AGROTECHNOLOGY & FOOD SCIENCES GROUP
WAGENINGEN UR

D

Second Quest Regular Trial Shipment

Mandarins from Chile to the Netherlands and the U.K.

J.E. de Kramer-Cuppen
H. Harkema
E.H. Westra

Report 733

2245517

Colophon

Title	Second Quest Regular Trial Shipment
Author(s)	J.E. de Kramer-Cuppen, H. Harkema, E.H. Westra
AFSG number	733
ISBN-number	-
Date of publication	January 24th 2007
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

© Agrotechnology and Food Sciences Group
Alle rechten voorbehouden. Niets uit deze uitgave mag worden verveelvoudigd, opgeslagen in een geautomatiseerd gegevensbestand of openbaar gemaakt in enige vorm of op enige wijze, hetzij elektronisch, hetzij mechanisch, door fotokopieën, opnamen of enige andere manier, zonder voorafgaande schriftelijke toestemming van de uitgever. De uitgever aanvaardt geen aansprakelijkheid voor eventuele fouten of onvolkomenheden.
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system of any nature, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the publisher. The publisher does not accept any liability for inaccuracies in this report.

The quality management system of Agrotechnology and Food Sciences Group is certified by SGS International Certification Services EESV according to ISO 9001:2000.

Abstract

The "Quest regular" system has been developed to reduce power consumption of reefer containers. The Quest Regular concept and corresponding CCPC software was tested in a real-life shipment of mandarins from Chile to the Netherlands and the U.K. in July 2006. The goal of the trial shipment was to compare power usage, temperature distribution and product quality of two Quest test containers to those of two reference containers, which were shipped simultaneously at original settings.

A 53% power saving was achieved over the whole trip.

During Quest Regular Mode, the minimum supply temperature often did not completely reach supply setting. Carrier has adapted the field trial software to enable supply setting to be reached in following trials.

The supply air fluctuations are hardly visible in the carton temperature data. The carton temperatures in the Quest containers were satisfactory, 0.5°C closer to setpoint than the reference containers, while the bandwidth was 0.4°C larger. The coolest cartons were 0.3°C further from the setpoint, while the warmest cartons were 0.3°C closer to the setpoint.

No relation could be found between the average temperature and product quality. Also, no effect on product quality could be found of pallet position and layer. This indicates that the Quest regime did not change quality output compared to normal regime.

Acknowledgements

This second real-life Quest trial was largely organized and performed by Maersk Line. 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, Mr. Hofmann of Maersk's Reefer Management Great Britain, Mr. Selsig of Maersk's Claims Rotterdam and 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. Dudley, Mr. McIntosh, Mr. Hofsdal and Mr. Bretherton.

Quality inspections at arrival and power and temperature data logging were supported by Smitmar and MMS. We would like to thank Mr. Smit 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. Boerrigter, Mr. v.d. Geijn and Mr. Verschoor for their help during the organisation of the trial and its preparations as well as the product quality assessments.

Finally, our thanks go to Ttiara, Greencell and Citronas, whose fruit was transported and who made quality inspection possible before and after transport.

 ©Agrotechnology and Food Sciences Group, member of Wageningen UR

Contents

1 Introduction

The "Quest regular" system has been developed to reduce power consumption of reefer containers. As a follow-up of the first real-life Quest trial with mangoes, it has been tested for mandarins in July 2006. In order to exactly determine the amount of power reduction, a comparison was made with two standard controlled reefer containers. All four 40 ft. containers were loaded with mandarins and were transported on the same vessel (Lexa Maersk). The shipment was from Chile (San Antonio) to The Netherlands (Rotterdam) and the U.K. (Felixstowe). The transport time was 25 days.

The test containers (MWCU6818880, Mandarins test 1 and MWCU6819824 Mandarins test 2) were equipped with and controlled by the "Quest Regular" software, also referred to as CCPC (Compressor-Cycle Perishable Cooling). The containers MWCU6726850, Mandarins ref 1 and MWCU6826206, Mandarins ref 2 served as reference containers. During the shipment power consumption of all containers was measured using externally added KWH-meters. The temperature distribution was measured using 8 or 9 sensors per container and logging the actual temperature every 30 minutes. Fruit samples for quality evaluation (18 cartons) were taken from 9 pallets in both containers test 1 and ref 1 (see scheme and location of the temperature sensors). Half of these test cartons 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. Upon arrival in the Netherlands a first quality inspection of the mandarins was carried out. The quality evaluation was extended by a shelf life 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 for mandarins. The energy saving method is only of value when product i.e. mandarin quality is not harmed by it.

2 Material and methods

2.1 Product

The mandarin variety was Clementine (extra fancy). The mandarins originated from different growers (in the Coquimbo area) and were supplied in different sizes. The product was pre-cooled at 6°C, product temperatures lying between 6 and 7°C.

Figure 1 Clementine, 60013

Figure 2 Clementine, 60172

2.2 Packaging and stowage

The mandarins were packed in cardboard boxes. The box size was 600x400 mm, stacked 14 boxes high (5 on a layer). In total 4 times 1400 cartons were packed, placed on 20 pallets.
The pallets used were wooden industrial pallets size 1200x1000 mm. 20 pallets were fitted in the container cross stacked (see also Figure 5).

2.3 Unit settings

The containers used were fitted with Carrier Thinline refrigeration units. The CCPC program (v. 9526) was installed on all units, using a microlink 3 card. The reference containers were running in normal mode with settings as usual for Clementine. For these, the CCPC software was only used to enable additional data logging. The Quest containers were running in CCPC mode.

The reference container settings were:

◊ Supply setpoint	4.5 °C = 40.1 F
◊ Fan setting	High
◊ Vent setting	75 m³/hr

The CCPC settings were:

◊ Supply setpoint	1.5 °C = 34.7 F
◊ Return Air Pulldown Low Limit	4.5 °C = 40.1 F
◊ Return Air Low Limit	4.5 °C = 40.1 F
◊ Return Air High Limit	5.5 °C = 41.9 F
◊ Fan setting	Alternating
◊ Vent setting	75 m³/hr

Defrost interval: was set to automatic and Humidity, Dehumidification and Bulb Mode were all set to OFF.

2.4 Voyage schedule

On July 12th the containers were loaded with mandarins. Subsequently, the containers were taken to the harbour of San Antonio. Two containers (MWCU 686 046 9 & MWCU 688 331 4) were equipped with column compressors and had to be changed for containers with standard compressors (MWCU 681 982 4 & MWCU 681 888 0). This was done during the evening of July 14th. The setup is shown in Table 1.

Table 1 Container setup

Container nr	Setup mode	Stuffing date	Commodity	Grower
MWCU 682 620 6	Normal (ref 2)	12/7/2006	Clementine	60507
MWCU 672 685 0*	Normal (ref 1)	12/7/2006	Clementine	60013
MWCU 681 982 4	CCPC (test 2)	14/7/2006	Clementine	60008
Old mwcu 686 046 9		*12/7/2006*		
MWCU 681 888 0*	CCPC (test 1)	14/7/2006	Clementine	60172
Old mwcu 688 331 4		*12/7/2006*		

* destination Rotterdam, others to Felixstowe

All containers were loaded to the vessel (Lexa Maersk) during the morning of July 16th (mid ship, bottom side, on deck, see Figure 19 the appendix).

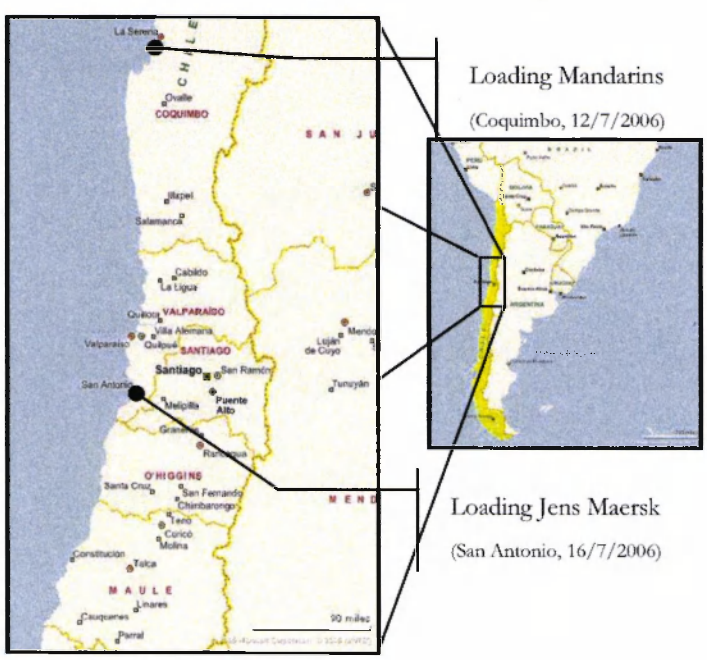


Figure 3 Map of loading and departure locations

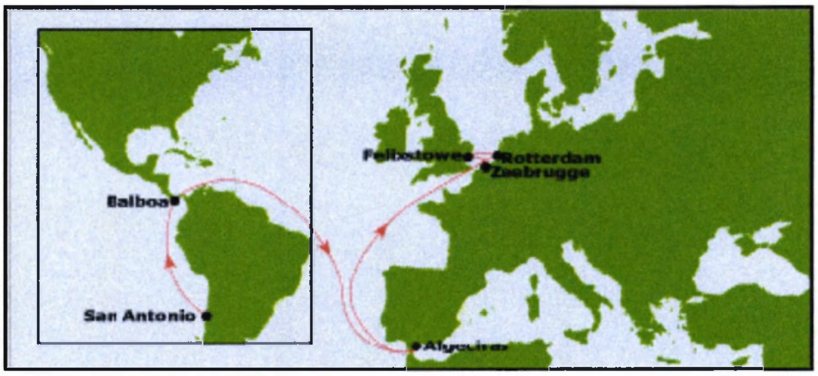


Figure 4 Map of the vessel route

The containers (MWCU 672 685 0 & MWCU 681 888 0) arrived in Rotterdam (the Netherlands) August 5th, the others arrived in Felixstowe (U.K.) on August 7th. Figure 17 and Figure 18 in the appendix depict the mean temperature and relative humidity in July for such a trip.

2.5 Unit and climate measurements

External KWh meters were attached to all units. The CCPC software installed on the containers included additional data logging, storing elaborate unit information every hour. Temperatures were measured by 5 Tiny Tags and 3 I-buttons inside the containers. In order to measure the temperature reaction of the fruit to the software system the Tiny Tags data loggers were placed next to the fruit to the sidewall of each carton. Data recording had been pre-set for every 30 minutes. Such instruments were placed in 5 pallets bottom and ¾ in height. In each container 3 pallets were also fitted with small bottles in order to retrieve gas decomposition samples of the internal container atmosphere.

Figure 5 shows the stowage of the pallets in the containers. The yellow marked pallets were fitted with temperature, relative humidity and gas decomposition sensors. These are also the pallets from which samples for shelf live testing were taken. The green marked pallets were fitted with USDA-probes (on the 6th layer), measuring product temperature. Probe 1 was installed in pallet 3, Probe 2 was installed in pallet 12 and Probe 3 and 4 were installed in pallet 19 and 20.

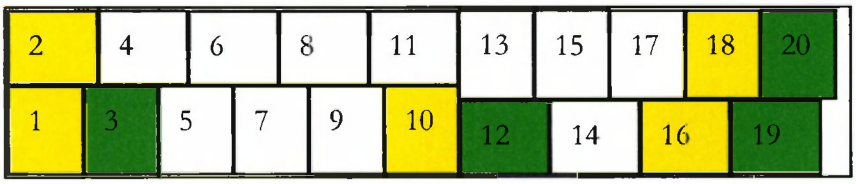


Figure 5 Container layout

2.6 Quality measurements

Mandarin pallets contained 14 layers of boxes. From pallets 1, 2, 3, 10, 12, 16, 18, 19 and 20 (see Figure 5) a box from layer 1 (bottom box) and a box from layer 10 were taken as sample boxes: 18 boxes per container. The mandarins were transported from the place of delivery in Holland to Wageningen in a cooled van (4.5°C). At arrival in Wageningen colour of all fruits was determined according to a colour scale of 1 – 5 (see Figure 6).

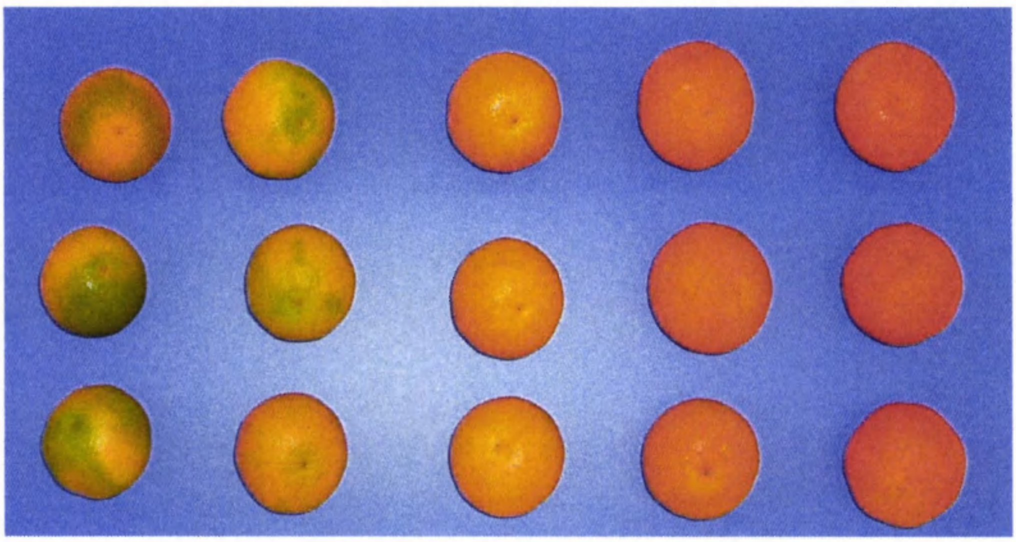


Figure 6 Colour scale for mandarins, from left to right: 1 – 5

The following external quality indicators were determined:

- "wigs" (fungal growth on the stem, Figure 7),
- lost stems,
- penicillium rot (Figure 8) and
- brown rot.

Per box 20 mandarins were cut through and determined on:

- "internal white" (Figure 9) and
- "internal loose" (Figure 10).

The remaining mandarins were stored at 18°C/75% relative humidity (RH) as a simulation of shelf life. After a 7 days' shelf life simulation the same quality indicators were determined again.

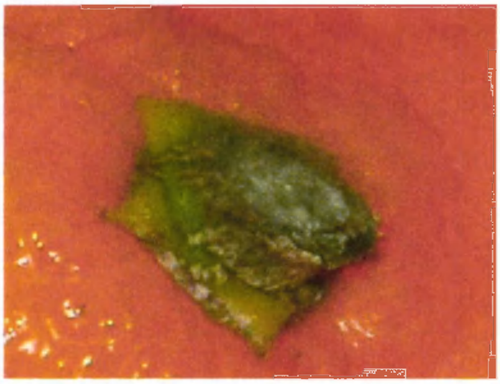


Figure 7 "wig"

Figure 8 Penicillium

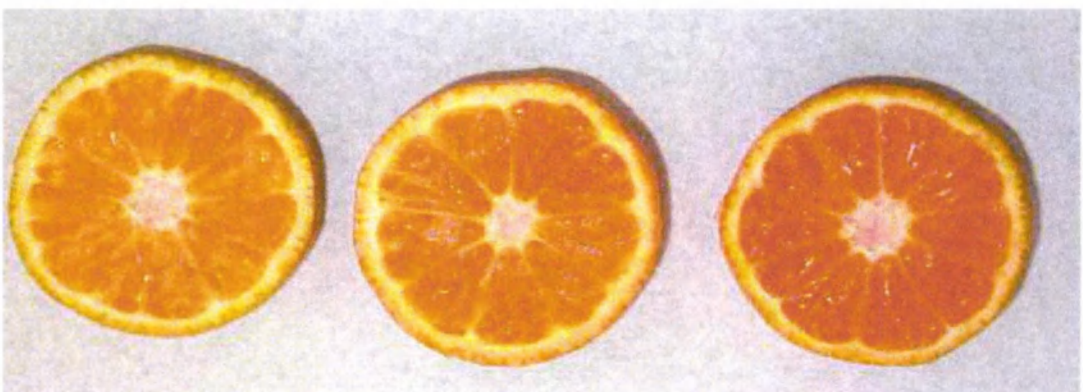


Figure 9 The two fruits on the left have "internal white", the tissue under the skin and between the fruit parts are white. The right fruit does not have "internal white".

Figure 10 This fruit has "internal loose" (opening between skin and fruit parts) as well as "internal white".

3 Temperatures

Figure 11 and Figure 12 show the Tiny Tag data for the coolest and warmest cartons, as well as the mean temperature of all cartons. This gives an overview of all carton temperature readings, which are shown in Figure 20 and Figure 21 in the appendix. Time instance July 13th 00:00 is defined as t=0. 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.

3.1 Temperature readings at the start of the trip

The initial temperature readings of the cartons in the test and reference containers are comparable, mostly between 5 and 7°C (see Figure 20 and Figure 21 in the appendix). Pulp temperature readings lie between 5 and 6°C (see Figure 22 to Figure 25 in the appendix).

3.2 Temperature readings during pull down

As the mandarins were pre-cooled, initial temperatures lay fairly close to setpoint already. The cartons are only cooled down by and additional 1 to 2°C, this takes approximately two days. A few relatively warm boxes in test and ref 1 need up to 4 days to pull down.

During day 3, CCPC Mode was turned off on unit Quest test 2 and the unit was (mistakably) set to cool continuously on the low Quest setpoint of 2.5°C. This causes an additional cool down of the product during the subsequent day, which is not part of normal Quest Regular operation. This was corrected in the harbour, just before loading to the vessel. Carton temperatures thus pull up again during day 4.

3.3 Supply air temperatures during Quest Regular Mode

During Quest Regular Mode, the minimum supply temperature often does not reach supply setting, but stops at about 0.5 deg C higher value (see Figure 22 to Figure 25 in the appendix).In some cases, e.g. after defrost and when ambient temperature is high, the supply air does reach its setpoint. Unit data show that SMV does not open fast enough. The PI-controllers P-action is not large enough to open the smv quickly when heat load is small. The I-action is reset when compressor is turned off and needs some time to build up, which does not happen fast enough with these fast cycles. Carriers proposed solution is to use same logic as is used for scroll-compressors already, namely to remember the smv position when compressor is turned off and using this old setting when starting up again. Carrier has adapted the field trial software accordingly for the following trials.

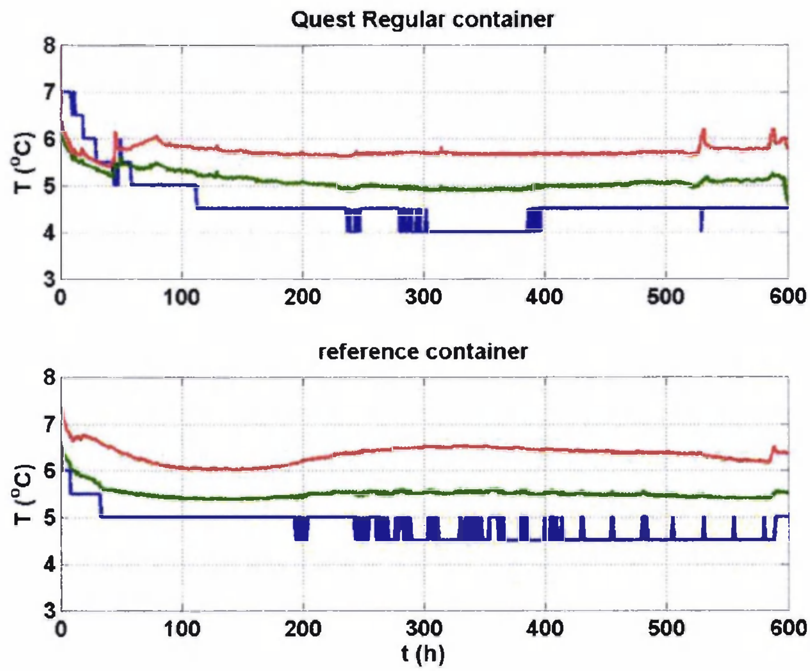


Figure 11 Temperature readings of Tiny Tags in cartons, coolest (-) and warmest (-) carton, as well as mean temperature for all cartons (-) , for both Mandarin 1 containers

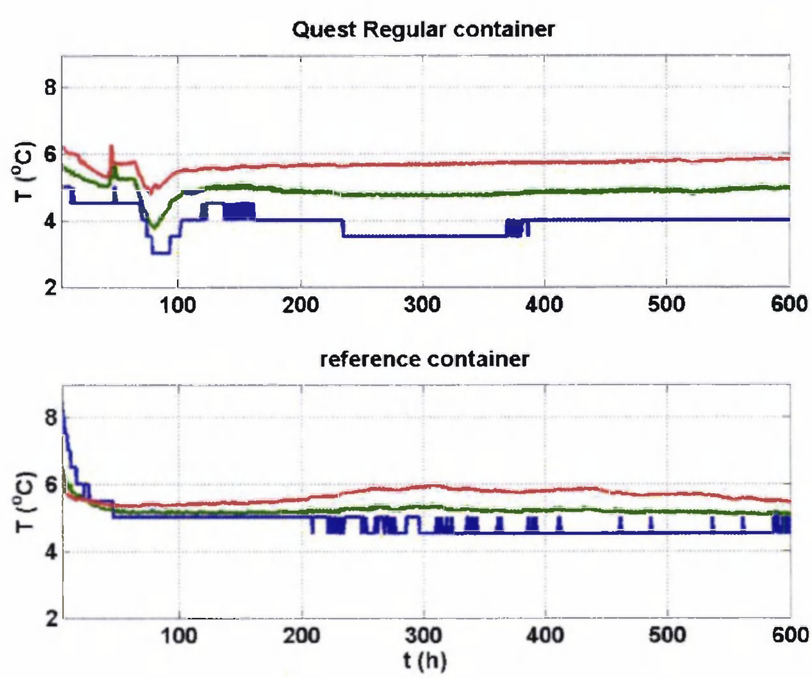


Figure 12 Temperature readings of Tiny Tags in cartons, coolest (-) and warmest (-) carton, as well as mean temperature for all cartons (-) , for both Mandarin 2 containers

3.4 Temperature readings during Quest Regular Mode

The supply air of the Quest containers fluctuates in time, but with such a high frequency, that the fluctuations are hardly visible in the carton temperature data (measured with a 30 min period).

The temperature data for the Quest Regular period (July 18th until August 2nd, t=120 – 480 h) have been summarized in Table 2 through 0. The tables contain information on the temperatures of the coolest and warmest cartons as well as the mean temperature of all cartons combined.

First of all, the deviation from the given setpoint is important (see column 3 of Table 3 and Table 6). The mean carton temperature of the Quest containers is 4.9°C. The mean carton temperature of the reference containers is 5.4°C. Thus, the Quest containers are 0.5°C closer to the setpoint of 4.5°C than the reference containers.

Secondly, the maximum bandwidth of the carton temperatures is considered (see column 2 and 4 of Table 2). Looking at the lowest and highest temperatures measured in the cartons, the maximum temperature difference between the coolest and warmest cartons was 2.1°C in the Quest containers and 1.8°C in the reference containers. Thus, in the most extreme situation, the Quest containers had a 0.3°C larger maximum temperature bandwidth than the reference containers.

Thirdly, the mean bandwidth of the carton temperatures is considered (see column 2 and 4 of Table 3). Looking at the mean of the carton temperatures in time, the temperature difference between the coolest and warmest cartons was 1.7°C in the Quest containers and 1.3°C in the reference containers. Thus, on average, the Quest containers had a 0.4°C larger temperature bandwidth than the reference container.

Fourthly, the deviation of the coolest carton from the given setpoint is important (see column 2 of Table 5 and Table 6). The coolest cartons of the Quest containers were 0.5°C below setpoint. The coolest cartons of the reference containers are 0.2°C above setpoint. Thus, the coolest cartons of the Quest containers are 0.3°C further from the setpoint than the reference containers.

Finally, the deviation of the warmest cartons from the given setpoint is important (see column 4 of Table 5 and Table 6). The warmest cartons of the Quest containers are 1.2°C above setpoint. The warmest cartons of the reference containers are 1.5°C above setpoint. Thus, the warmest cartons of the Quest containers are 0.3°C closer to the setpoint than the reference containers.

Overall, carton temperatures in the Quest container were satisfactory and quite close to the setpoint and the temperatures in the reference container. The Quest container cartons were

Table 2 The ranges of the minimum, maximum and mean carton temperature readings (from July 18th 00:00 to August 2nd 00:00 for mandarin)

	min carton T (℃)	mean carton T (℃)	max carton T (℃)
Quest container 1	4.0 to 4.5	4.9 to 5.3	5.6 to 5.9
Quest container 2	3.5 to 4.5	4.7 to 5.1	5.5 to 5.8
reference cont. 1	4.5 to 5.0	5.4 to 5.6	6.0 to 6.5
reference cont. 2	4.5 to 5.0	5.1 to 5.4	5.4 to 6.0

Table 3 The mean of the minimum, maximum and mean carton temperature readings

	mean min carton T (℃)	mean mean carton T (℃)	mean max carton T (℃)
Quest container 1	4.3	5.0	5.7
Quest container 2	3.8	4.8	5.7
reference cont. 1	4.7	5.5	6.3
reference cont. 2	4.7	5.2	5.7

Table 4 The deviations from setpoint for the minimum, maximum and mean carton temperature readings

	dev min carton T (℃)	dev mean carton T (℃)	dev max carton T (℃)
Quest container 1	-0.5 to 0.0	0.4 to 0.8	1.1 to 1.4
Quest container 2	-1.0 to 0.0	0.2 to 0.6	1.0 to 1.3
reference cont. 1	0.0 to 0.5	0.9 to 1.1	1.5 to 2.0
reference cont. 2	0.0 to 0.5	0.6 to 0.9	0.9 to 1.5

Table 5 The deviations from setpoint for the mean of the minimum, maximum and mean carton temperature readings

	dev mean min carton T (℃)	dev mean mean carton T (℃)	dev mean max carton T (℃)
Quest container 1	-0.2	0.5	1.2
Quest container 2	-0.7	0.3	1.2
reference cont. 1	0.2	1.0	1.8
reference cont. 2	0.2	0.7	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

	ΔT coolest carton (℃)	ΔT mean carton (℃)	ΔT warmest carton (℃)
Quest 1 & ref 1	0.0	+0.5	+0.6
Quest 2 & ref 2	-0.5	+0.4	0.0

0.5°C closer to setpoint, while the bandwidth was 0.4°C larger. The coolest cartons were 0.3°C further and the warmest cartons 0.3°C closer to the setpoint.

USDA readings during the trip are shown in Figure 22 to Figure 25 in the appendix. Temperatures in the Quest containers lay closer to setpoint than USDA readings of the reference containers.

3.5 Temperatures at the end of the trip

Figure 13 and Figure 14 show a snapshot of the carton temperatures near the end of the trip. They show that carton temperatures of the Quest containers lie closer to setpoint than in the reference containers. Also, they give an indication of the temperature distributions over the various locations inside the containers.

Upon stripping of the containers in Rotterdam (reference 1 and Quest test 1), surveyor Mr. Smit measured pulp temperatures of samples throughout the container. The data and calculations are given in Appendix XX. The mean Quest pulp temperature lay 0.9°C closer to setpoint than the reference. The minimum measured pulp temperature lay 0.2 °C further from setpoint; the maximum was 0.1°C closer to setpoint.

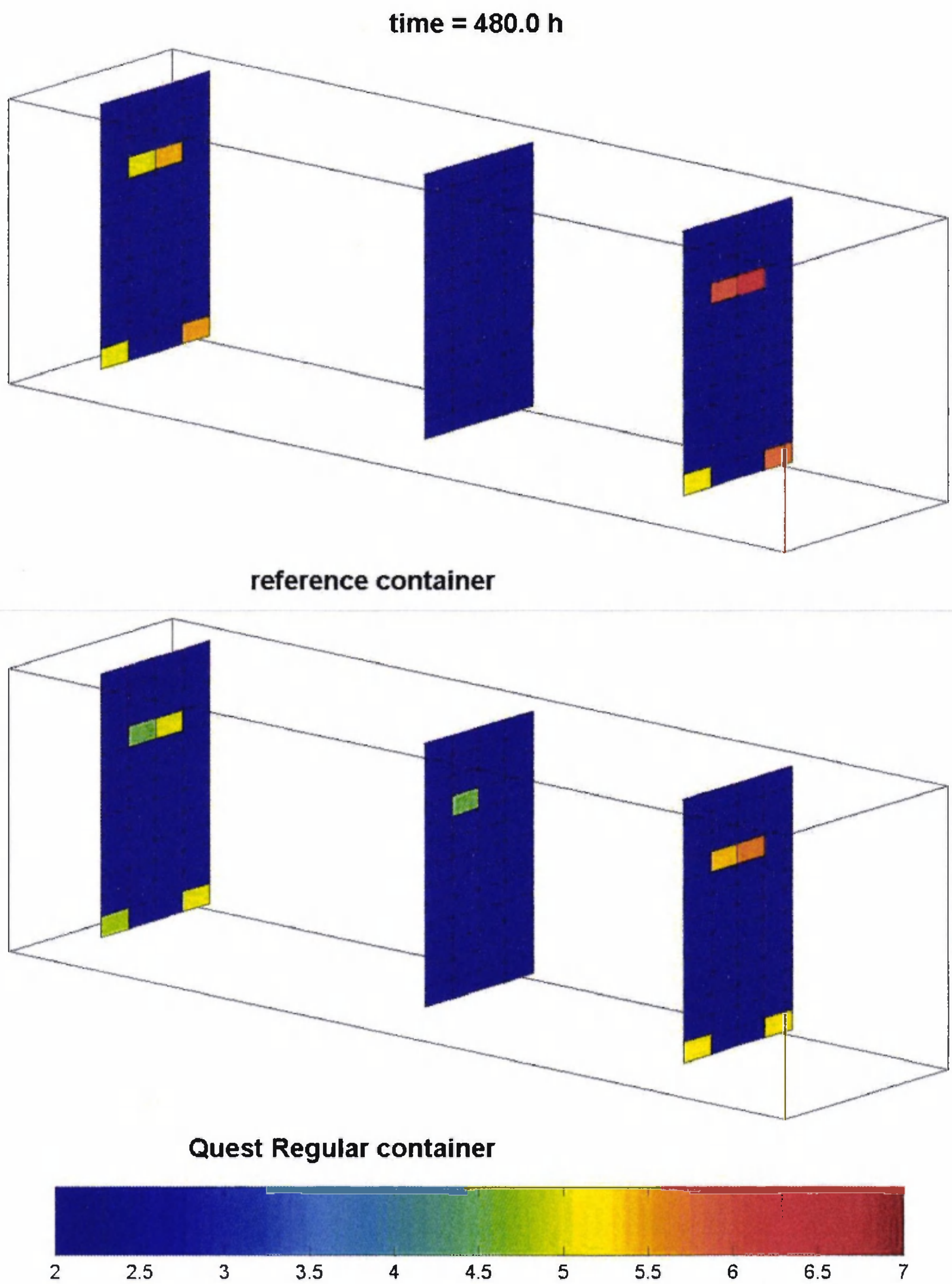


Figure 13 Tiny Tag readings of the carton temperatures near the end of the trip, on August 2nd 00:00, Mandarin 1

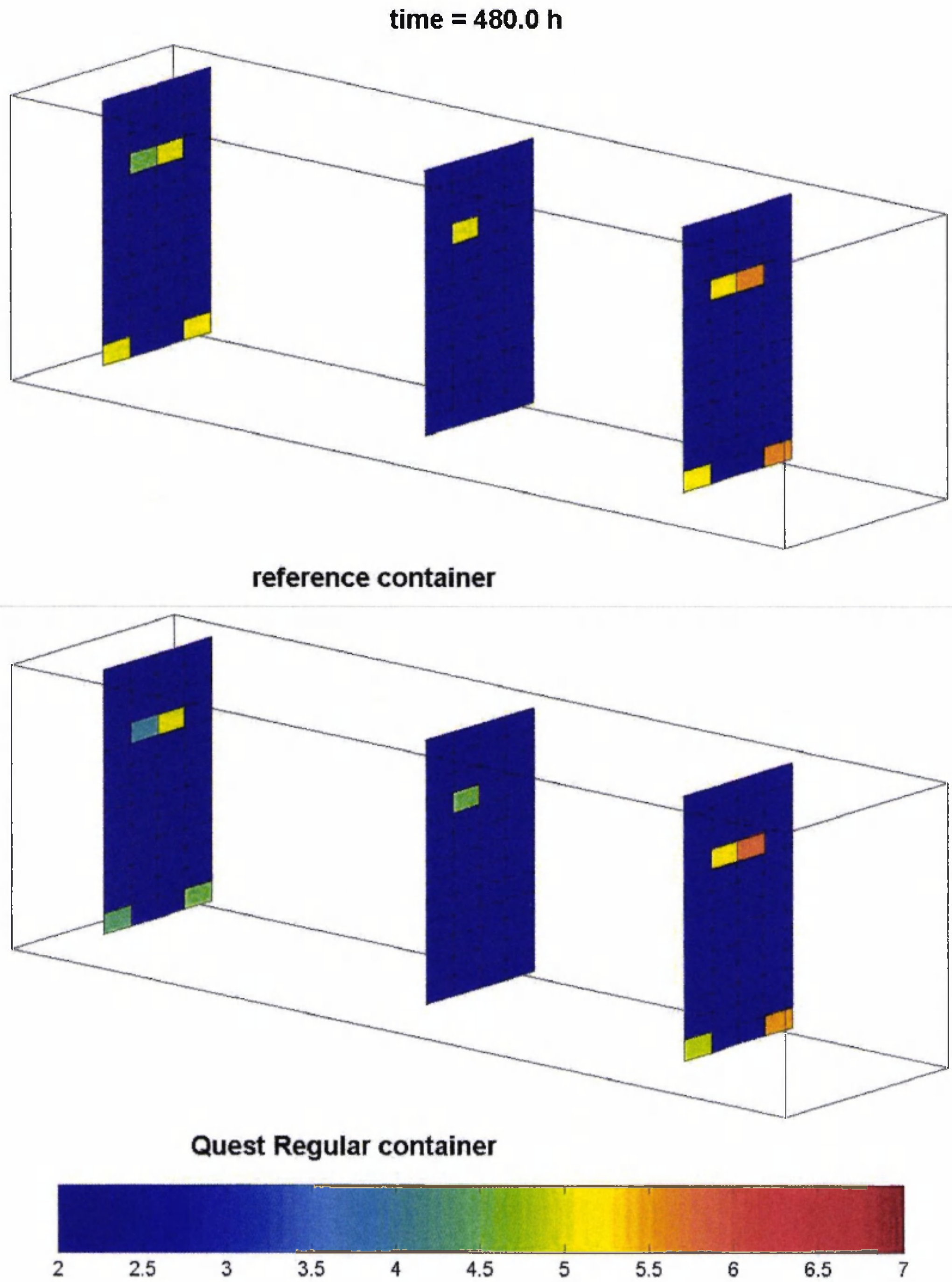


Figure 14 Tiny Tag readings of the carton temperatures near the end of the trip, on August 2nd 00:00, Mandarin 2

4 Power Consumption

Power consumption data were read from the kWh meters by Maersk employees twice a day during the sea voyage. Time and energy data were taken from the kWh meters and ambient temperature readings were read from the unit's user interface see Figure 15. Time axis is such that t = 0 starts at July 13th 2006 00:00.

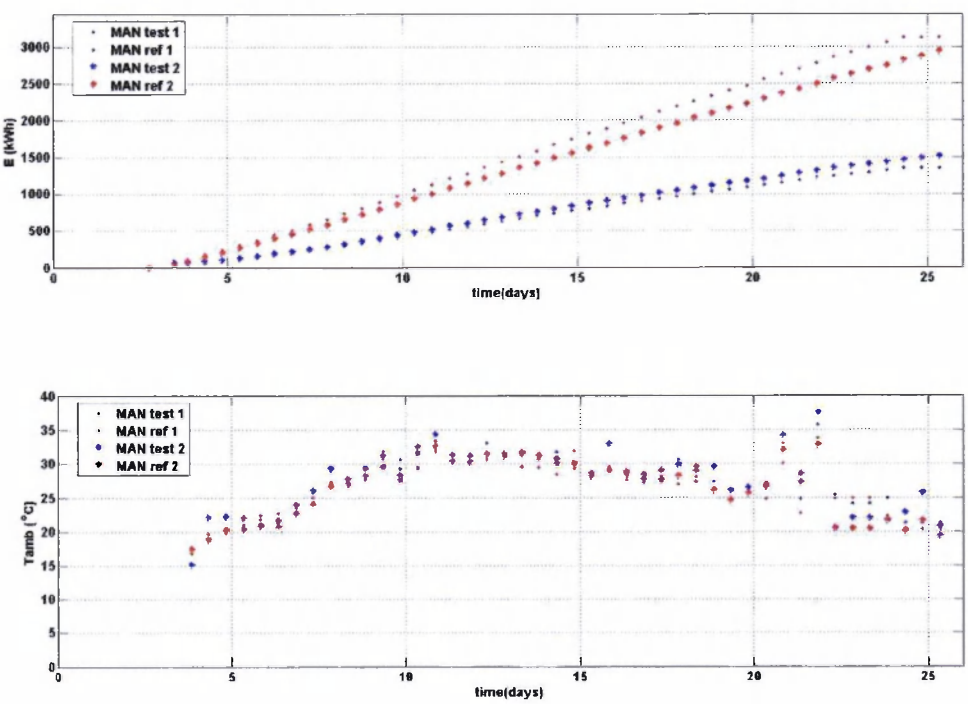


Figure 15 Energy and temperature readings as a function of time for both container sets

The reference containers used 3133 and 2940 kWh in 542 hour, a mean power usage of 5.8 and 5.4 kW. The Quest container used 1348 and 1514 kWh in 542 h, a mean power usage of 2.5 and 2.8 kW, which is 57 and 49% less compared to the reference containers. The power and savings per day are shown in Figure 16. Mean savings are 53%.

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 34 through Figure 37 in the appendix. (For comparison, also the active hours and defrost time of the units are shown.) Compressor off time intervals last approximately 25 minutes, about twice as long as the compressor-on time intervals. The compressor off periods become somewhat shorter when ambient temperature is higher. Compressor on times than become slightly longer. Other factors of influence are defrost intervals, the reduced fan speed during compressor-off time intervals and the somewhat reduced amount of ventilation during low fan speed/compressor off periods.

Defrost setting is AUTO, leaving the unit to learn from its measurement data how often a defrost action is necessary. Both reference units defrost about once a day, whereas the test containers defrost period increases to about once every 4 days. The defrost actions take approximately 18 minutes. These small values indicate that little ice was present on the coil. The reduced amount of defrost actions for the Quest containers is due to the reduction in compressor run hours (approximately 1/3rd).

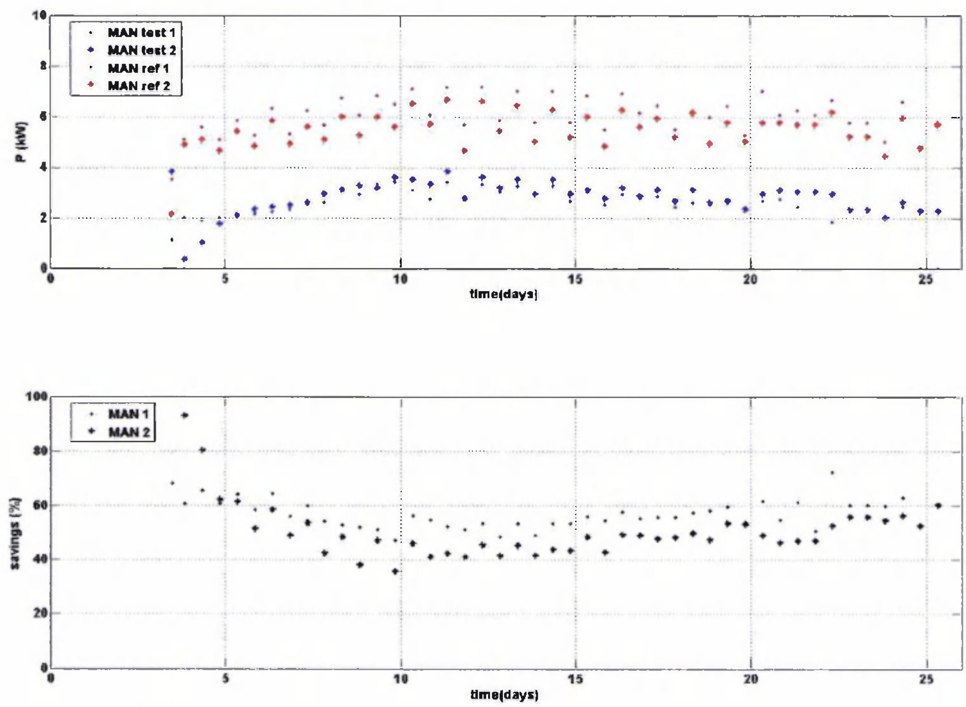


Figure 16 Power and savings as a function of time for both container sets

5 Evaluation of fruit quality

5.1 General remarks

According to the first impressions at arrival from Smitmar and Citronas the quality of the mandarins of containers MWCU 6726850 (Mandarins Reference 1) and MWCU 6818880 (Mandarins Quest1) did not differ from current containers. Some rotten fruits (Penicillium) were found; the number of rotten fruits was acceptable.

Product specialists from AFSG described the average quality of the mandarins as good. Some incidental rotten fruits (Penicillium) were found, and in some boxes mandarins showed fungal infection ("wigs") on the pedicel (stem). The number of mandarins with wigs was not unusual. Because the mandarins in each of the containers were from different growers no comparison between containers can be made; possible differences can be due to the grower as well.
For analysis of effects of *pallet number* and *layer* the data from the pallets 1, 2, 10, 16 and 18 were used (10 boxes), because the mandarins from the other pallets were from other growers.

Atmosphere samples taken showed very low, 32 ppb, i.e. negligible ethylene levels in Quest containers and no (i.e. immeasurable) ethylene in the Reference containers.

5.2 External quality

As Table 7 shows that the colour development during shelf life is not very large. After 14 days of shelf life there was a rise in the number of fruits with Penicillium in the mandarins from the Quest container. It is not clear whether this is due to the grower or the container.
The high amount of mandarins without stem in the Quest container is probably due to the grower(s). One should note that differences between containers may be due to growers and not necessarily to containers.

No effect of the position of the pallet and the level of the box on product quality could be found. Mandarins from two boxes on the "high" position of pallet 2 (one in the Reference container and one in the Quest container) had more fungal infection on the stem ("wigs") after 14 days of shelf life than mandarins from other boxes. An explanation of this phenomenon could not be found. In these boxes no extreme temperature deviations were found.

Table 7 External quality

	Reference container (growers 60011, **60013**, 60172, 60500)		Quest container (growers 60011, 60014, **60172**)	
day of shelf life --->	day 0	day 14	day 0	day 14
Colour [0 - 5]	3.9	4.2	3.8	4.3
Penicillium [#/box]	< 1	< 1	< 1	2.4
Brown rot [#/box]	< 1	< 1	< 1	< 1
No stem [%]	0	1	8	15
Wig (fungi on stem) [%]	19	14	5	13

The **bold** grower numbers represent the main grower per container.

5.3 Internal quality

Mandarins from the reference container (or grower 60013 and others) showed more internal white than the mandarins from the Quest containers (or grower 60172 and others). As noticed before this difference cannot be ascribed to the containers.

Table 8 Internal quality

	Reference container (growers 60011, **60013**, 60172, 60500)		Quest container (growers 60011, 60014, **60172**)	
day of shelf life --->	day 0	day 14	day 0	day 14
Internal loose [%]	3	2	1	4
Internal white [%]	6	13	3	5

The **bold** grower numbers represent the main grower per container.

5.4 Average temperature and quality

For analysis of effects of the average temperature the data from the pallets 1, 2, 16 and 18 were used (8 boxes per container), the average temperature was calculated from July 18th 00:00 to August 2nd 00:00. In the Reference container the lowest average temperature was 4.7°C (pallet 1, layer 1); the highest average temperature was 6.3°C (pallet 18, layer 10). In the Quest container the lowest and highest average temperatures were 4.3°C (pallet 10, layer 10)) and 5.7°C (pallet 18, layer 10). No relation could be found between the average temperature and product quality, neither for the Quest container nor for the Reference container.

In order to determine the effect of the pallet position and the layer, data from pallets 1, 2, 10, 16 and 18 were used (10 boxes per container). No effect on product quality could be found of pallet position and layer in the Quest container and the Reference container.

6 Conclusions

6.1 Power savings

The reference containers had a mean power usage of 5.6 kW; this was 2.7 kW for Quest, a 53% saving.

6.2 Temperatures

The supply air of the Quest containers fluctuates in time, but with such a high frequency, that the fluctuations are hardly visible in the carton temperature data (measured with a 30 min period).

During Quest Regular Mode, the minimum supply temperature often did not reach supply setting, but stops at about 0.5 deg C higher value. Carrier has adapted the field trial software to remember the smv position when compressor is turned off and using this old setting when starting up again. This should enable supply setting to be reached in following trials.

The carton temperatures in the Quest container were satisfactory and quite close to the setpoint and the temperatures in the reference container. The Quest container cartons were 0.5°C closer to setpoint, while the bandwidth was 0.4°C larger. The coolest cartons were 0.3°C further and the warmest cartons 0.3°C closer to the setpoint.

6.3 Product quality

Comparison between containers was not possible because each container contained mandarins from a different grower, possible quality differences between mandarins from different containers may be due to the container or to the grower.

No relation could be found between the average temperature and product quality. Also, no effect on product quality could be found of pallet position and layer. This indicates that the Quest regime did not change quality output compared to normal regime.

References

[1] http://www.cdc.noaa.gov/cgi-bin/Composites/comp.pl

Appendix I: Ambient conditions from San Antonio to Rotterdam

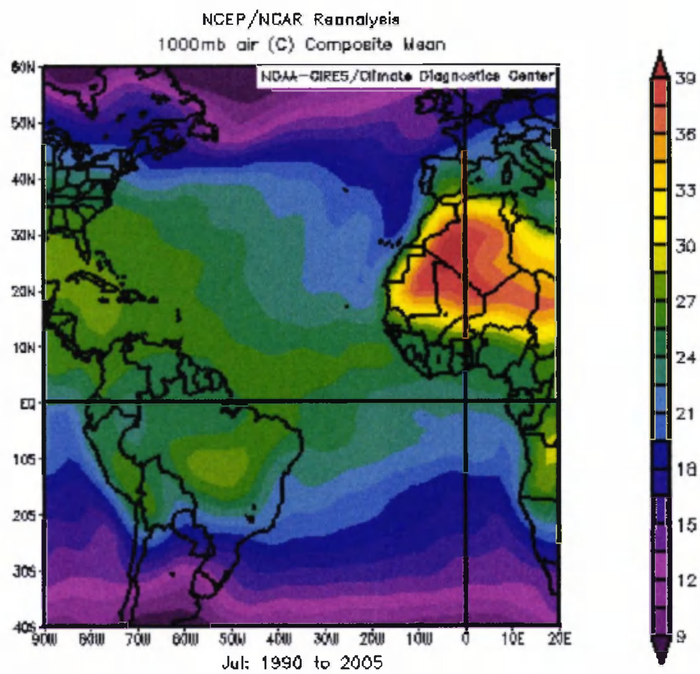


Figure 17 Mean July temperature between San Antonio (Chile) and Rotterdam (The Netherlands)

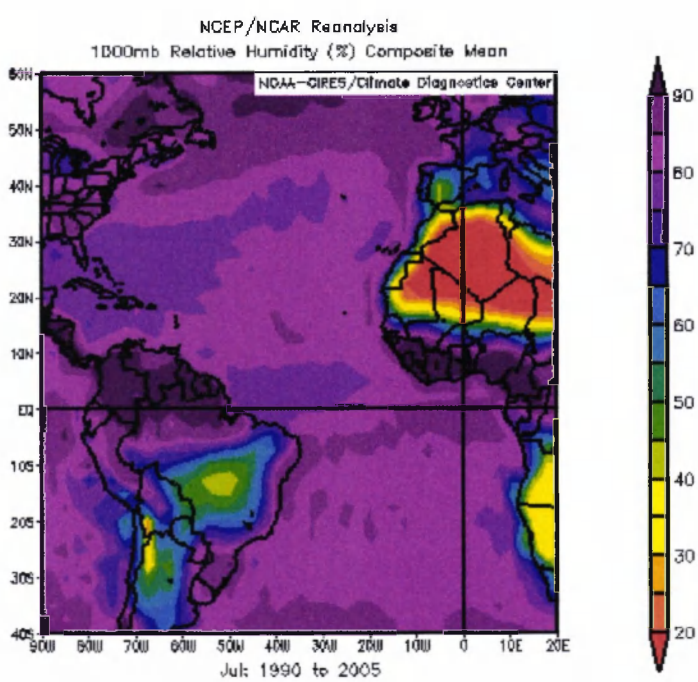


Figure 18 Mean July relative humidity between San Antonio and Rotterdam

Appendix II: Photos of mandarin and apple containers on vessel

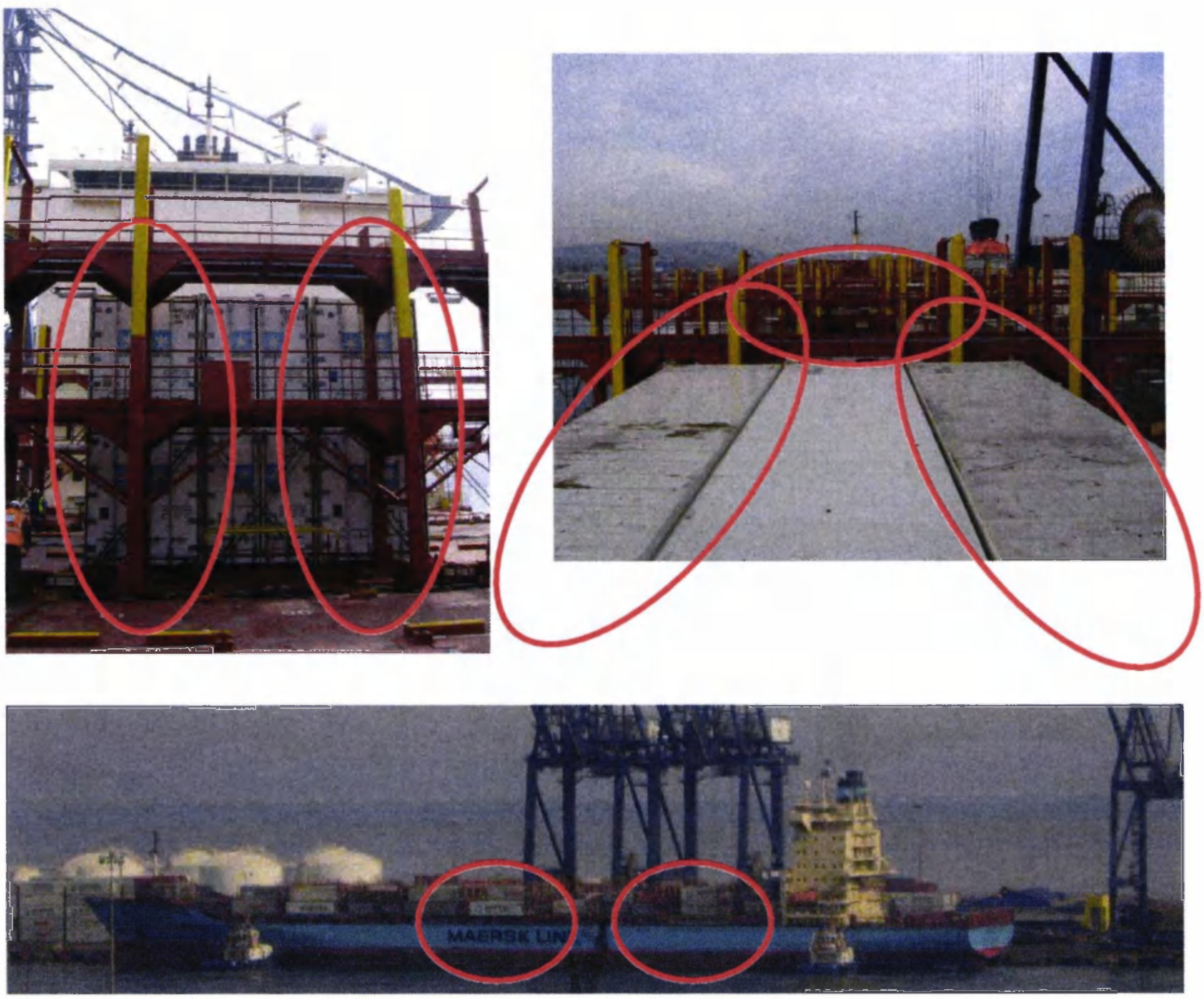


Figure 19 Photos of containers upon Lexa Maersk

Appendix III: Pulp temperatures at the end of the trip

PULP TEMPERATURES

MWCU6726850 (NORMAL):

Pallet no,	20	19	18	16	12	10	7	4	3	2	1
Top	6.8	5.9	6	5.5	5.4	5.7	5.2	5.9	5.2	6.2	5.2
Middle	6.8	5.9	6.1	5.4	5.3	5.2	5	5.2	4.9	5.6	5.4
Bottom	6.1	5.7	5.5	5	5.3	5.3	4.9	5.4	5.1	5.3	5

MWCU6818880 (QUEST):

Pallet no,	20	19	18	16	12	10	3	2	1
Top	6.7	4.8	4.5	5	4.2	4.4	4.3	5.2	4.1
Middle	6.3	5.2	4.7	4.6	4.1	4.2	3.9	4.2	4
Bottom	5.2	4.8	4.5	4.5	4.2	4.1	3.9	4.3	3.9

DIFF SETPOINT (4,5) - MWCU6726850:

Pallet no,	20	19	18	16	12	10	7	4	3	2	1
Top	2.3	1.4	1.5	1	0.9	1.2	0.7	1.4	0.7	1.7	0.7
Middle	2.3	1.4	1.6	0.9	0.8	0.7	0.5	0.7	0.4	1.1	0.9
Bottom	1.6	1.2	1	0.5	0.8	0.8	0.4	0.9	0.6	0.8	0.5

DIFF SETPOINT (4,5) - MWCU6818880

Pallet no,	20	19	18	16	12	10	3	2	1
Top	2.2	0.3	0	0.5	-0.3	-0.1	-0.2	0.7	-0.4
Middle	1.8	0.7	0.2	0.1	-0.4	-0.3	-0.6	-0.3	-0.5
Bottom	0.7	0.3	0	0	-0.3	-0.4	-0.6	-0.2	-0.6

DIFF MWCU6818880 - MWCU6726850

Pallet no,	20	19	18	16	12	10	3	2	1
Top	-0.1	-1.1	-1.5	-0.5	-1.2	-1.3	-0.9	-1	-1.1
Middle	-0.5	-0.7	-1.4	-0.8	-1.2	-1	-1	-1.4	-1.4
Bottom	-0.9	-0.9	-1	-0.5	-1.1	-1.2	-1.2	-1	-1.1

MWCU6726850 (NORMAL):

min	mean	max	std
4.9	5.5	6.8	0.49

MWCU6818880 (QUEST):

min	mean	max	std
3.9	4.6	6.7	0.68

DIFF SETPOINT (4,5) - MWCU6726850:

min	mean	max
0.4	1.0	2.3

DIFF SETPOINT (4,5) - MWCU6818880

min	mean	max
-0.6	0.1	2.2

DIFF MWCU6818880 - MWCU6726850

min	mean	max
-1.5	-1.0	-0.1

PERFORMANCE QUEST closeness to setpoint in reference to NORMAL

min	mean	max
-0.2	0.9	0.1

Appendix IV: Carton temperatures

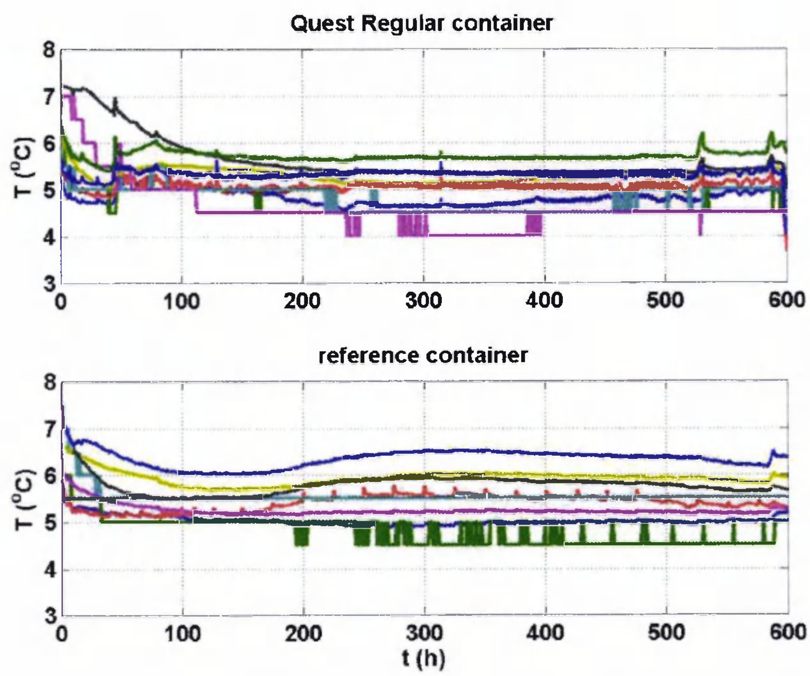


Figure 20 Temperature readings of Tiny Tags in cartons, all data, for both Mandarin 1 containers

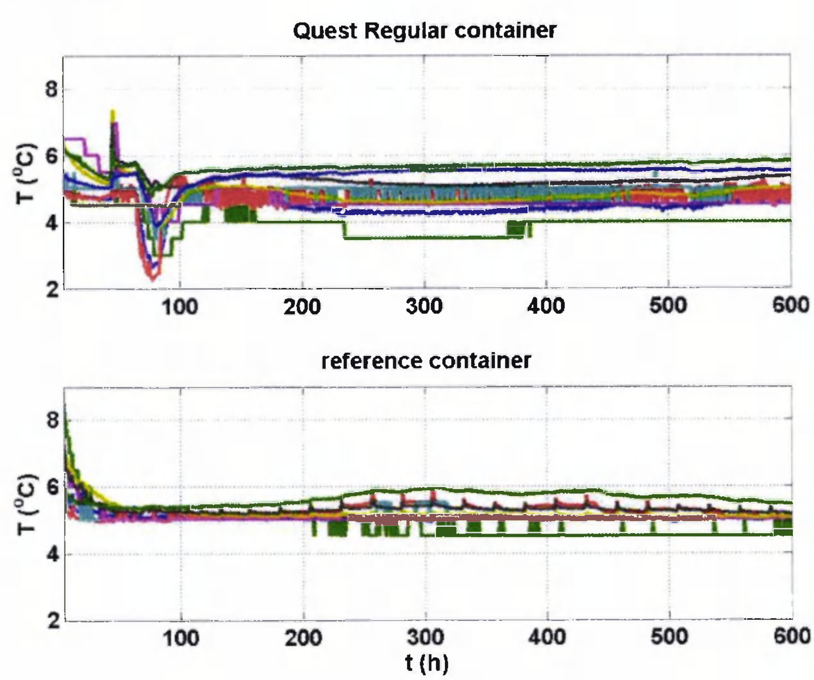


Figure 21 Temperature readings of Tiny Tags in cartons, all data, for both Mandarin 2 containers

Appendix V: Unit temperature readings as a function of time

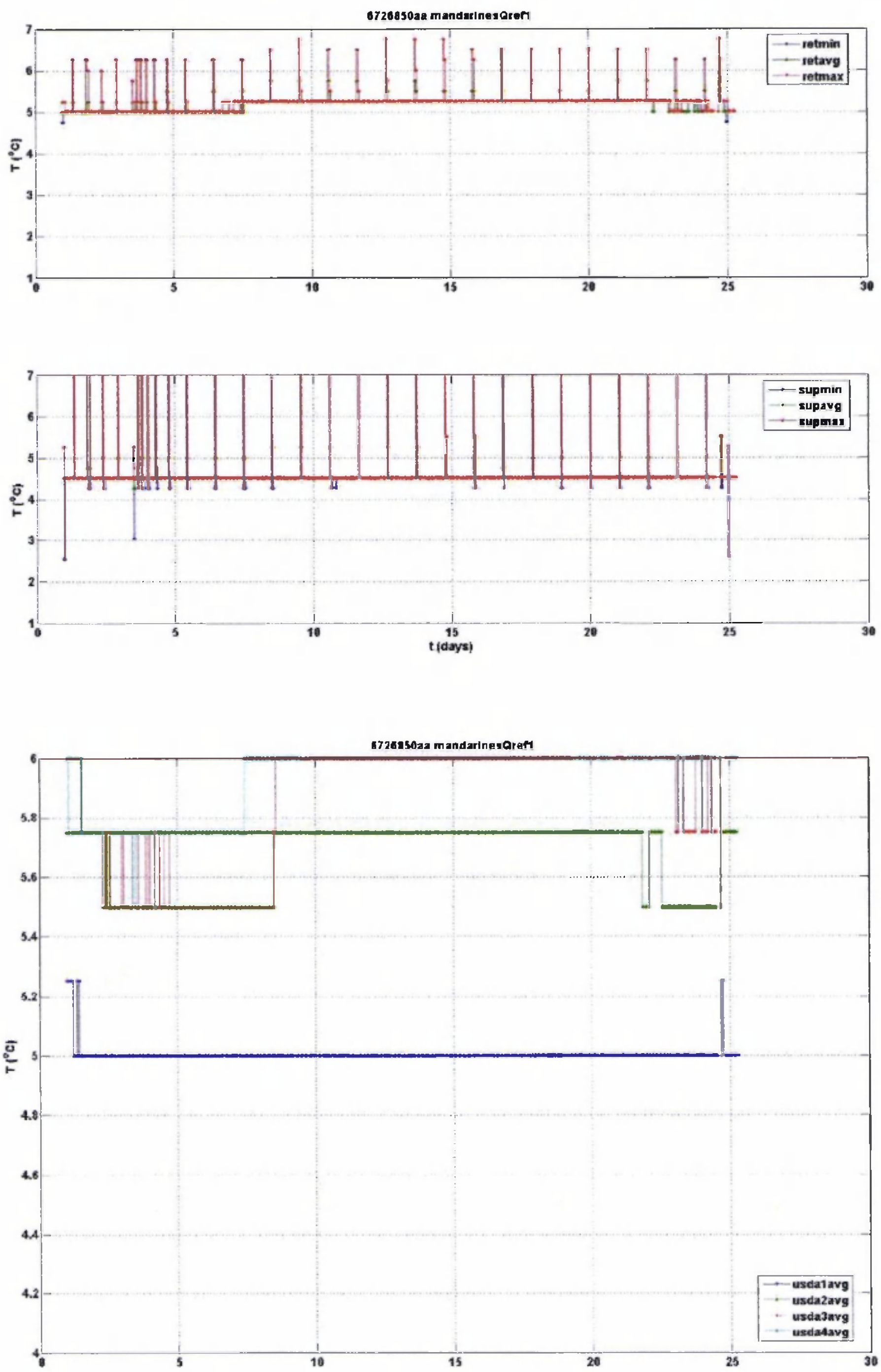


Figure 22 Temperature readings from the unit for the Mandarin ref 1container.

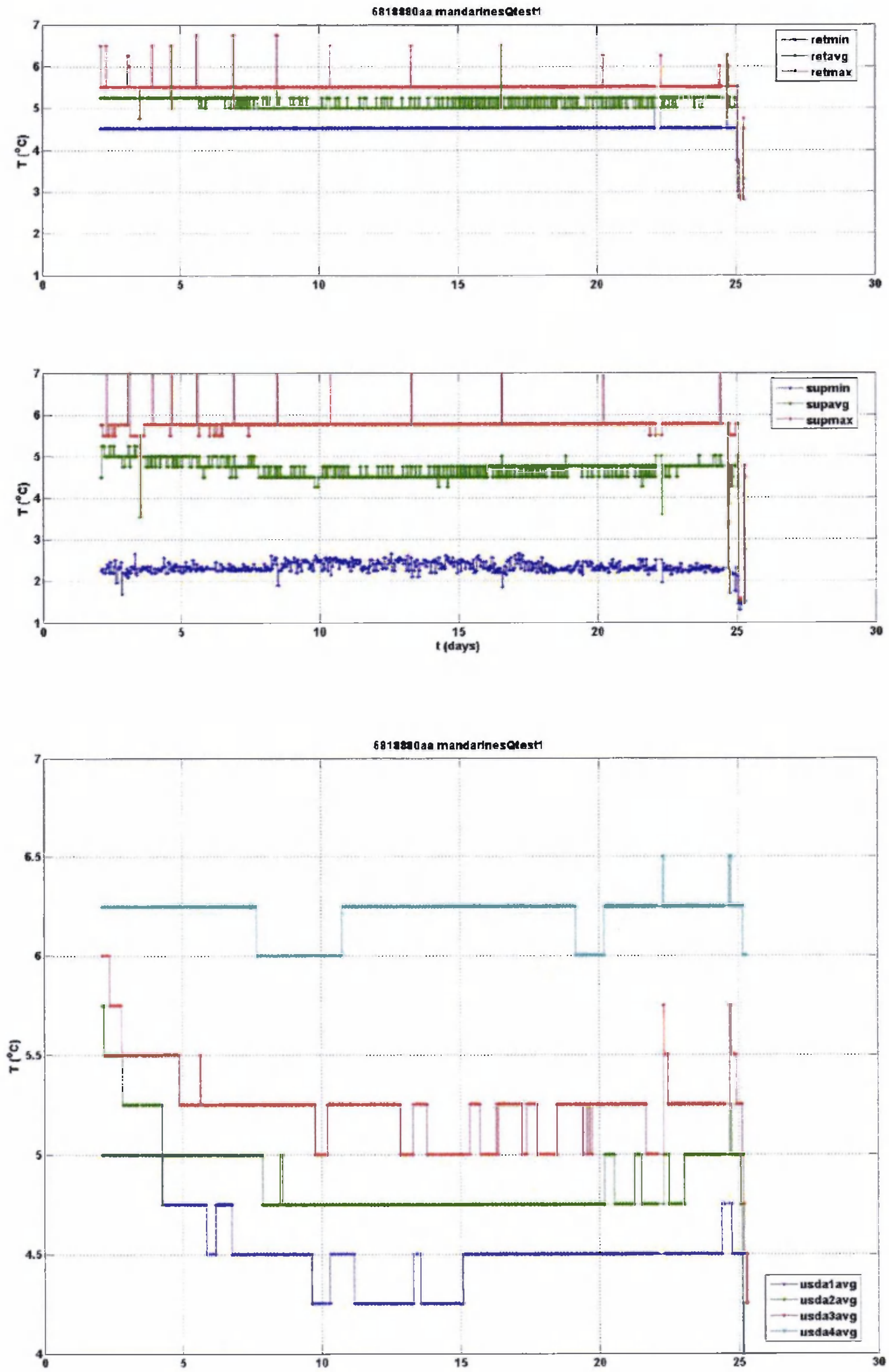


Figure 23 Temperature readings from the unit for the Mandarin test 1container.

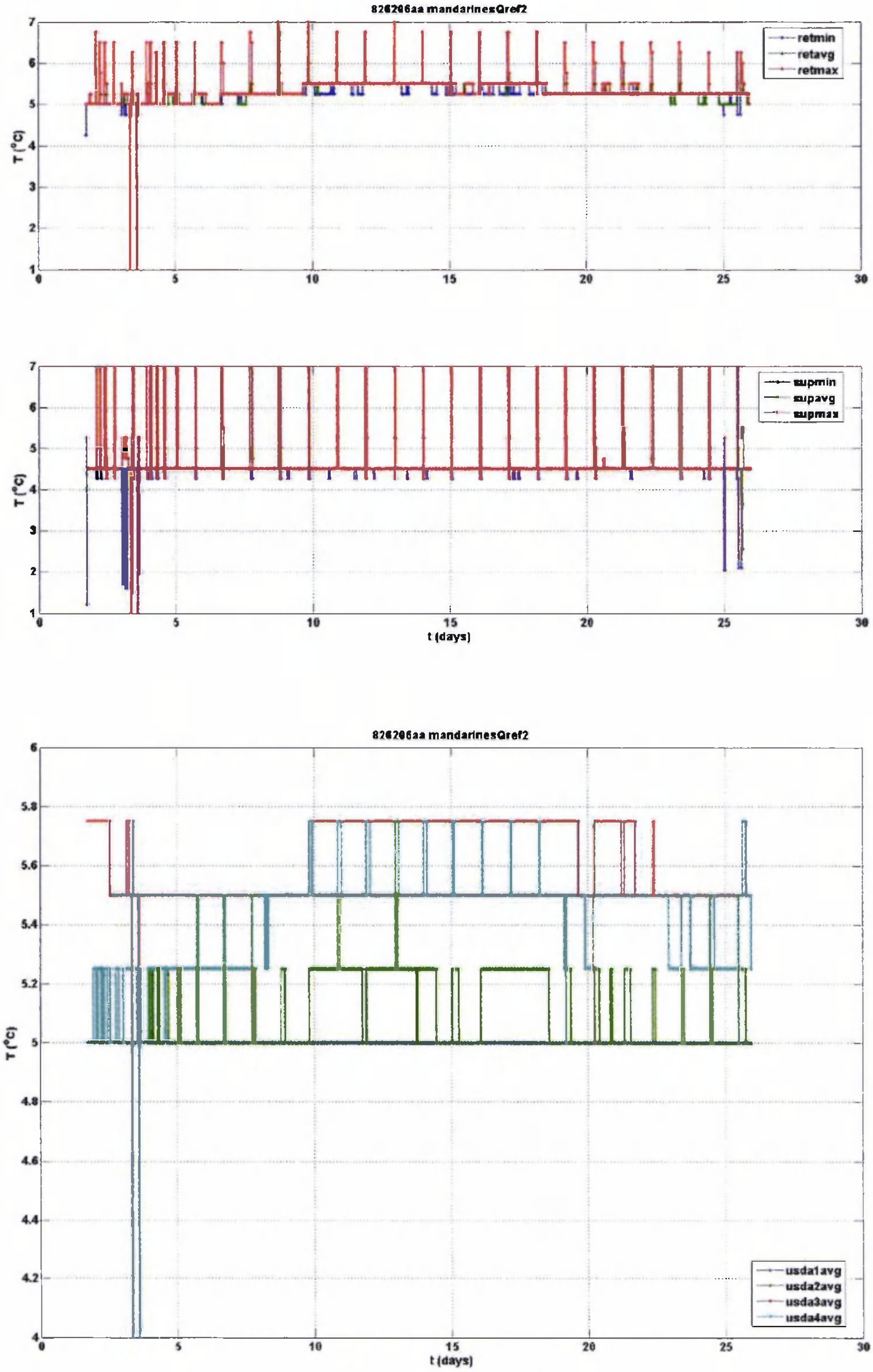


Figure 24 Temperature readings from the unit for the Mandarin ref 2 container.

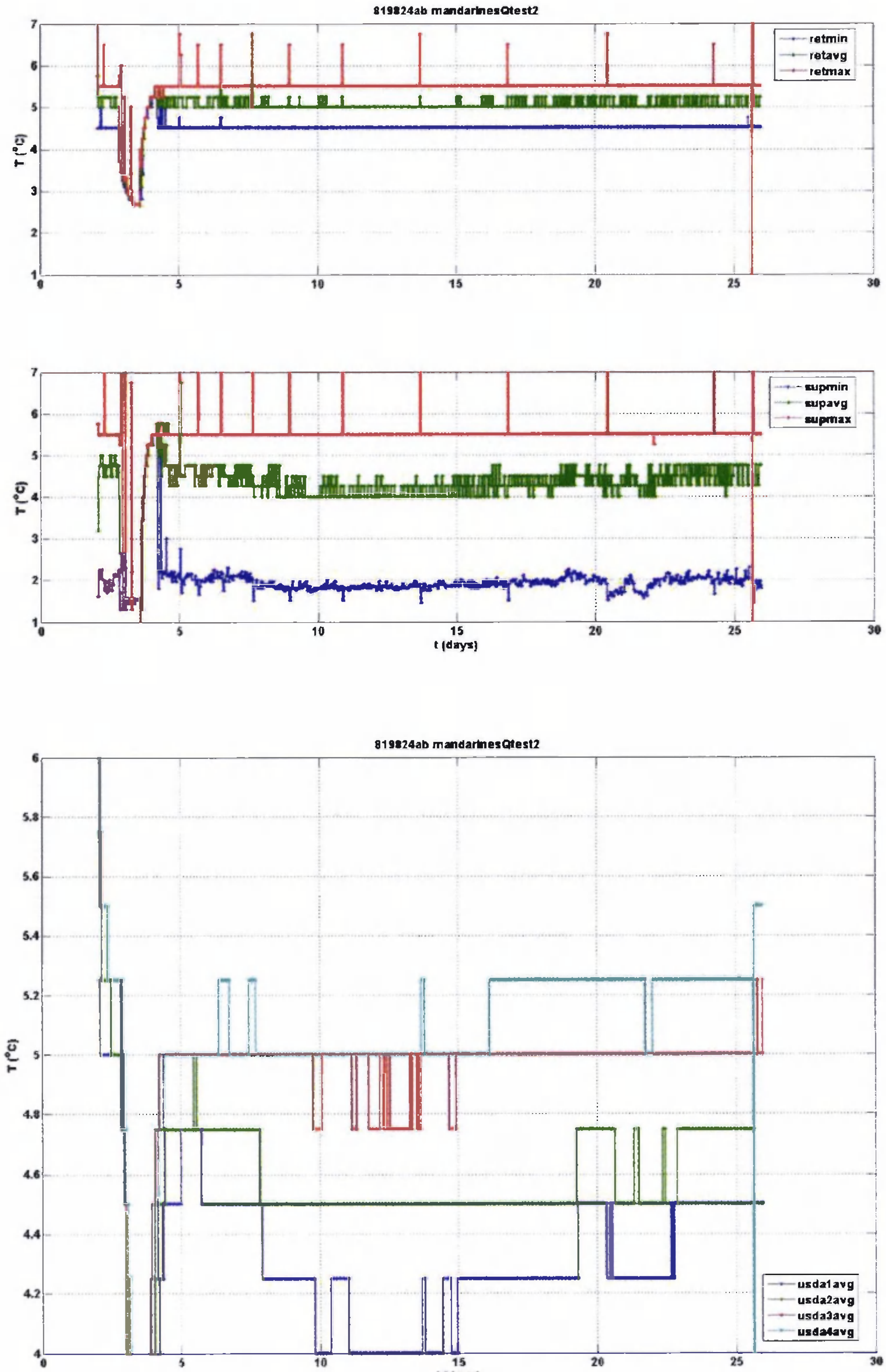


Figure 25 Temperature readings from the unit for the Mandarin test 2 container.

Appendix VI: Snapshot pictures of carton temperature readings

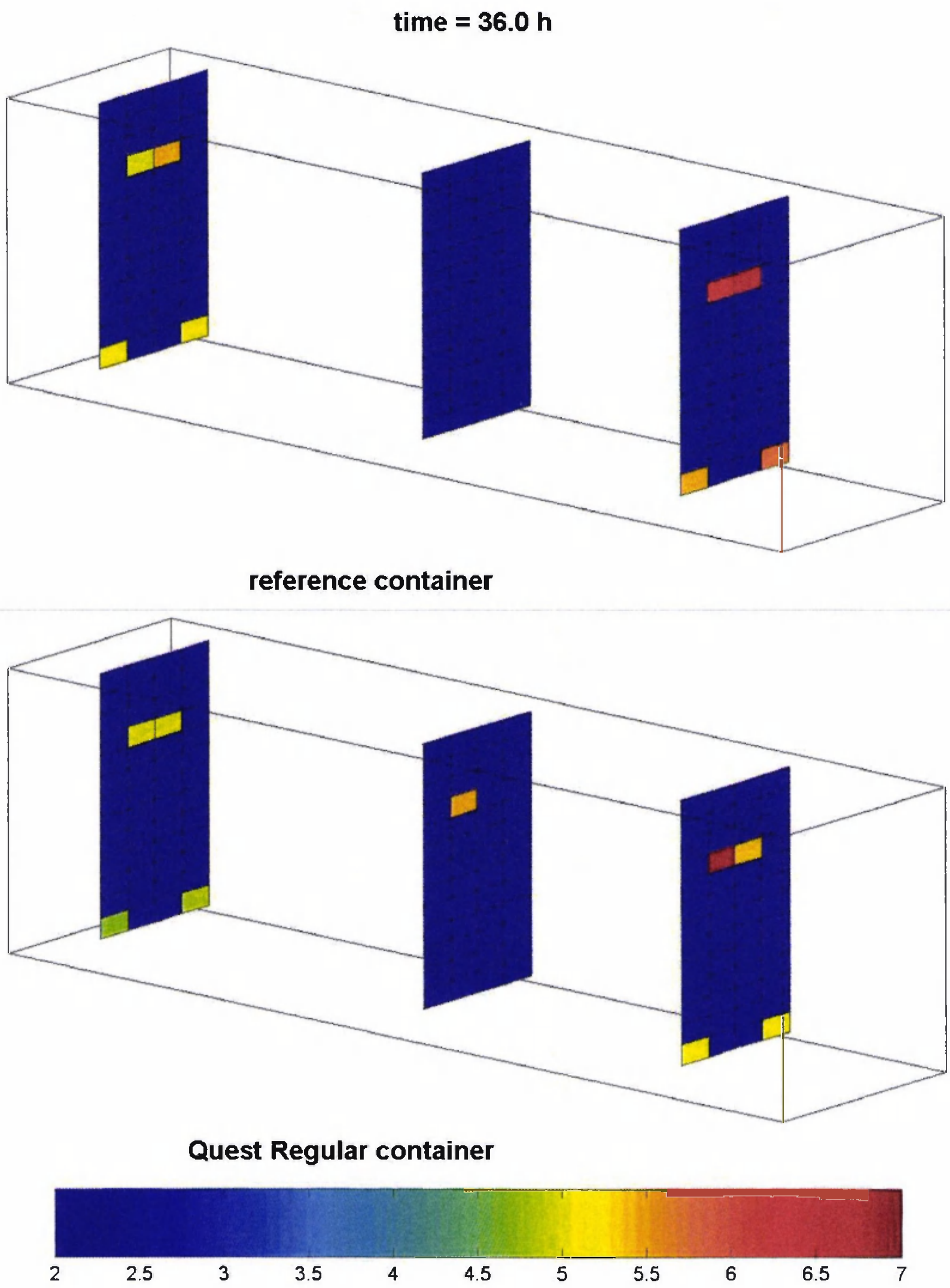


Figure 26 Tiny Tag readings of the carton temperatures 1,5 days after the start of the trip, on July 14th 12:00, Mandarin 1

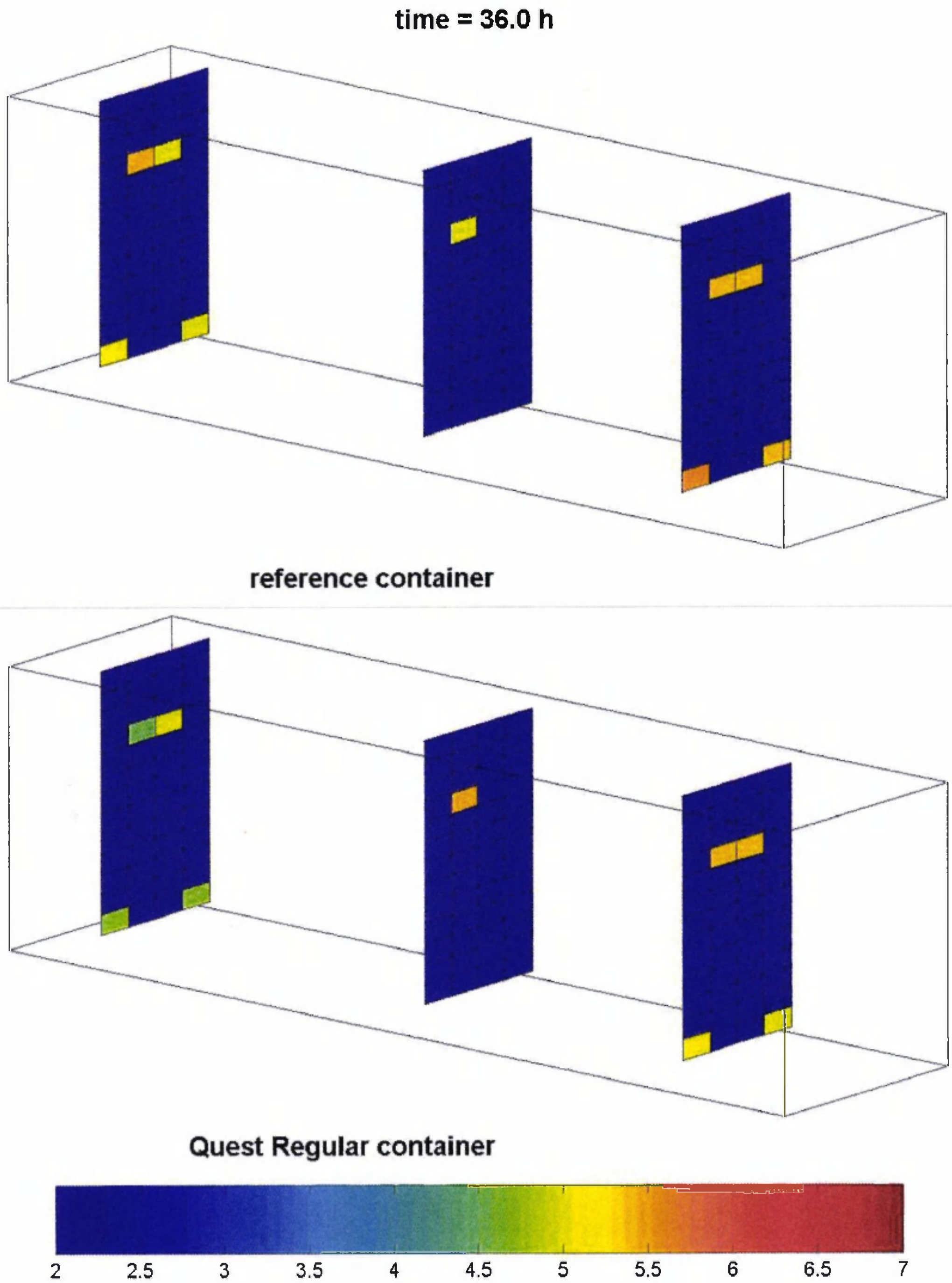


Figure 27 Tiny Tag readings of the carton temperatures 1,5 days after the start of the trip, on July 14th 12:00, Mandarin 2

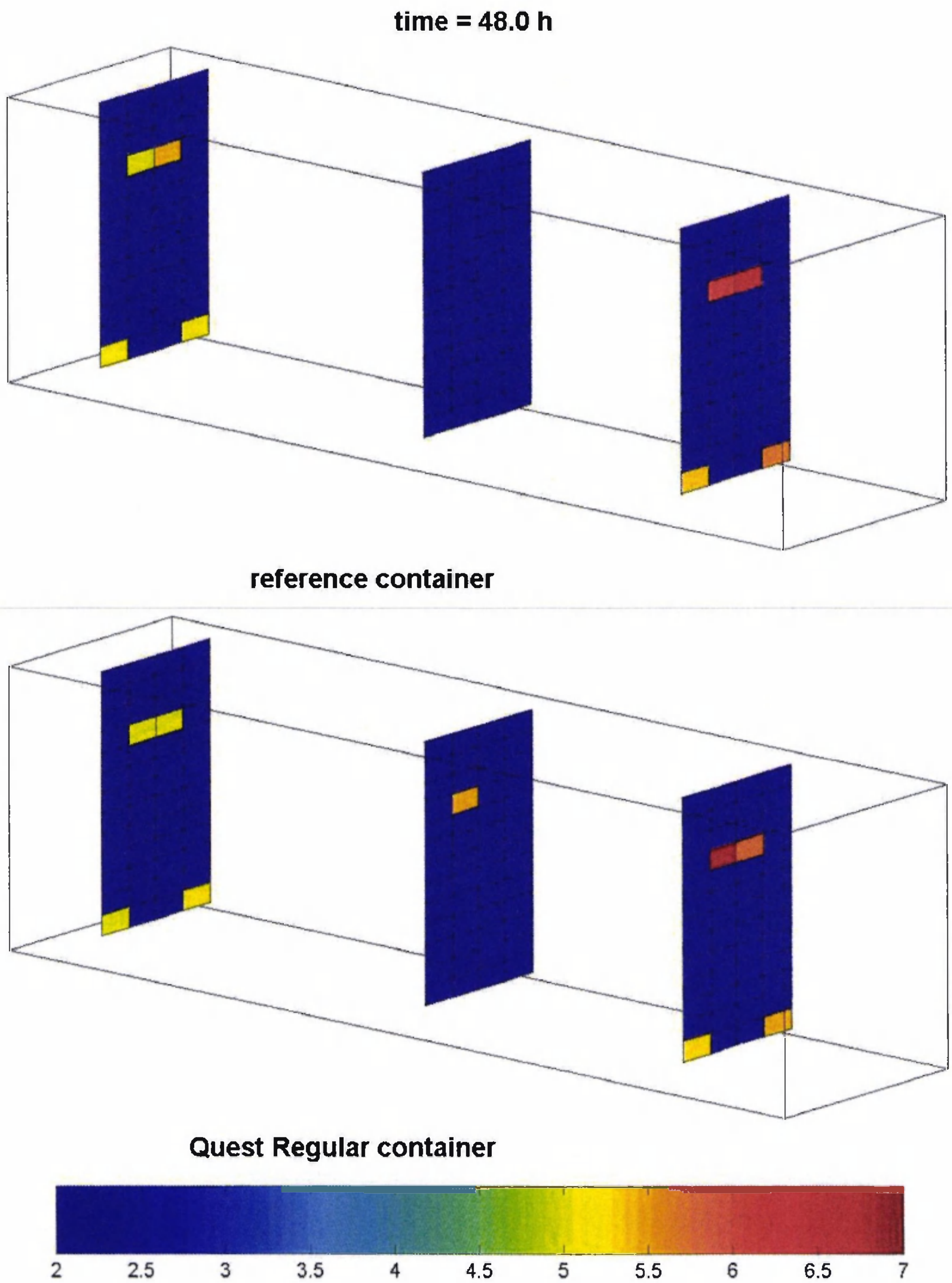


Figure 28 Tiny Tag readings of the carton temperatures after two days, on July 15th 00:00, Mandarin 1

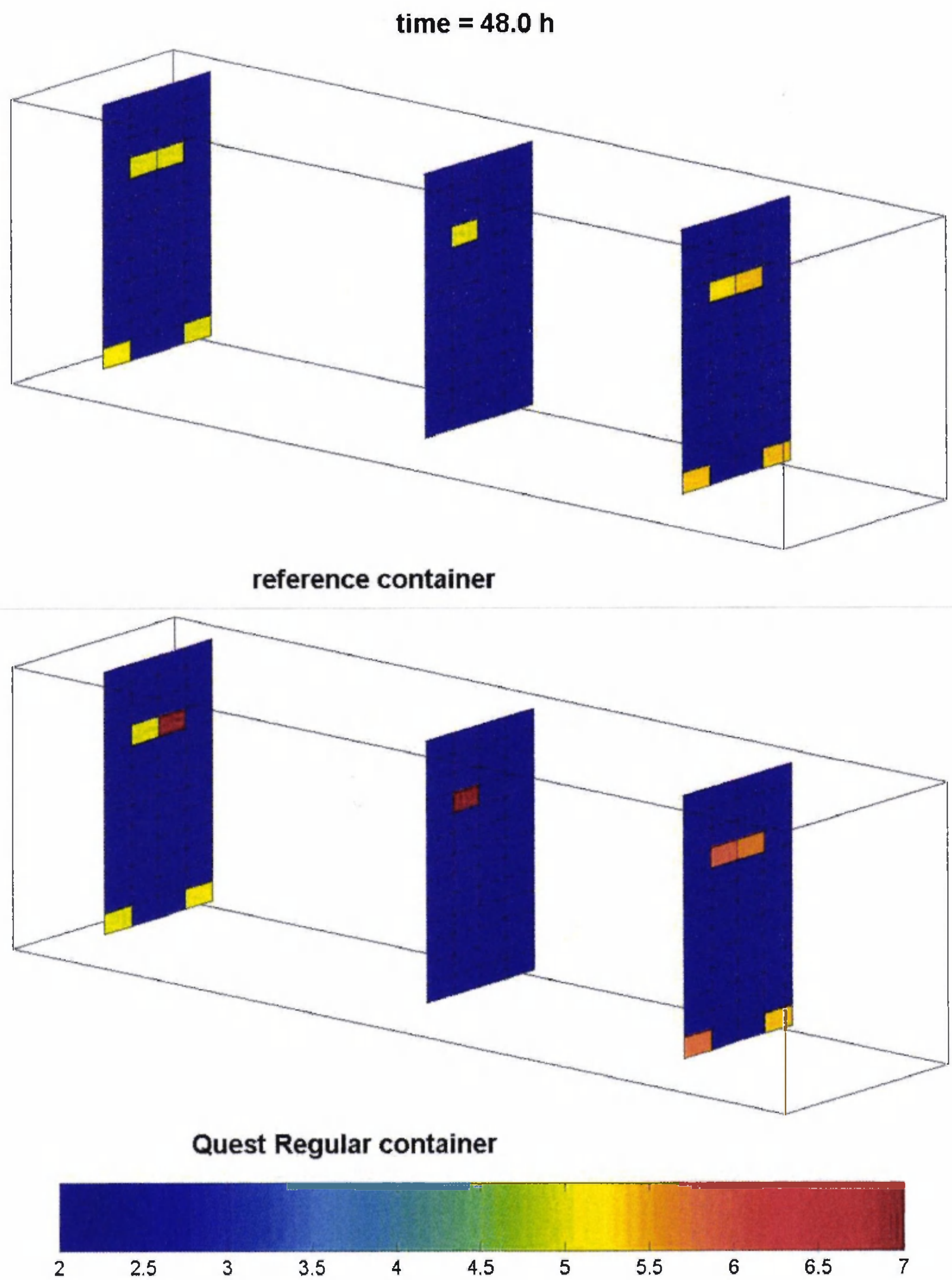


Figure 29 Tiny Tag readings of the carton temperatures after two days, on July 15th 00:00, Mandarin 2

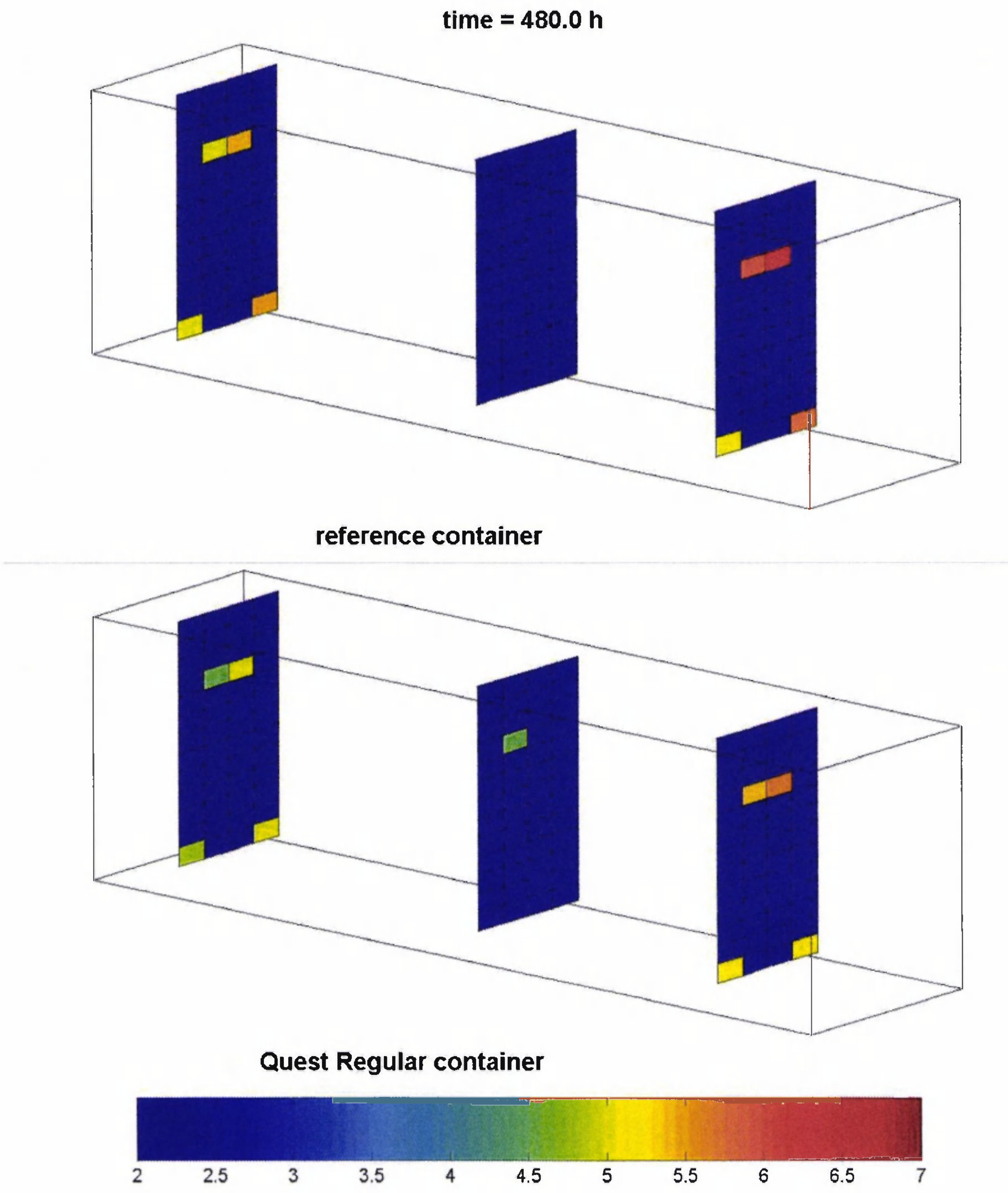


Figure 30 Tiny Tag readings of the carton temperatures near the end of the trip, on August 2nd 00:00, Mandarin 1

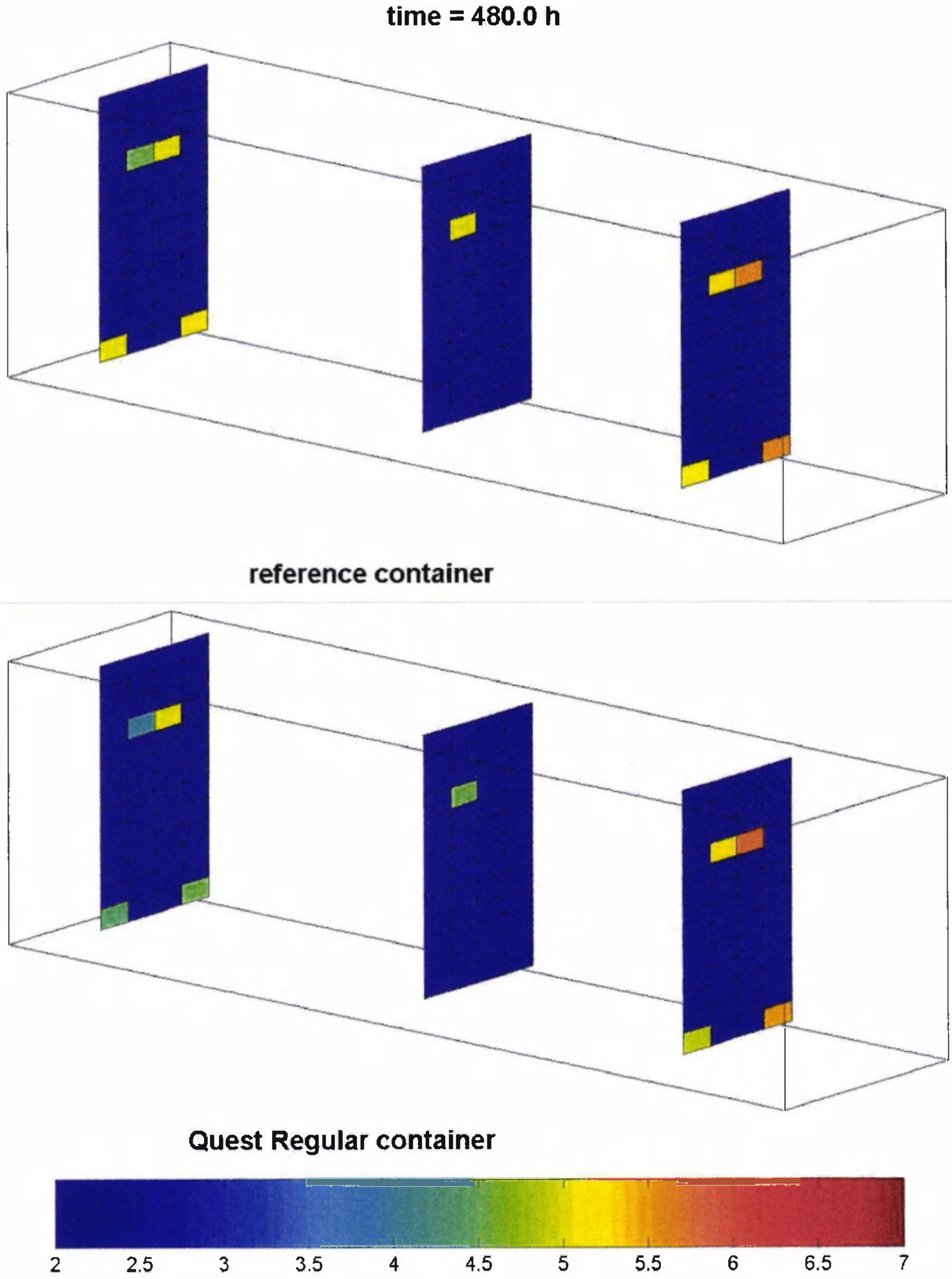


Figure 31 Tiny Tag readings of the carton temperatures near the end of the trip, on August 2nd 00:00, Mandarin 2

Appendix VII: Ambient temperatures

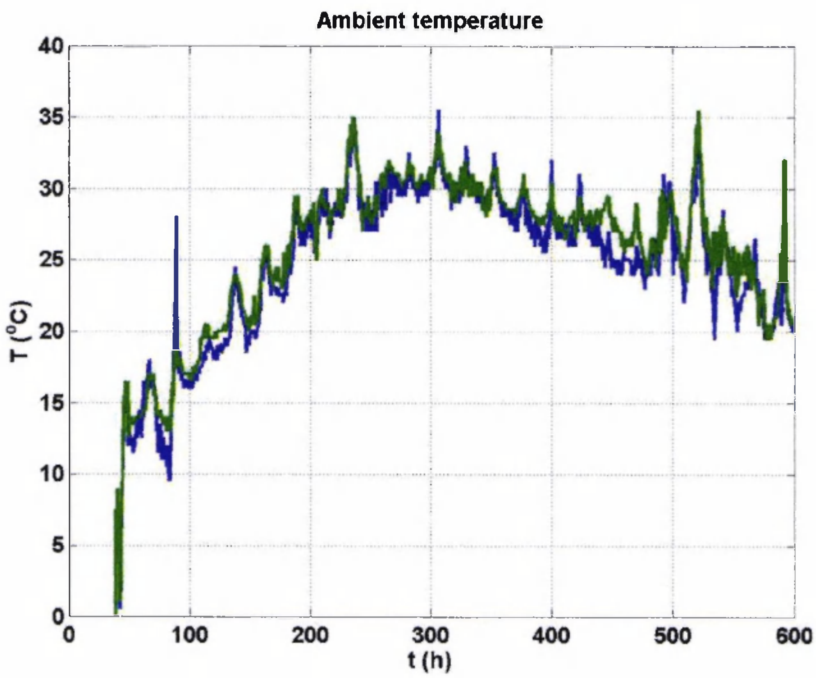


Figure 32 Ambient temperature readings from the Tiny Tag/Ibutton on the outside of the container, Mandarin test 1 en ref 1

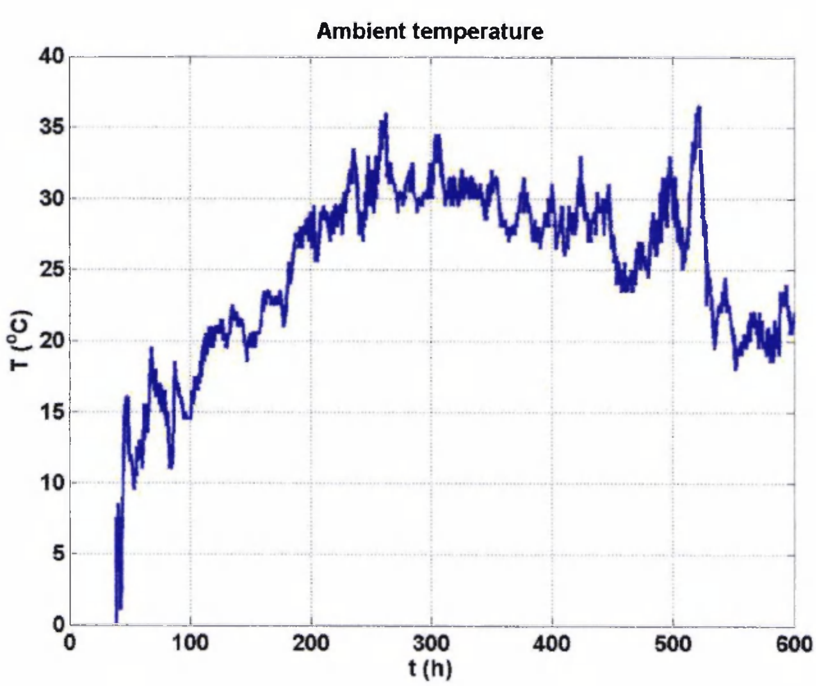
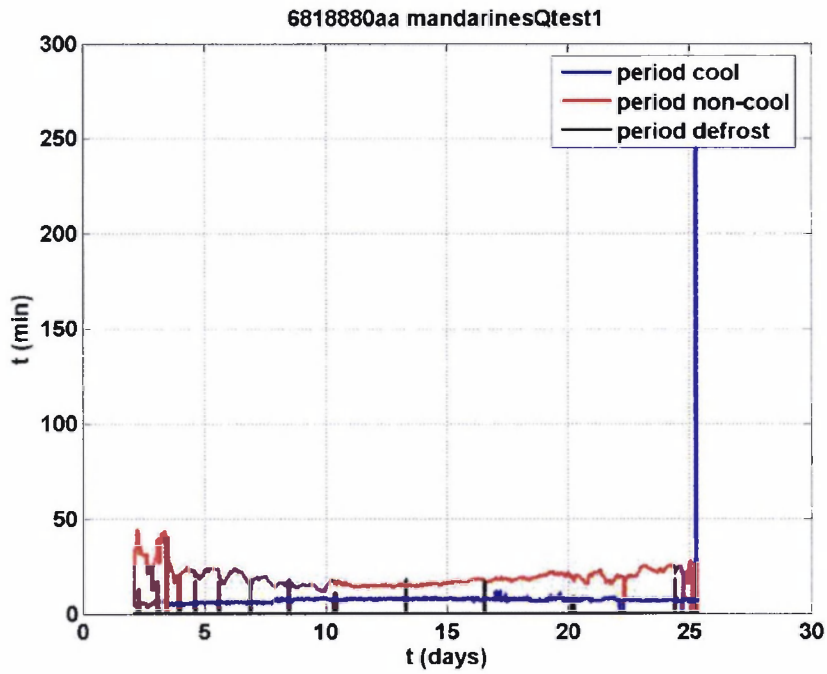


Figure 33 Ambient temperature readings form the Tiny Tag/Ibutton on the outside of the container, Mandarin test 2

Appendix VIII: Unit activity graphs



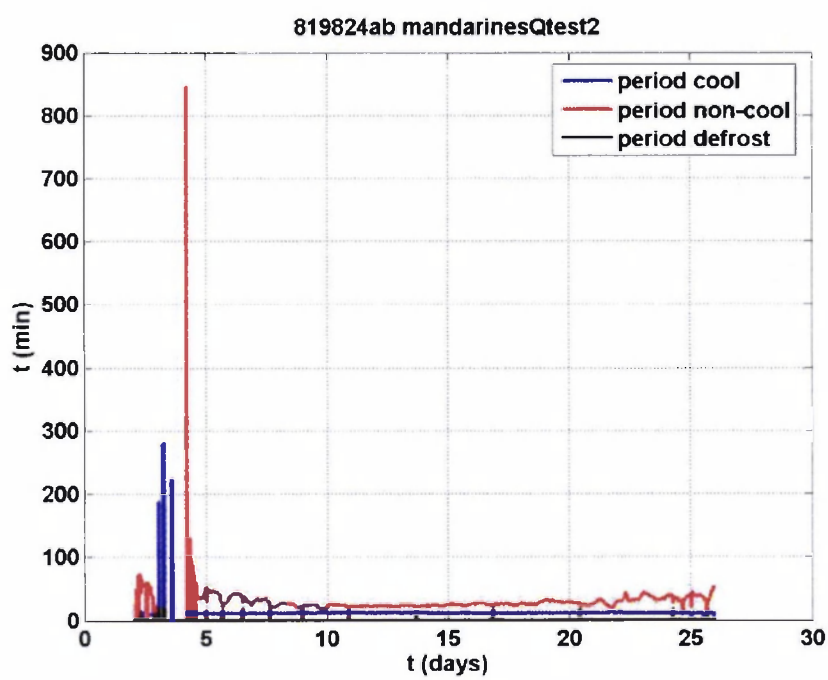
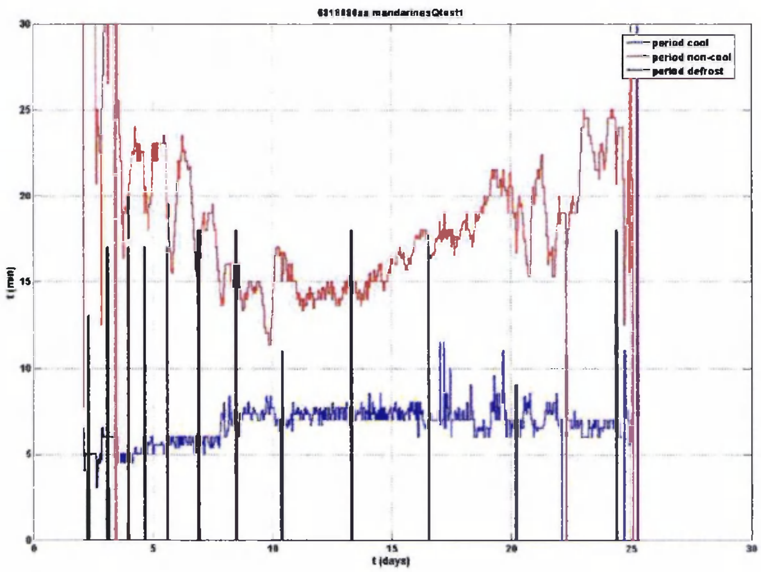


Figure 34 The number of minutes per cooling, non-cooling and defrost period as a function of time for the Quest Mandarin containers. At each time instant during the voyage when a period is finished a bar is drawn with the number of minutes that that period has lasted. If the period is smaller than an hour, the bars turn into a line.



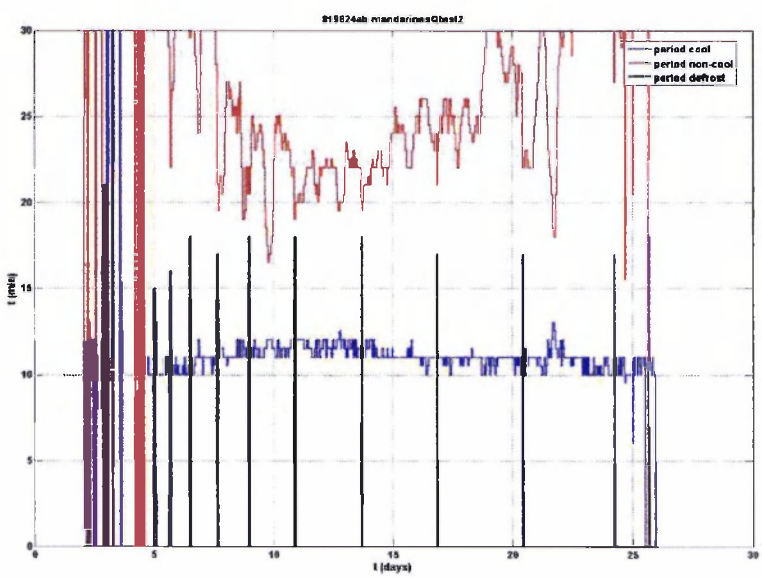


Figure 35 Zoom-in of the number of minutes per cooling, non-cooling and defrost period as a function of time for the Quest Mandarin containers.

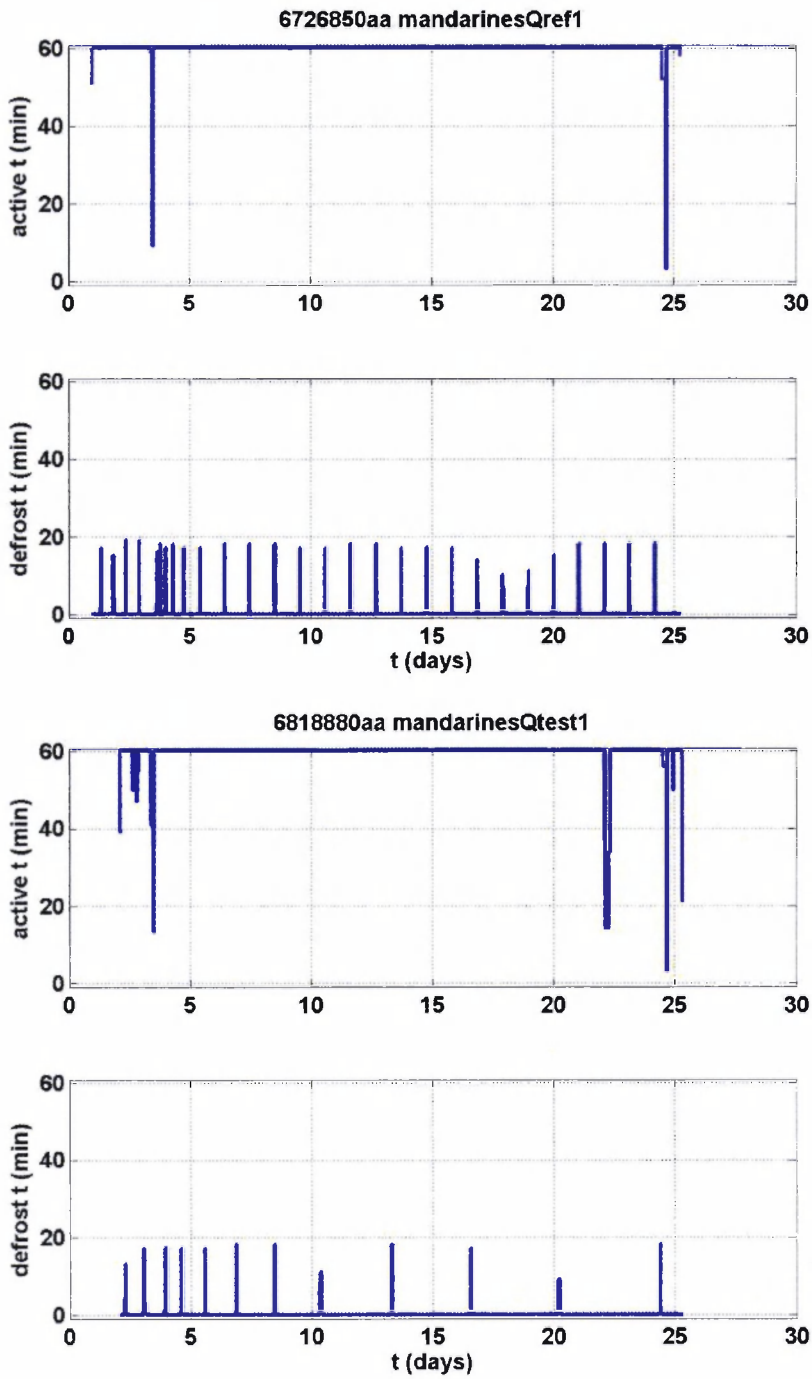


Figure 36 The number of minutes active, non-active and defrost period as a function of time for the Mandarin 1 containers. Every hour of the trip the number of minutes that was used for defrost was recorded. The number of minutes the unit was active was recorded as well, which is mostly 60 min/hour but sometimes less.

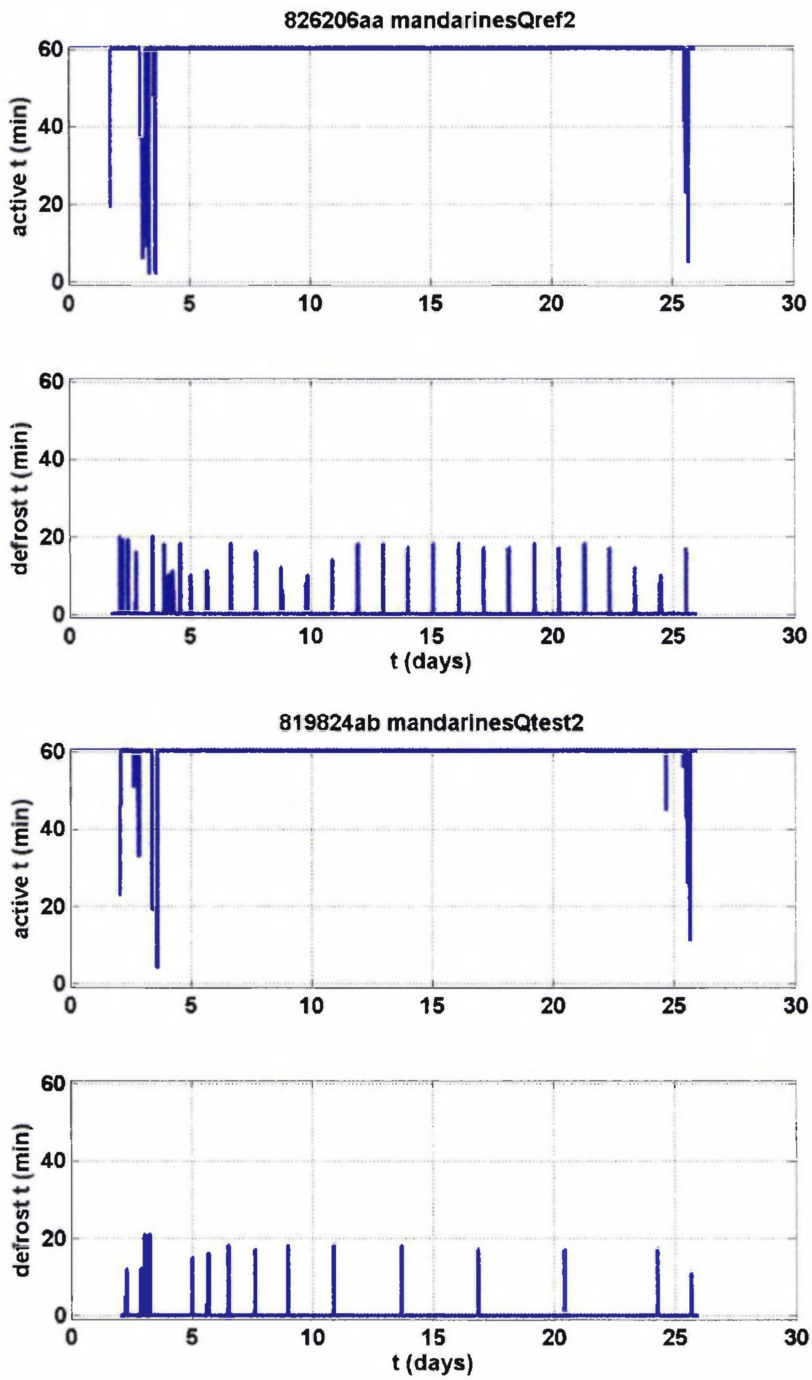


Figure 37 The number of minutes active, non-active and defrost period as a function of time for the Mandarin 2 containers. Every hour of the trip the number of minutes that was used for defrost was recorded. The number of minutes the unit was active was recorded as well, which is mostly 60 min/hour but sometimes less.

Appendix IX: Power measurements before departure

Container nr	Setup mode	Commodity	14/7/2006	15/7/2006 18:00	16/7/2006 11:00
MWCU 682 620 6	Normal	Clementine		291	327
MWCU 672 685 0	Normal	Clementine		310	370
MWCU 681 982 4*	CCPC	Clementine	299	341	406
MWCU 681 888 0	CCPC	Clementine	344	376	395

* Container was set in Normal mode and reset to CCPC mode on 16/7/2006 10:50 (Local Chilean Time)