 pt1: 1992, manufactured by Gemini Data Loggers UK Ltd, under BS EN ISO9001: 2000 (NQA Certificate 6134). Sensory accuracy ± 0.2°C.

For MWCU 6775222 there were 26 TinyTags within the container and one no. 14 positioned inside the kilowatt meter to give an indication of ambient temperature.

Four PT 100 container probes, three inserted into the pulp and one within the T-bar. One Sensitech TempTale 4 in each container, positioned third row across thirteenth tier within the carton, as per customary practice for all shipments sent by the shipper.

In order to measure the temperature reaction of the fruit to the software system; the TinyTag data loggers had been placed next to the fruit either in the middle or to the sidewall of each carton. Data recording had been pre-set for every 30 minutes and the period under consideration is 12:00 December 23rd 2005 until 17:00 on January 5th 2006. Such instruments were placed in 6 pallets top, middle and bottom locations. As the pallets were stowed two athwart, 3 pallets contained 6 instruments positioned on opposing pallet faces. Each instrument was numbered 1 to 27.

Table 1: Layout of Loggers

Front (Bulkhead)		
Pallet 1		**Pallet 2**
3	6	9
2	5	8
1	4	7
Pallet 3		**Pallet 4**
12	15	18
11	14	17
10	13	16
Pallet 5		**Pallet 6**
21	24	27
20	23	26
19	22	25
Door		

Container probes were located:
(a) Probe 1: Pulp, eleventh tier, cartons 5 of pallet 1
(b) Probe 2: Under pallet no 5 within the T-bar to the centre 70/80cms from the end of the T-bar.
(c) Probe 3: Pulp, second tier carton 13, pallet 3
(d) Probe 4: Pulp twentieth tier cartons thirteen pallet 3." [1]

2.6 Quality measurements

Low temperature injury of mangoes can manifest itself in different ways:

- Degradation of outer tissue: pitting and sunken areas on the surface of the fruits
- Secondary rot occurrence
- Irregular ripening: failure to ripen or unequal ripening

For this reason the fruits were placed in a ripening room set on 20°C for a period of 6 days. The ripening stage and quality parameters were inspected on day 1, 4 and 7 after the transport phase.

Directly after the unloading of the containers, the fruit quality was inspected by the quality inspector of the receiving company (Bocchi) and a representative of MMS (P. Myers). A&F inspected the fruit samples taken for further ripening the next day. During the period from sampling to the first inspection at A&F products were kept on 10°C. After the initial inspection fruits were placed in a ripening room at 20°C and inspected again 3 and 6 days after the start of the ripening period.

During the ripening period the following quality parameters were measured:

• Blush:	% of the whole surface
• Background colour:	scale 0 (dark green) to 5 (yellow)
• Flesh colour:	scale 0 (white) to 5 (orange/yellow)
• Firmness:	1) manually: 0 (very hard) to 5 (very soft)
• Firmness:	2) penetrometer value: >13 kg (very hard); 2-3 (soft)
• Defects:	Latex flow
	Rot: stem-end rot and other rot occurrences
	Anthracnose
	Others

Using ANOVA (analysis of variances) significant differences will be calculated and correlations between temperature (e.g. container and location in the container) will be analyzed to be able to explain possible differences in quality and ripening effects. For these statistic methods it is a requirement that all the test samples are equal i.e. are from the same grower and must have the same size.

3 Temperatures

3.1 Temperature readings at the start of the trip

When comparing the temperature readings of both containers, it should be noted that the fruit in the reference container was loaded up to 2°C warmer then the fruit loaded into the Quest container. The mango pulp temperature readings in the reference container at loading were 0.3 – 1.1°C warmer, as can be seen from the data in Table 9 and Table 10 in the appendix. The carton temperature readings started 12 hours later, but also show (in more detail) that the reference container temperatures are warmer at the beginning of the trip. Around noon on December 23rd, temperatures measured in the cartons were approximately 2°C higher in the reference container then in the Quest container, see Table 11 and Table 12 in the appendix. (Note that time readings can differ between both units, as well as the Tiny Tags, since the clocks were not set equal.)

Figure 1 depicts all initial Tiny Tag readings (carton temperatures). The left hand side represents the unit end of the containers, the right hand side is the door end. In the reference container, the cartons close to the door and ceiling are quite warm, up to 12°C. In the Quest container, the cartons on these positions are also somewhat warmer then the ones close to the unit, up to 10°C. (Note that pull down has started before this time instance, some cooling has been performed already.)

3.2 Temperature readings during the trip

Figure 2 shows temperature data over time of both units. The Quest container performed a pull down from December 22nd 16:00 to 23:00, where after Quest Regular cycling (also called CCPC mode) is activated. After approximately 48 h, CCPC Mode was turned off and the unit was (mistakably) set to cool continuously on 6.7°C. This causes an additional cool down of the product during the subsequent 5 days, which is not part of normal Quest Regular operation. On December 27th at 17:00 the settings for the Quest container were corrected and CCPC mode was turned on again. Because of the low temperatures in the container at that time, CCPC mode turned the compressor for 15 hours allowing the return air to reach the return air high limit of 9.9°C. Hereafter Quest regular cycling starts again and lasts until the end of the trip. During the whole trip defrost actions are taken after every 6 hours of compressor run-time. The defrost actions take approximately 18 minutes and 0.5 kW. These small values indicate that no ice was present on the coil and defrost was not necessary. The reference container performed a pull down for approximately 3 hours, where after the unit runs in normal operation continuously, cooling with a supply temperature of 8.9°C. No defrost actions are taken, since the defrost thermistor sensor does not measure temperatures below it's boundary of 10°C.

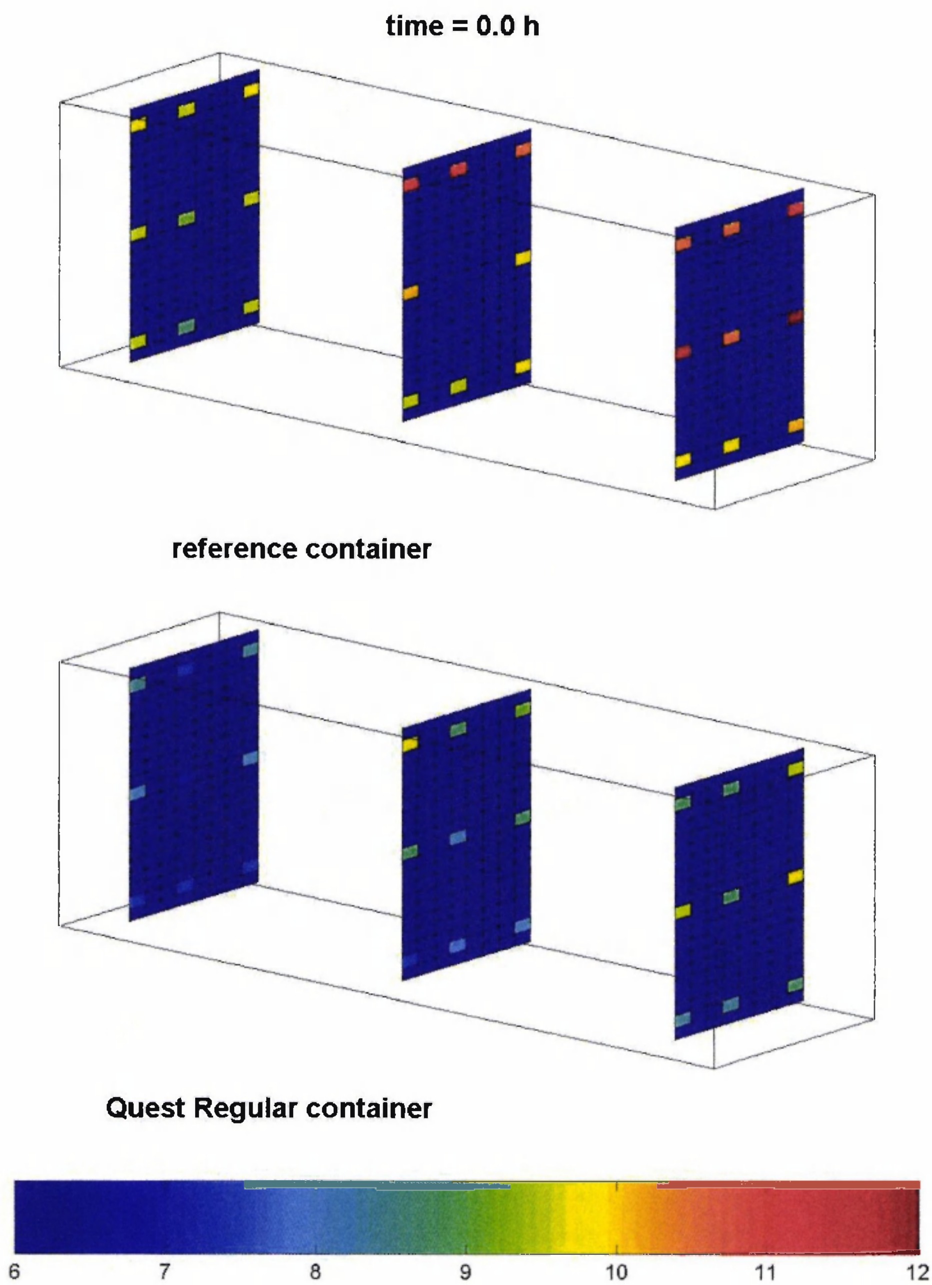


Figure 1 Tiny Tag readings of the carton temperatures on December 23rd 11:30, during the first phases of the trip

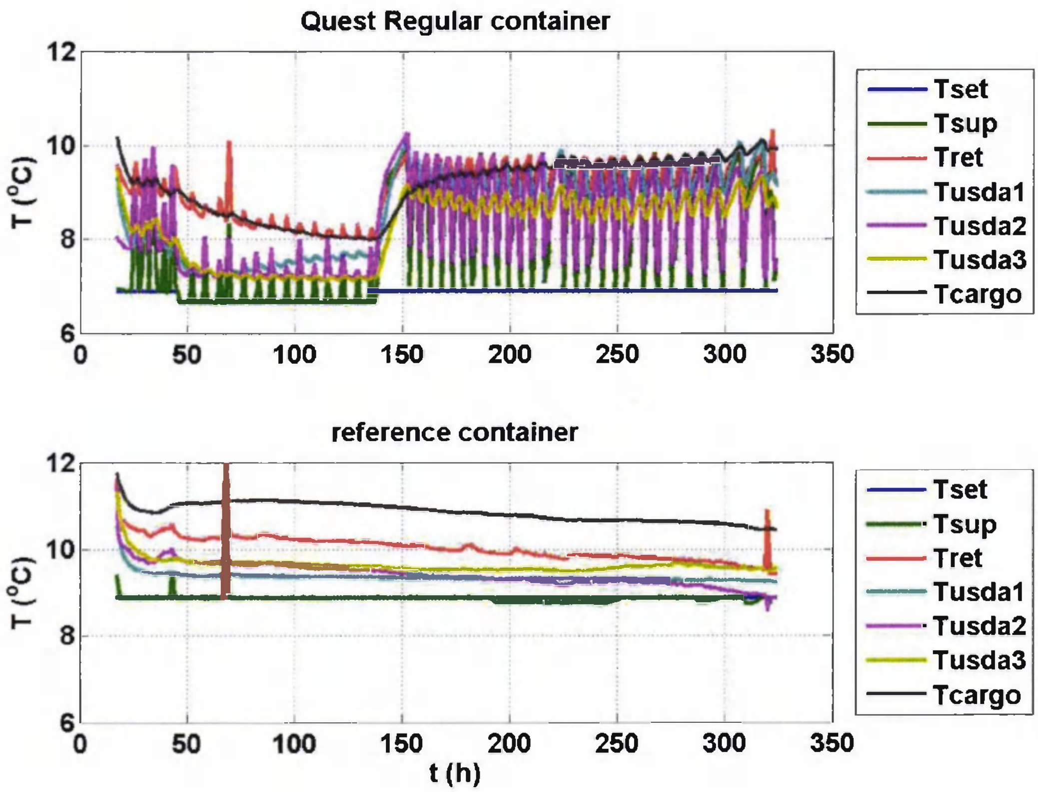


Figure 2 Temperature readings from the units, for both containers. Tusda1, Tusda3 and Tcargo are pulp temperature readings. Tsup, Tret and Tusda2 are air temperature readings.

Figure 3 shows the Tiny Tag data for the coolest and warmest carton, as well as the mean temperature of all cartons, for both containers. This gives an overview of all carton temperature readings, which are shown in Figure 8 in the appendix. To get a good impression of the spatial distributions of the carton temperatures and how these change in time, see the movies on the accompanying cd: QRtrial1_testcont.avi, QRtrial1_refcont.avi and QRtrial1_both.avi.

3.2.1 Temperature readings during pull down and low temperature setting

Quest Regular settings were chosen such that pull down (with supply air of 6.9°C) lasts until return air reaches the reference setpoint of 8.9°C[2]. This takes advantage of Quest Regular's use of return air temperature readings for control, making sure that the cargo cools down sufficiently before starting the cycling mode. Consequently, part of the cargo will be somewhat cool at the start of the trip, as can be seen in the somewhat low pulp temperature readings during the first

---

[2] *It could also be argued that this setting should be set 1°C higher then the reference setpoint, because users expect the load to be warmer then the setting. However, A&F experts chose this setting since hot spots in the load that are not pulled down correctly would have a more negative influence on mango quality then the cool start-off of the products close to the unit, which warm up again during the remainder of the trip. On average current settings are expected to give a better temperature distribution.*

few hours of CCPC mode, see Table 13 in the appendix and Figure 1. For comparison, data of the reference container are given in Table 14, see appendix.

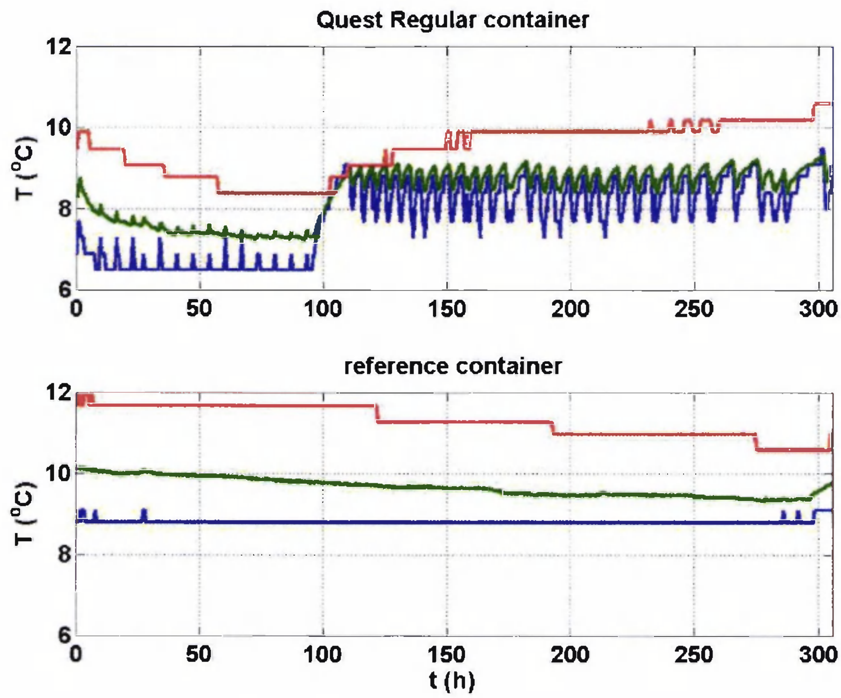


Figure 3 Temperature readings of Tiny Tags in cartons, coolest (-) and warmest (-) carton, as well as mean temperature for all cartons (-) , for both containers

After pull down, the maximum carton temperatures in the Quest container is already 10°C, whereas it is still 12°C for the reference container. During cycling the cool cartons would become warmer again, while the warmer cartons stay in the desired range. This is not clearly visible in the graphs, since after approximately 48 h, Quest Regular Mode is turned off and the unit is (mistakably) set to cool continuously on 6.7°C. This causes an additional cool down of the product during the subsequent 5 days, which is not part of normal Quest Regular operation.

Pull down of the reference container supply air finishes within a few hours. However, a carton temperature difference of 2.9°C is present for a large part of the trip. The reference container fruit keeps cooling slowly during shipment and only reaches it's lowest maximum value of 10.6°C on January 3rd. At that time, the maximum difference in carton temperatures is 1.8°C.

3.2.2 Temperature readings during Quest Regular Mode

Figure 9 in the appendix shows the temperature distribution at the start of the second Quest Regular cycling period, as well as the carton temperatures of the reference container at that time. The initial temperatures for the Quest container lie between 8 and 10°C, a somewhat cold starting point, but close to the desired range, while the reference container is somewhat warm with temperatures between 9 and 12°C. Figure 10 in the appendix shows the temperature distributions near the end of the trip on the evening of December 3rd. The carton temperatures of the Quest container now lie between 9 and 10.5°C, as desired. At the same time instance, the reference container temperatures also lie in the desired range, with a few more hotspots near 11°C.

The temperature data for this second Quest Regular period (December 28th until January 4th) have been summarized in Table 2 through Table 6. The tables contain information on the temperatures of the coolest and warmest cartons as well as the mean temperature of all cartons combined. The carton temperatures in the Quest container fluctuate in time with a relatively high frequency, which amplitude is less relevant to the product then its mean value. Therefore, not only the lowest and highest recorded temperatures are taken into account, but also the mean temperature of each carton.

First of all, the deviation from the given setpoint is important. The mean carton temperature of the Quest container is 8.8°C. The mean carton temperature of the reference container is 9.5°C. Thus, the Quest container is 0.5°C closer to the setpoint of 8.9 °C then the reference container.

Secondly, the maximum bandwidth of the carton temperatures is considered. Looking at the lowest and highest temperatures measured in the cartons, the maximum temperature difference between the coolest and warmest carton was 3.3°C in the Quest container and 2.9°C in the reference container. Thus, in the most extreme situation, the Quest container had a 0.4°C larger temperature bandwidth then the reference container.

Thirdly, the mean bandwidth of the carton temperatures is considered. Looking at the mean of the carton temperatures in time, the temperature difference between the coolest and warmest carton was 1.7°C in the Quest container and 2.3°C in the reference container. Thus, on average, the Quest container had a 0.6°C smaller temperature bandwidth then the reference container.

Fourthly, the deviation of the coolest carton from the given setpoint is important. The coolest carton of the Quest container is 0.7°C below setpoint. The coolest carton of the reference container is 0.1°C below setpoint. Thus, the coolest carton of the Quest container is 0.6°C further from the setpoint then the reference container.

Finally, the deviation of the warmest cartons from the given setpoint is important. The coolest carton of the Quest container is 1.0°C above setpoint. The warmest carton of the reference container is 2.2°C below setpoint. Thus, the warmest carton of the Quest container is 1.2°C closer to the setpoint then the reference container.

Overall, carton temperatures in the Quest container were satisfactory and quite close to the setpoint and the temperatures in the reference container. Depending on the focus on deviations, minimum, mean or maximum temperatures, the performance is somewhat worse, equal or better then the reference, compared to the given setpoint. However, only qualitative conclusions should be drawn for the temperature performance. An unbiased quantitative comparison can not be made, because of the different loading temperatures and the mistaken settings.

	min carton T (°C)	mean carton T (°C)	max carton T (°C)
Quest container	7.3 to 8.8	8.4 to 9.3	9.5 to 10.6
reference container	8.8 to 9.1	9.3 to 9.8	10.6 to 11.7

Table 2 The ranges of the minimum, maximum and mean carton temperature readings from December 28th 00:00 to January 4th 23:30 for both containers

	mean min carton T (°C)	mean mean carton T (°C)	mean max carton T (°C)
Quest container	8.2	8.8	9.9
reference container	8.8	9.5	11.1

Table 3 The mean of the minimum, maximum and mean carton temperature readings from December 28th 00:00 to January 4th 23:30 for both containers

	dev min carton T (°C)	dev mean carton T (°C)	dev max carton T (°C)
Quest container	-1.6 to -0.1	-0.5 to +0.4	+0.6 to +1.7
reference container	-0.1 to +0.2	+0.4 to +0.9	+1.7 to +2.8

Table 4 The deviations from setpoint for the the minimum, maximum and mean carton temperature readings from December 28th 00:00 to January 4th 23:30 for both containers

	dev mean min carton T (°C)	dev mean mean carton T (°C)	dev mean max carton T (°C)
Quest container	-0.7	-0.1	+1.0
reference container	-0.1	+0.6	+2.2

Table 5 The deviations from setpoint for the mean of the minimum, maximum and mean carton temperature readings from December 28th 00:00 to January 4th 23:30 for both containers

	ΔT coolest carton (°C)	ΔT mean carton (°C)	ΔT warmest carton (°C)
Quest container	-0.6	+0.5	+1.2

Table 6 The difference in deviation from setpoint for the Quest container compared to the reference container, for the coolest, mean and warmest carton, December 28th 00:00 to January 4th 23:30

4 Power Consumption

Power consumption data were read from the kWh meters by Maersk employees at the start and end of the trip as well as twice a day during the second Quest Regular period. Time and energy data were taken from the kWh meters and ambient temperature readings were read from the unit's user interface, see Figure 4 and Table 15 in the appendix.

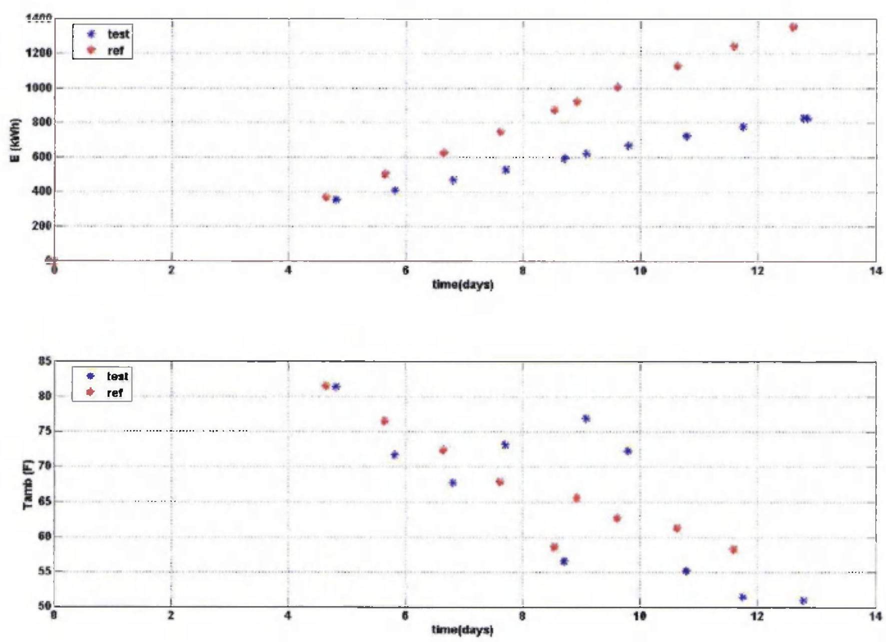


Figure 4 Energy and temperature readings as a function of time for both containers

The reference container used 1392 kWh in 302.38 hour, a mean power usage of 4.6 kW. The Quest container used 829 kWh in 308.26 h, a mean power usage of 2.7 kW, which is 41% less compared to the reference container. The top part of Figure 4 shows that the savings are collected during the second part of the voyage, during the second Quest Regular period. The first part of the trip has a mean saving of 28% (22-12-05 to 29-12-05, including the 5 days of CCPC off). The second part of the trip (29-12-05 to 05-01-06, the second Quest Regular period) has a mean saving of 52%. The power and savings per day are shown in Figure 5.

The power savings are largely due to the periods that the compressor is turned off during cycling, the length of which can be seen in Figure 13 in the appendix. (For comparison, the active hours and defrost time of the unit is shown in Figure 14 in the appendix.) During the first Quest Regular cycling period, compressor off time intervals last approximately 100 minutes, somewhat shorter then the compressor-on time intervals. During the second Quest Regular cycling period, compressor off time intervals last for 200 to 300 minutes, much longer then the compressor-on time intervals of 100 minutes. The difference with the first period can be explained by the higher heat load in tropical areas. The measured ambient temperatures are shown in Figure 12 in the appendix. Other factors of influence are defrost intervals, the reduced fan speed during compressor-off time intervals and the uncertain amount of ventilation (which could have been 40 m3/h for both containers or perhaps 15 m3/h for the Quest container during part of the voyage).

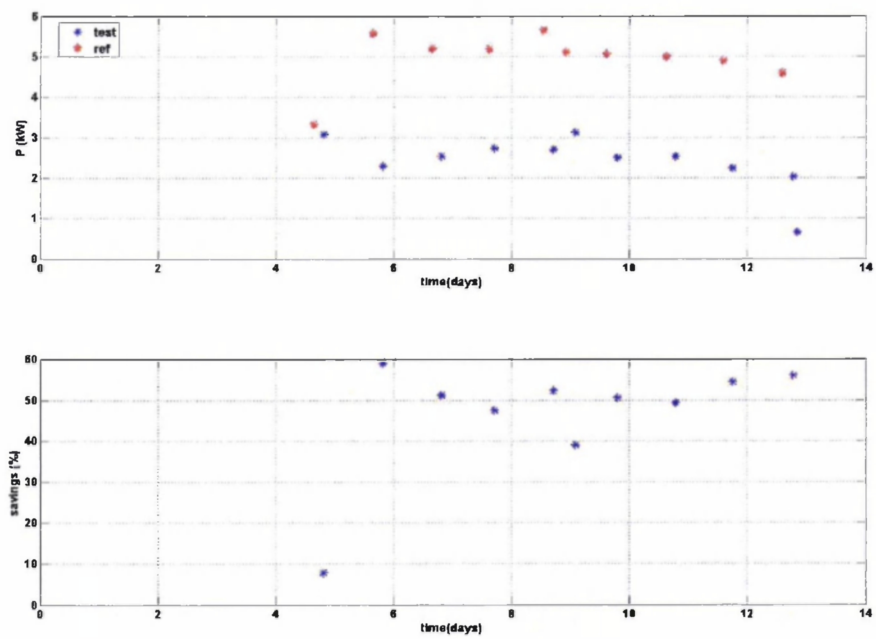


Figure 5 Power and savings as a function of time for both containers

5 Evaluation of fruit quality and ripening behaviour

The temperature setting of container 3 (reference) was 8.9°C. The intention was to maintain the same average temperature in the test container, but with an allowed band width. Quality inspections should show that this would not give rise to chilling injury or other negative quality effects. Unfortunately it happened that the Quest Regular control mode was switched off during the first 5 days of the shipment. Settings were restored from day 6. Because of this, the actual product temperature became lower than intended. During approximately 48 hours product temperature was lower than the generally accepted threshold value for chilling.

Bocchi, MMS and A&F inspected the quality of the product at unloading of the cargo. None of them saw any major quality defect. The general judgment was that the quality of all shipped products was considered good to very good. Only some individual fruits showed some ripening and softening. Fruits coming out of test container tended to be more immature than the fruits coming out of the reference container. This opinion was based on how the fruits looked like when the sample cartons were spread out on the floor in two groups. After cutting some fruits incidentally split stone, stem-end rot or a cavity in the flesh was found. However these infected fruits were found in both containers and in a minor amount. On most fruits some latex flow was found. The occurrence of this defect was the same in both containers.

The quality inspector of Bocchi preferred the mangoes coming out of the test container. His argument was that the more immature mangoes out of this container gives Bocchi extra distribution time i.e. handling procedures and further transport can be organized more optimal. Product out of the test container can be distributed one day extra while product out of the reference container must be transferred within one day to the receiving German retailers looking to the ripening stage. However these differences in ripeness may be due to different batches as containers were not loaded identically. More likely is that the lower temperatures during the first 5 days of the trip are responsible for the observed difference.
The MMS quality inspection results at this inspection moment are reported separately (see report 5307.01/KP by MMS.

Table 7 shows the summarized results of the quality inspection at A&F during the ripening period. The sample cartons came from various growers (indicated by printed nr. on cartons). It became clear that, only a few cartons from the same grower were put in both containers, mostly not corresponding to the same locations in the reference container. For a correct analysis of possible correlations between product quality and temperature (due to container type and location) product from the same grower is necessary. For this reason it is impossible to show correlations between location (temperature) and quality development.

			blush	Peel color (0 green -5)			Firmness (0 hard -5)			Flesh color (0 white -5)			penetrometer value (kg)			
container	grower	Nr. cartons	%	0	3	6	0	3	6	0	3	6	0	3	6	<--- day
3	?	3	42	1.0	1.8	2.3	0.0	1.1	2.0	-	2.7	2.4	-	7.5	3.9	
3	1	1	44	0.8	2.3	3.0	0.0	1.3	3.0	-	2.5	2.5	-	9.2	2.6	
3	3	16	56	0.3	1.4	2.0	0.0	1.1	2.4	-	2.2	2.8	-	8.1	3.7	
3	12	5	33	0.8	1.4	2.0	0.0	0.9	2.5	-	1.7	2.5	-	7.5	3.1	
3	199	1	48	1.8	3.0	4.0	0.0	1.8	3.0	-	2.5	4.0	-	6.4	2.8	
3	1022	1	69	0.9	1.9	3.3	0.0	1.5	2.5	-	2.8	3.0	-	7.5	3.3	
4	?	4	43	0.7	2.0	2.8	0.0	1.4	3.0	-	2.0	2.6	-	7.2	3.2	
4	12	2	46	0.9	1.8	2.1	0.0	1.7	3.4	-	2.5	2.8	-	5.1	2.6	
4	137	15	43	1.0	2.2	2.9	0.0	1.7	3.0	-	2.4	2.9	-	6.7	3.3	
4	199	6	54	1.8	3.0	3.7	0.0	1.7	2.9	-	2.6	3.0	-	6.5	2.3	
cont 3		**27**	50	0.6	1.6	2.2	0.0	1.1	2.4	-	2.2	2.7	-	7.9	3.5	
cont 4		**27**	46	1.1	2.3	3.0	0.0	1.7	3.0	-	2.4	2.9	-	6.6	3.0	

Table 7 Quality measurements of mangoes transported in a Quest Regular controlled reefer container (nr. 3) and a reference container (nr.4) and subsequently stored at 20°C.

Fruits were not inspected internally on day 0. Half of the fruits were cut at day 3 and 6 to inspect internal quality. Data on flesh colour and penetrometer value on day 0 are missing for this reason. Almost all fruits coming from both container 3 and 4 ripened normally and equally. Fruits coming from the reference container (nr.4) were softer after both 3 and 6 days compared to fruits coming out of the test container. Both firmness (both methods) and colour are developing in the same direction and do not indicate damage to the fruit as a result of the transport conditions.

Rot incidence on the surface of the fruits can be seen as a major indicator of chilling, especially after a ripening period on the fruits. Rot scores are summarized in Table 8. After cutting some samples showed a rather high incidence of stem-end rot. Looking to the reference container (4), grower nr. 137 contributes most to the total amount of rot. In container 3, grower nr. 12 has a relative high score. This observation makes clear that the observed rot occurrence (stem-end rot) is typically a result of poor initial quality of the shipped product. Bocchi's quality inspector mentioned that the harvest conditions in Brazil were far from optimal this season. Longer periods of rain in the weeks prior to harvest and shipping make the product susceptible for this quality aspect. The rot occurrence is obviously not an effect of the transport temperatures or the differences between the two containers. The opinion of A&F product specialists is that with these relative high rot scores the product should be characterized as a moderate to poor quality product. The same fruit can have stem end rot and at the same time other rot. This is not separated in the data.

container	grower	N cartons	n mangoes	Stem-end rot n	Stem-end rot %	Other rot (surface) n	Other rot (surface) %
3	?	3	18	1	6	1	6
3	1	1	4	0	0	0	0
3	3	16	120	9	8	6	5
3	12	5	28	4	14	2	7
3	199	1	5	0	0	0	0
3	1022	1	8	0	0	0	0
4	?	4	24	2	8	0	0
4	12	2	12	2	13	1	8
4	137	15	104	23	22	11	11
4	199	6	54	3	6	0	0
cont 3		27	183	14	8	10	5
cont 4		27	194	30	15	12	6

Table 8 Amounts of rotten fruits in samples out of a Quest Regular controlled container (nr. 3) and a reference container (nr. 4) after a period of 3 and 6 days ripening at 20°C.

6 Conclusions

6.1 Power savings

The reference container had a mean power usage of 4.6 kW, this was 2.7 kW for the Quest, which is a 41% saving. This includes the period that CCPC mode was turned off for approximately 5 days during the first part of the trip. The second part of the trip, during which CCPC Mode was on, (29-12-05 to 05-01-06, the second Quest Regular period) has a mean saving of 52%.

6.2 Temperatures

To compare the temperatures in the cartons, the second Quest Regular period will be considered. The carton temperatures in the Quest container fluctuate in time with a relatively high frequency, which amplitude is less relevant to the product then its mean value. Therefore, not only the lowest and highest recorded temperatures are taken into account, but also the mean temperature of each carton.

First of all, the deviation from the given setpoint is important. The mean carton temperature of the Quest container is 8.8°C. The mean carton temperature of the reference container is 9.5°C. Thus, the Quest container is 0.5°C closer to the setpoint of 8.9 °C then the reference container.

Secondly, the maximum bandwidth of the carton temperatures is considered. Looking at the lowest and highest temperatures measured in the cartons, the maximum temperature difference between the coolest and warmest carton was 3.3°C in the Quest container and 2.9°C in the reference container. Thus, in the most extreme situation, the Quest container had a 0.4°C larger temperature bandwidth then the reference container.

Thirdly, the mean bandwidth of the carton temperatures is considered. Looking at the mean of the carton temperatures in time, the temperature difference between the coolest and warmest carton was 1.7°C in the Quest container and 2.3°C in the reference container. Thus, on average, the Quest container had a 0.6°C smaller temperature bandwidth then the reference container.

Fourthly, the deviation of the coolest carton from the given setpoint is important. The coolest carton of the Quest container is 0.7°C below setpoint. The coolest carton of the reference container is 0.1°C below setpoint. Thus, the coolest carton of the Quest container is 0.6°C further from the setpoint then the reference container.

Finally, the deviation of the warmest cartons from the given setpoint is important. The coolest carton of the Quest container is 1.0°C above setpoint. The warmest carton of the reference container is 2.2°C below setpoint. Thus, the warmest carton of the Quest container is 1.2°C closer to the setpoint then the reference container.

Overall, carton temperatures in the Quest container were satisfactory and quite close to the setpoint and the temperatures in the reference container. Only qualitative conclusions should be drawn for the temperature performance. An unbiased quantitative comparison can not be made, because of the different loading temperatures and the mistaken settings.

6.3 Product quality

Due to the fact that not all the test samples consisted of product coming from one grower only general conclusions with respect to quality and ripening behavior are possible and valid.

The Quest Regular controlled container slowed down the ripening processes of the mangoes more than the reference container did. This may be caused by the (low) temperature setting during the first 5 days. Another explanation may be that the observation is incorrect due to differences in the load. The ripening differences were regarded by the receiving company as an added value of the Quest Regular control mode. Riper product forces Bocchi to distribute the mangoes immediately to the German end user.

Chilling effects did not occur in both containers. The ripening of all mangoes was regular and normal. External rot incidence in both containers was the same.
There is no indication that the Quest Regular control mode has a negative effect on the quality maintenance of mangoes.

Relative high percentages of stem-end rot were found in both containers and are most likely caused by the grower i.e. a poor initial quality before shipping. This rot occurrence and development is independent of the used container control mode.

The test is valuable because it is demonstrates that the power consumption of mango shipping in Reefer containers can be reduced to a high extend without any negative effect on product quality. With test samples from the same grower more detailed information could have been extracted out of the test. To prove the robustness of the Quest control mode more shipments should be monitored.

References

[1] MARINE MANAGEMENT SURVEYS LTD, MARINE SURVEYORS & CARRIERS LIABILITY SURVEYORS, Ref: 5307.02/KP, TEMPERATURE ANALYSIS REPORT QUEST TRIAL, January 2006

[2] MARINE MANAGEMENT SURVEYS LTD, MARINE SURVEYORS & CARRIERS LIABILITY SURVEYORS, Ref: 5307.01/KP, PRELIMINARY SURVEY REPORT QUEST TRIAL, January 2006

Appendix I: Ambient conditions from Pecem to Rotterdam

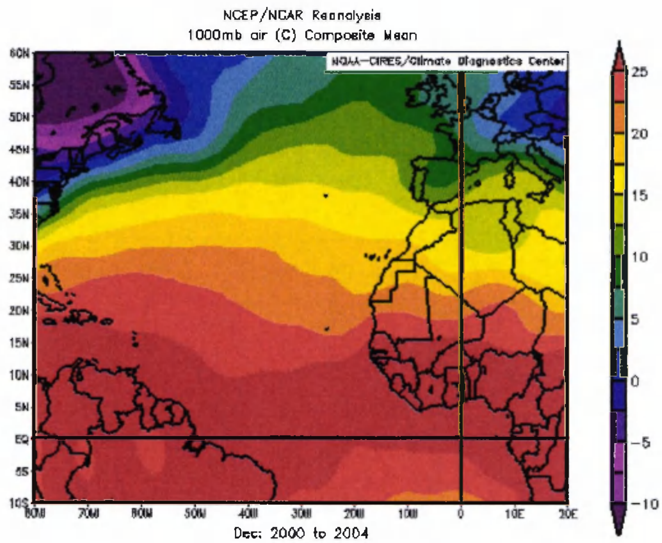


Figure 6 Mean December temperatures between Pecem and Rotterdam

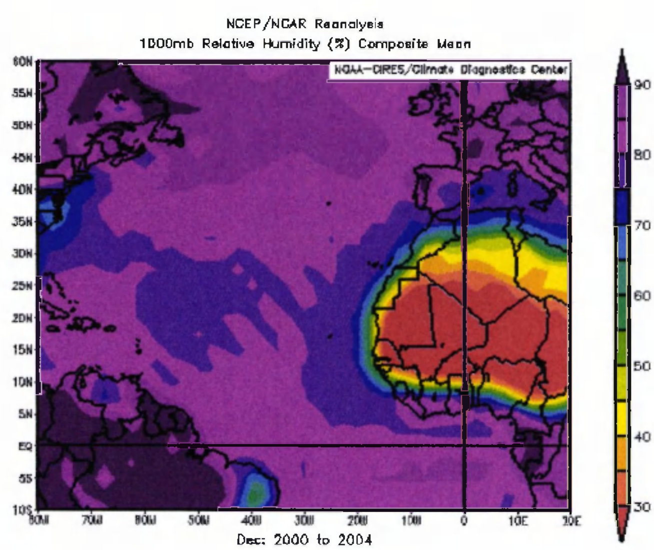


Figure 7 Mean December relative humidity between Pecem and Rotterdam

Appendix II: Pulp temperatures at the start of the trip

DATE	TIME	SETP (°C)	SUP (°C)	RET (°C)	USDA1 (°C)	USDA2 (°C)	USDA3 (°C)	CARGO (°C)
22-12-2005	18:00	8.88	9.14	10.8	10.29	10.43	10.99	11.55
22-12-2005	19:00	8.88	8.89	10.66	10.07	10.17	10.71	11.41
22-12-2005	20:00	8.88	8.88	10.67	9.9	10.08	10.5	11.28

Table 9 Unit data from reference container at loading, from file MWCU6775222_TempLog.txt

DATE	TIME	SETP (°C)	SUP (°C)	RET (°C)	USDA1 (°C)	USDA2 (°C)	USDA3 (°C)	CARGO (°C)
22-12-05	15:00	6.88	7.60	10.72	10.16	9.65	10.27	10.70
22-12-05	16:00	6.88	6.9	9.76	9.74	8.32	9.88	10.47
22-12-05	17:00	6.88	6.95	9.59	9.32	8.07	9.52	10.19

Table 10 Unit data from Quest container at loading, from file MWCU6739457_TempLog.txt

DATE	TIME	mean carton T (°C)	min carton T (°C)	max carton T (°C)
23-12-05	11:30	10.14	8.80	12.00
23-12-05	12:00	10.11	8.80	11.70
23-12-05	12:30	10.12	8.80	12.00

Table 11 Summary of Tiny Tag carton temperature data from reference container at start of measurement, from file all loggers MWCU 6775222.xls

DATE	TIME	mean carton T (°C)	min carton T (°C)	max carton T (°C)
23-12-05	11:30	8.38	6.9	9.9
23-12-05	12:00	8.28	6.9	9.9
23-12-05	12:30	8.57	7.7	9.9

Table 12 Summary of Tiny Tag carton temperature data from Quest container at start of measurement, from file all loggers MWCU 6739457.xls

Appendix III: Pulp temperatures after pull down

	USDA1 (°C)	USDA3 (°C)	CARGO (°C)
minimum temperature	7.7	7.9	8.9
mean temperature	8.0	8.2	9.1
maximum temperature	8.5	8.5	9.3

Table 13 Minimum, maximum and mean pulp temperature readings during the first (short) Quest Regular Mode time interval from 22-12-05 23:00 to 23-12-05 22:00

	USDA1 (°C)	USDA3 (°C)	CARGO (°C)
minimum temperature	9.4	9.8	10.8
mean temperature	9.6	10.1	11.0
maximum temperature	9.5	9.8	10.9

Table 14 Minimum, maximum and mean pulp temperature readings for the reference container 22-12-05 23:00 to 23-12-05 22:00

Appendix IV: Carton temperature readings as a function of time

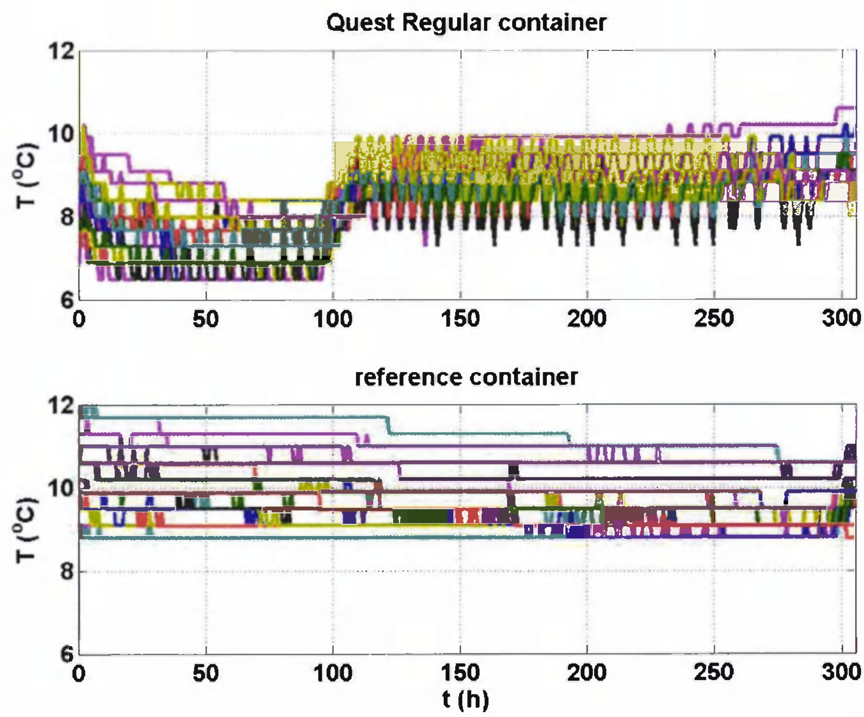


Figure 8 Temperature readings of Tiny Tags in cartons, all data, for both containers

Appendix V: Snapshot pictures of carton temperature readings

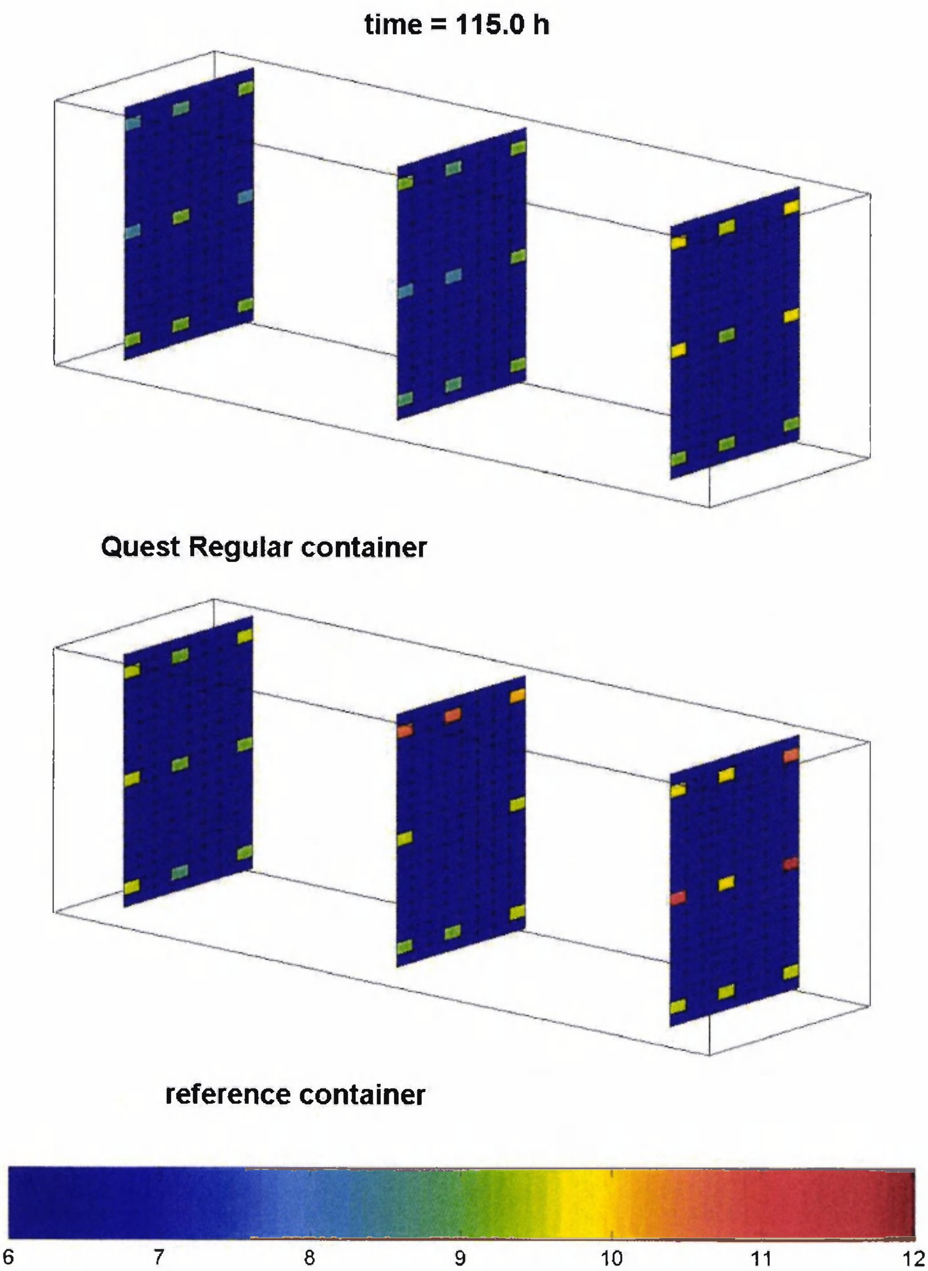


Figure 9 Tiny Tag readings of the carton temperatures at the start of the Quest Regular mode period, on December 28th 06:30

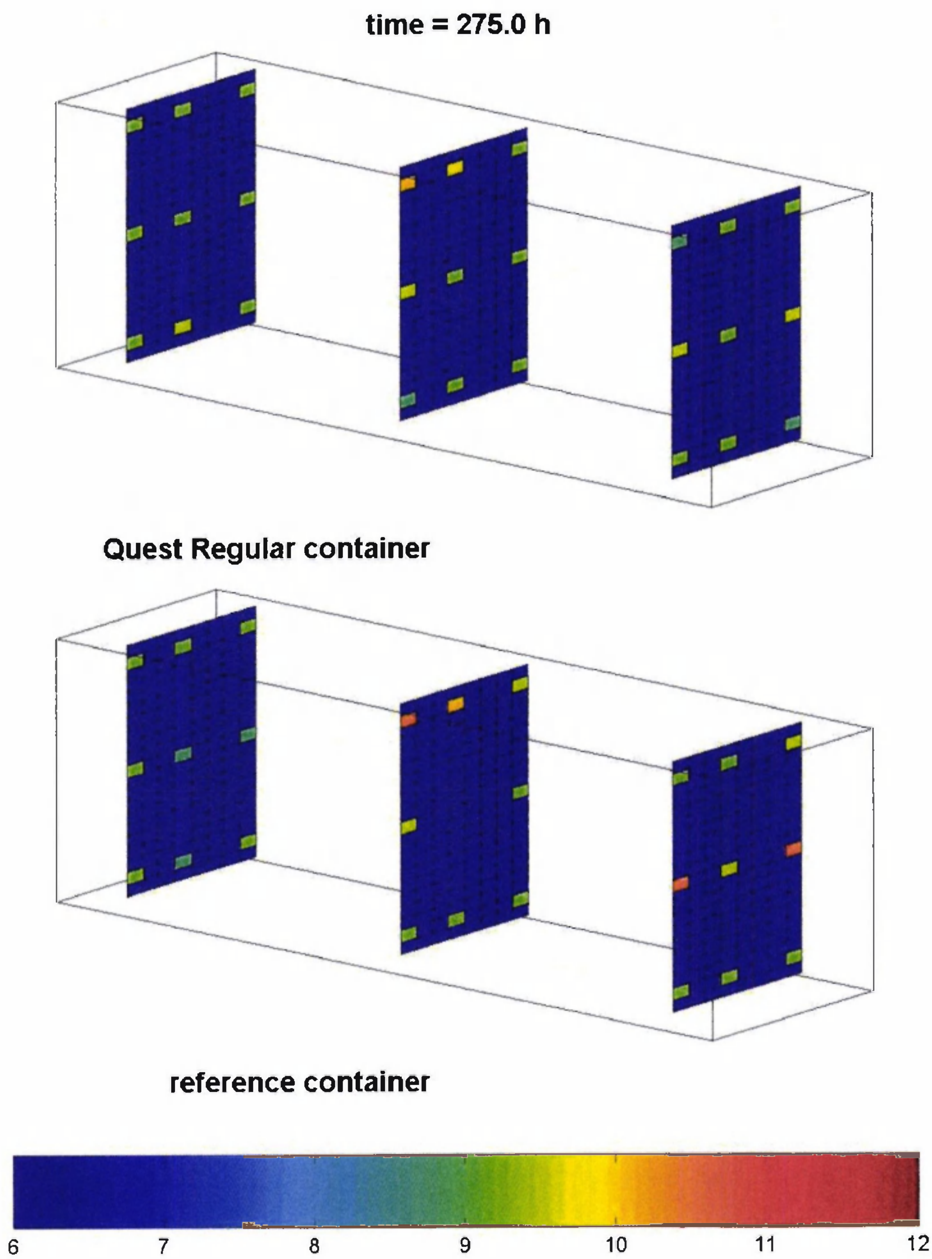


Figure 10 Tiny Tag readings of the carton temperatures near the end of the Quest Regular mode period, on December 3rd 22:30

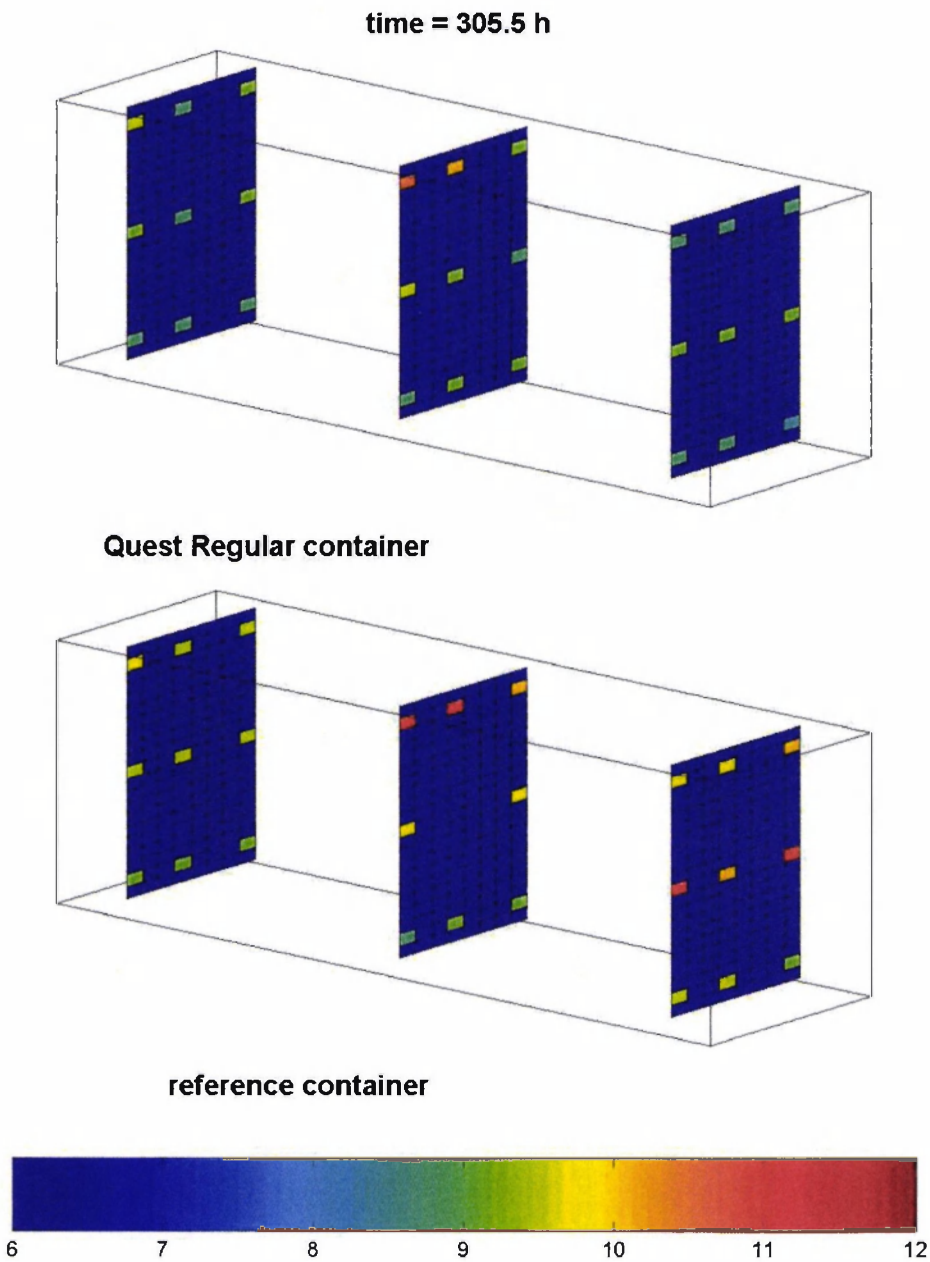


Figure 11 Tiny Tag readings of the carton temperatures at the end of the trip, on January 5th 05:00

Appendix VI: Ambient temperatures

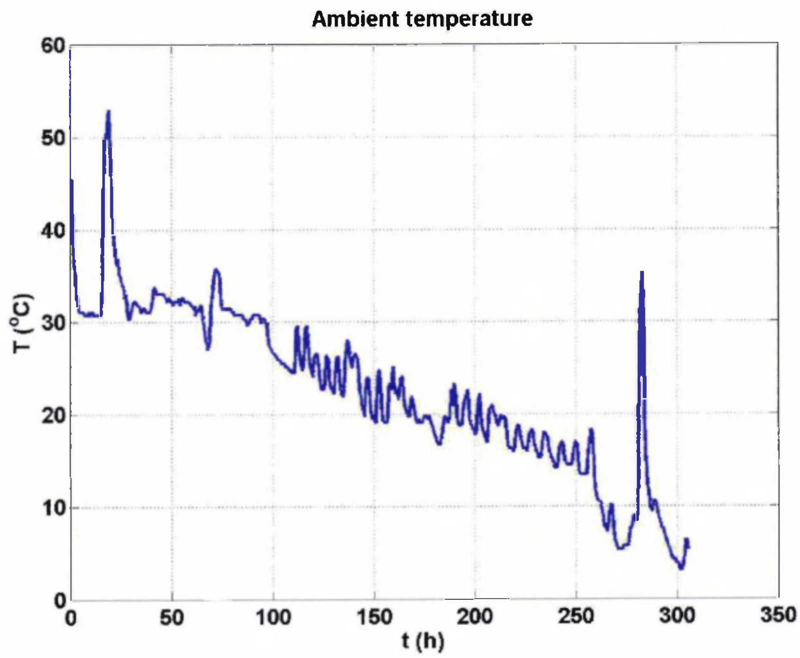


Figure 12 Ambient temperature readings form the Tiny Tag in the kWh-meter

Appendix VII: Power consumption data

Reference:

t (h)	Tamb (F)	E (kWh)
315.27	-	2892
426.76	81.6	3264
434.76	80.2	3315
450.76	76.6	3398
458.76	74.5	3449
474.76	72.5	3523
482.76	75.1	3573
498.22	68.0	3645
505.07	69.4	3692
520.28	58.7	3770
529.44	65.7	3817
546	62.8	3901
553.38	64.1	3939
570.37	61.4	4023
577.95	62.0	4060
593.59	58.4	4137
601.84	60.7	4177
617.65	-	4248

Quest:

t (h)	Tamb (F)	E (kWh)
677.39	-	1853
792.85	81.4	2208
800.85	82.6	2255
816.85	71.7	2263
824.85	69.6	2285
840.85	67.8	2324
848.85	66.2	2354
862.47	73.2	2383
871.23	63.3	2414
886.53	56.6	2448
895.48	76.9	2476
912.62	72.3	2519
919.39	68.1	2542
936.28	55.2	2579
943.98	53.8	2599
959.5	51.5	2631
967.86	45.1	2651
984.14	51.0	2681
985.65	-	2682

Table 15 Power consumption measurement data from both units

t(days)	Ptest(kW)	Pref(kW)	Savings(%)	T(F)
4.6	3.0	3.4	7.9	81.4
5.0	5.9	6.4	7.8	82.6
5.6	0.5	5.2	90.4	71.7
6.0	2.8	6.4	56.9	69.6
6.6	2.4	4.6	47.3	67.8
7.0	3.8	6.3	40.0	66.2
7.6	2.1	4.7	54.3	73.2
7.9	3.5	6.9	48.4	63.3
8.5	2.2	5.1	56.7	56.6
8.9	3.1	5.1	39.0	76.9
9.6	2.5	5.1	50.5	72.3
9.9	3.4	5.1	34.0	68.1
10.6	2.2	4.9	55.7	55.2
10.9	2.6	4.9	46.8	53.8
11.6	2.1	4.9	58.1	51.5
11.9	2.4	4.8	50.7	45.1
12.6	1.8	4.5	59.0	51.0

Table 16 Calculated power and savings measurement data for both units as a function of time

Appendix VIII: Unit activity graphs

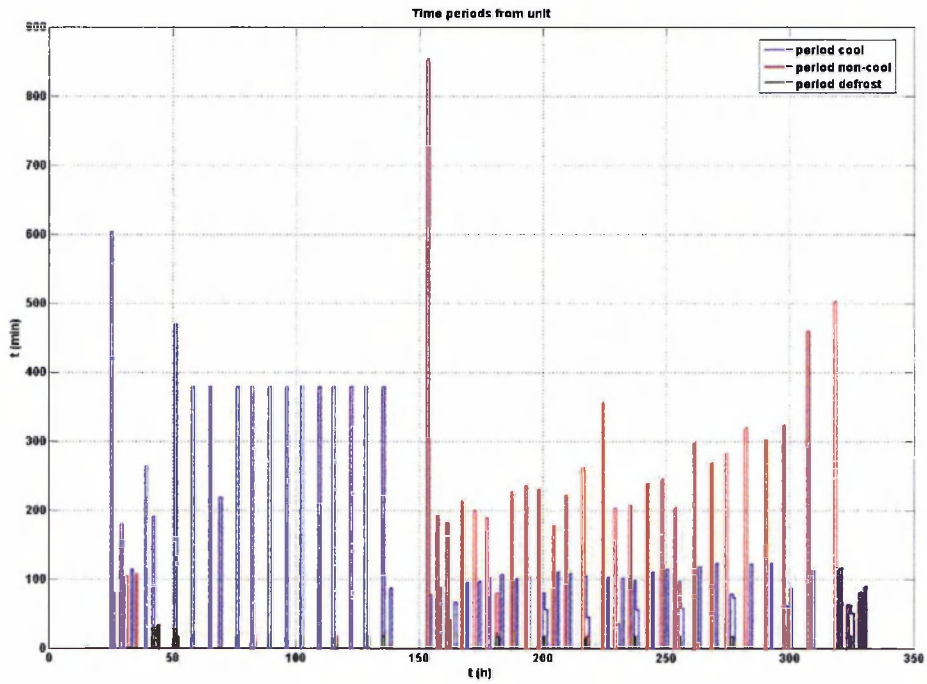


Figure 13 The number of minutes per cooling, non-cooling and defrost period as a function of time for the Quest container. At each time instant during the voyage when a period is finished a bar is drawn with the number of minutes that that period has lasted. For instance, around time instance 140h of the trip, a non-cooling period starts that lasts for approximately 850 minutes and ends around time instance 154 of the trip, this is the compressor off period after the settings were corrected and just before the second Quest regular cycling period.

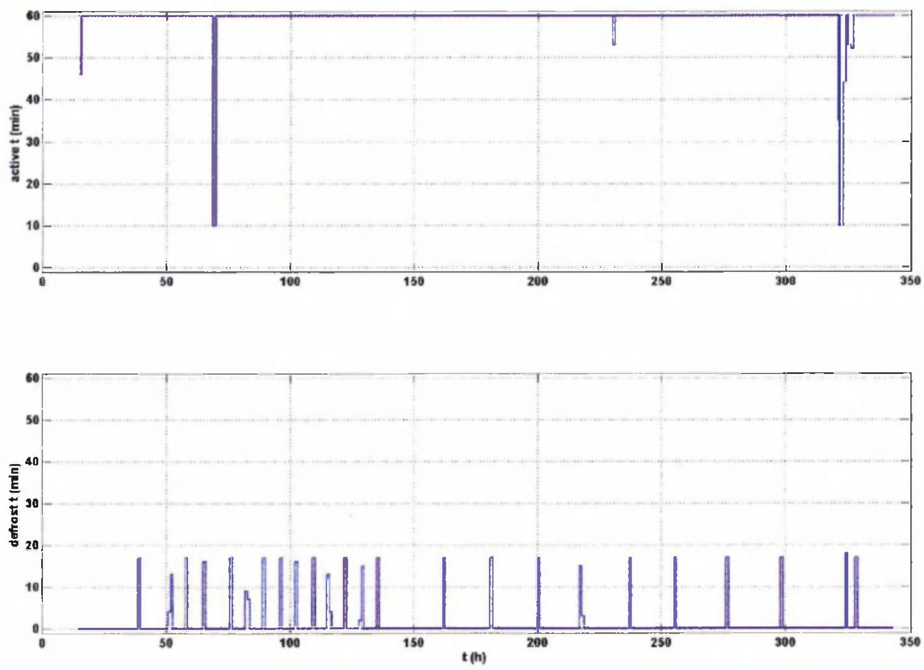


Figure 14 The number of minutes active, non-active and defrost period as a function of time for the Quest container. Every hour of the trip the number of minutes that was used for defrost was recorded. The number of minutes the unit was active was recorded as well, which is mostly 60 min/hour but sometimes less. For instance, around time instance 70h of the trip, the unit was turned off for approximately 50 minutes.