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Ninth Quest Regular Trial Shipment

Mangos from Ecuador to the Netherlands and England

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Report 824

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 mangos from Ecuador to the Netherlands and England in December 2006. The goal of the trial shipment was to test the software and compare the power usage of 2 test containers (with the same settings test1 and test2) to a reference container, which was shipped simultaneously at original settings.

Including the pull down phase, mean savings over the whole trip are 31%. Power savings during cycling are approximately 43% and rise up to 49% when ambient temperature becomes cooler.

Both test containers reached the minimum supply temperature. Also, the return air temperatures lay closer to the setpoint of 9°C than that of the reference container.

The mean savings during the trip could be improved by choosing a less conservative limit to start cooling at the low supply air setpoint.

Acknowledgements

This ninth 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, Mr. Nielsen and Mr. Hansen of Maersk's Centre Reefer Management, Mr. de Castro Alves of Maersk's Reefer Operations - South America, Mr. Soehring of Pacific Container Transport S.A., Mr. Constante, Mrs. López and Mr. Dávila of Maersk Ecuador and Mr. Smith and Mr. Slangen of Maersk Benelux.

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 and Mr. Rogers.

We would like to thank Mr. Pailes of MMS for his contribution to the trial.

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

Contents

1 Introduction

The "Quest regular" system has been developed to reduce power consumption of reefer containers. As a follow-up of the real-life Quest trials with mangos, apples, mandarins, bananas, melons and pineapples it has been tested for long shipments of bananas, pineapples and mangos in December 2006. In order to determine the amount of power reduction, a comparison was made with a standard controlled reefer container. All three 40ft. containers were loaded with mangos and transported on the vessels Maersk Rosario, Santa Catalina and Jeppesen Maersk. The shipment was from Ecuador (Guayaquil) to the Netherlands (Rotterdam) and England (Felixstowe). The transport time was 18 days to Rotterdam and 21 to Felixstowe.

Two test containers, MWCU 6695430 (test1) and PONU 4513959 (test2), were equipped with and controlled by the "Quest Regular" software, also referred to as CCPC (Compressor-Cycle Perishable Cooling). Container MWCU 6603394 (ref1) served as reference container. During the shipment power consumption of all containers was measured using externally added KWH-meters.

It was not possible to attend the loading of the containers. Therefore, no initial product quality measurements were taken. Also, no additional temperature loggers were placed inside the containers. Therefore, this report only contains the analyses of the unit datacorder readouts and the kWh measurements. More information on the product quality outturn may be available in the MMS report.

2 Material and methods

2.1 Product

The mangos originated from the Guayaquil area in Ecuador.

2.2 Unit settings

All three containers used were fitted with Carrier Thinline refrigeration. The CCPC program was installed on the test units (version 9590), using a microlink 3 card or a microlink 2/3 adapter. The reference container was running in normal mode with settings as usual for mangos. The test containers were running in CCPC mode.

The reference container settings were:

◊ Supply setpoint	9.0 °C = 48.2 F
◊ Fan setting	High
◊ Vent setting	30 m^3/h

The CCPC settings were:

◊ Supply setpoint	7.0 °C = 44.6 F
◊ Return Air Pulldown Low Limit	9.0 °C = 48.2 F
◊ Return Air Low Limit	9.0 °C = 48.2 F
◊ Return Air High Limit	10.0 °C = 50.0 F
◊ Fan setting	Alternating
◊ Vent setting	30 m^3/h

Defrost interval was set to automatic and Humidity, Dehumidification and Bulb Mode were all set to OFF for all containers. The in Range Limit (Code 30) was set to 0.5°C.

2.3 Voyage schedule

On December 8th the containers were loaded with mangos. Subsequently, the containers were taken to the harbour of Guayaquil. Two containers (test1 and ref1) were loaded on the Maersk Rosaria December 11th. The test2 container was loaded on the Santa Catalina on December 12th. The setup is shown in Table 2.

Table 2 Container setup

Container nr	Setup mode	Stuffing date	Commodity
MWCU 6695430	CCPC (test1)	8/12/2006	Mango
MWCU 6603394	NORMAL (ref1)	8/12/2006	Mango
PONU 4513959	CCPC (test2)	8/12/2006	Mango

All containers were loaded to the vessel (Maersk Rosario) on December 11th. The containers arrived in Rotterdam (the Netherlands) on December 30th and in Felixstowe (England) on

January 3rd 2007. Figure 5 and Figure 6 in the appendix depict the mean temperature and relative humidity in December for such a trip.

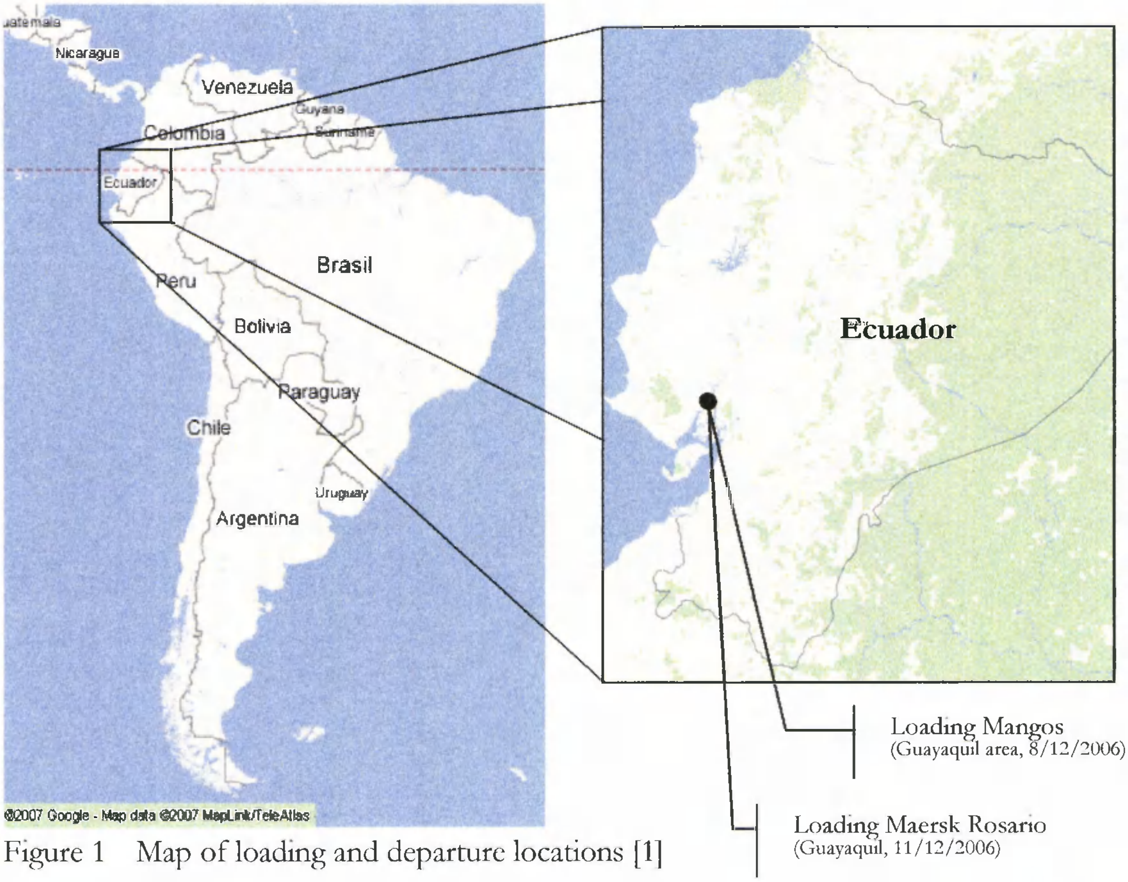

Figure 1 Map of loading and departure locations [1]

Figure 2 Map of the vessels route (left Maersk Rosario[ab], right Jeppesen Maersk) [2]

2.4 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.

[a] *Guayaquil to Balboa*
[b] *Test2 container was shipped on the Santa Catalina to Balboa*

3 Temperatures

For the ref1 unit only the first day of ccpc-data was available. For this reason only the temperatures from the basic logview file are analysed. For the test units also the elaborate ccpcdata is available. None of the containers contained additional temperature sensors inside the cartons.

3.1 Temperature readings during pull down

Pull down was executed in CCPC mode for all test containers. Containers ref1 and test1 start to pull down on December 8th. The number of days for the return air to reach the high return air limit (Thlim = 10°C) and the pull down limit (Tpdlim = 9°C) are shown in Table 3. (The test containers start to pull down at the low supply air setpoint when reaching the high return air limit and start to cycle at reaching the pull down limit.)

Table 3 Pull down periods

Container	T_1 (°C)	T_2 (°C)	Time to T_1 (days)	Time to T_2 (days)
Ref1	10	*9.5*	3	*22*
Test1	10	9	9	11
Test2	10	9	4	5

The long time to reach Thlim shows that test1 probably has a higher heat load than test2 and Ref1. Cycling does not start until after 11 days, which reduces the mean savings during the trip. This could be avoided by choosing a less conservative limit to start cooling at the low supply air setpoint, e.g. when return air reaches Tsp + 2 instead of when it reaches Thlim (= Tsp +1).

3.2 Supply air temperatures during Quest Regular Mode

The units with the Quest settings (test1 and test2) reach the appropriate supply temperatures of 7.0°C. For these units the average supply temperature error during cooling lies between 0.5 and 1.0°C.

3.3 Return air readings during Quest Regular Mode

In Table 4 the error between setpoint and return air are shown.

Table 4 Temperature difference between setpoint and return air

Container	Error (°C)	Difference with Refl (°C)
Refl	0.88	-
Test1	0.63	0.25
Test2	0.71	0.17

Both test containers (test1 and test2) have a return air temperature that is closer to the setpoint of 9°C than that of the reference container.

4 Power Consumption

Power consumption data were read from the kWh meters by Maersk employees once/twice a day during the sea voyage. Time and energy data were taken from the kWh meters, see Figure 3. Time axis is such that t = 0 starts at December 5th 2006 16:00.

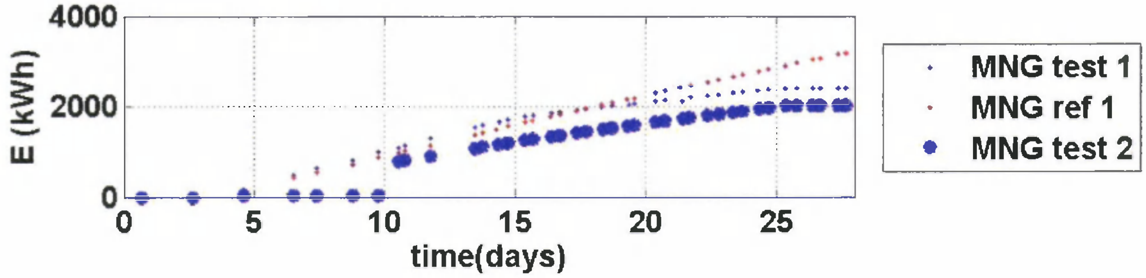

Figure 3 Energy readings as a function of time for the three container sets

On board the Jeppesen, test1 was running with a water cooled condenser, while the others had air cooling of the condenser, see Table 5. Also, ref1 was stored on deck instead of in the cargo hold. This will also have affected the power consumption of the reefers. The simultaneously shipped test containers showed a 0.8 kW higher power consumption for air cooled instead of water cooled condensers.

Table 5 Type of condenser cooling of the reefers and ventilation setting at unloading

Container	Condenser cooling	Location	Mean Power (kW)
ref1	air cooled condenser	Deck	5.6
test1	water cooled condenser	Cargo Hold	4.4
test2	air cooled condenser	Cargo Hold	3.6

The reference container (ref1) used 3071 kWh in 552 hour, a mean power usage of 5.6 kW.

The test containers (test1 and test2) used 2406 and 2012 kWh in 552 h, a mean power usage of 4.4 and 3.6 kW, which is 21% less and 36% less compared to the reference container. Note that test1 started cycling after 11 days into the trip and its condenser was water instead of air cooled.

Taking into account the differences in condenser cooling, the best savings estimation is that of test2 compared to ref1: 36 %. This includes the pull down phase during which the unit is not cycling yet.

The power consumption and savings per day are shown in Figure 4. Power savings during cycling are approximately 49%.

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 17 and Figure 18 in the appendix. (For comparison, also the active hours and defrost time of the units are shown.)

- Compressor off time intervals for test1 last approximately 40 - 60 minutes, about 1.5 – 2.5 times as long as the compressor-on time intervals
- Compressor off time intervals for test2 last approximately 25 - 50 minutes, about 1.5 - 2 times as long as the compressor-on time intervals.

The compressor off periods become longer when ambient temperature is lower. Compressor on time periods stay the same. Other factors of influence are the reduced fan speed during compressor-off time intervals and the reduced amount of ventilation during low fan speed/compressor off periods.

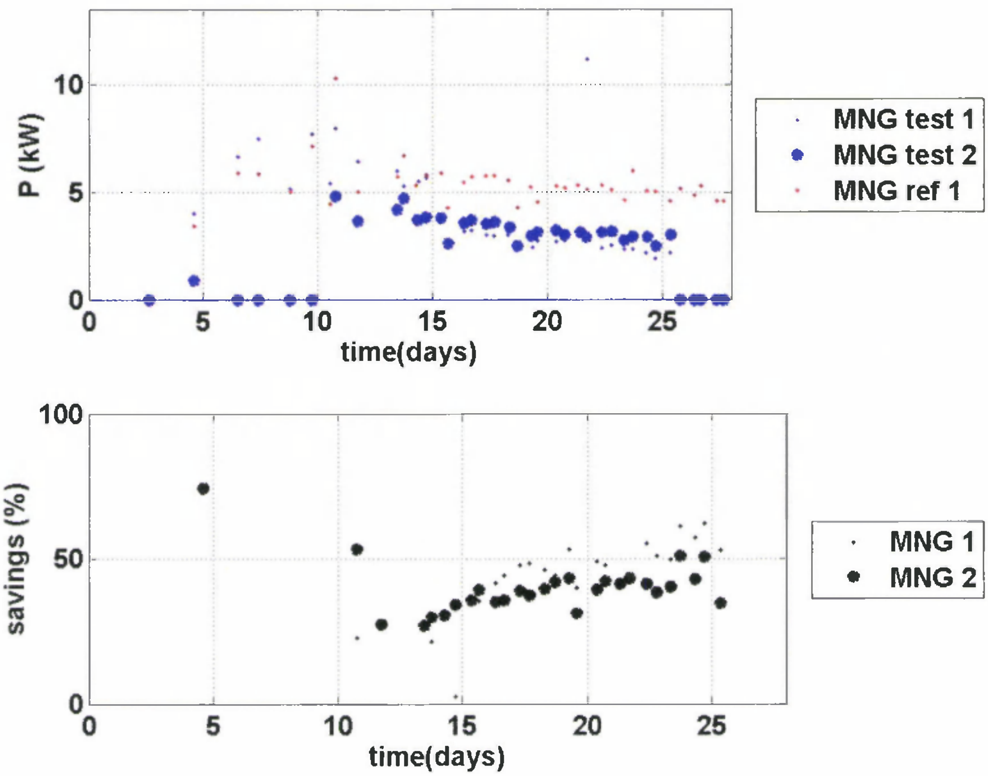

Figure 4 Power and savings as a function of time

5 Conclusions

5.1 Power savings

Table 6 shows the mean savings for the various quest settings. This includes the pull down phase during which the unit is not cycling yet. For test1, the difference in condenser cooling should be taken into account.

Table 6 Approximate power savings

Settings	Approximate savings (%)	Remark
Quest 1 (default)	21	> 21%? difference in condenser cooling
Quest 2 (default)	36	

Power savings during cycling are approximately 43% and rise up to 49% when ambient temperature becomes cooler.

5.2 Temperatures

Both test containers reached the minimum supply temperature. Also, the return air temperatures lay closer to the setpoint of 9°C than that of the reference container.

One of the two test containers starts cycling late, because return air takes 11 days to reach the high return air limit. Such reduces the mean savings during the trip. This could be avoided by choosing a less conservative limit to start cooling at the low supply air setpoint, e.g. when return air reaches Tsp + 2 instead of Thlim (= Tsp +1).

References

[1] http://www.googlemaps.com/

[2] http://www.maersksealand.com/

[3] http://www.cdc.noaa.gov/cgi-bin/GrADS.pl

Appendix I: Ambient conditions between Ecuador and Europe

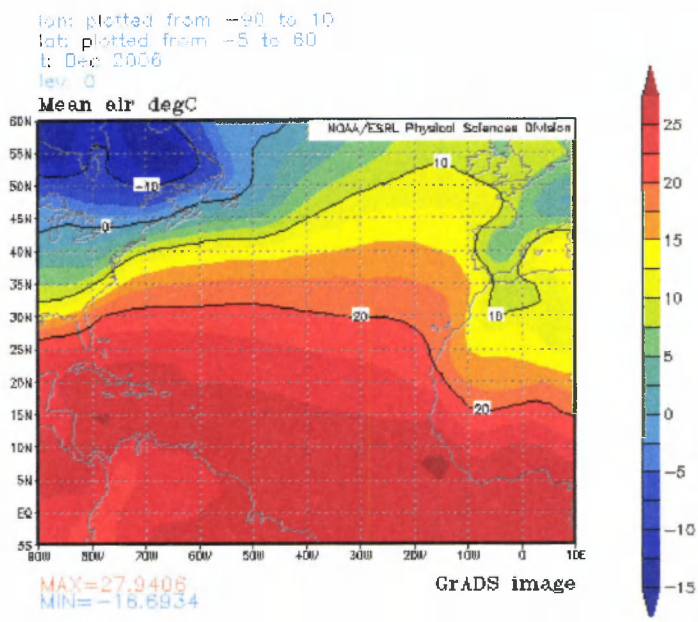

Figure 5 Mean December temperature between Ecuador and Europe [3]

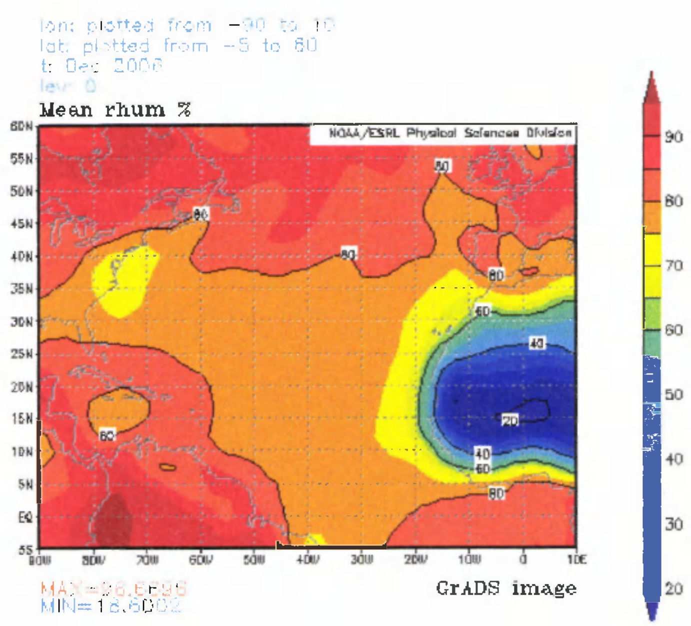

Figure 6 Mean December relative humidity between Ecuador and Europe [3]

Appendix II: Unit temperature readings as a function of time

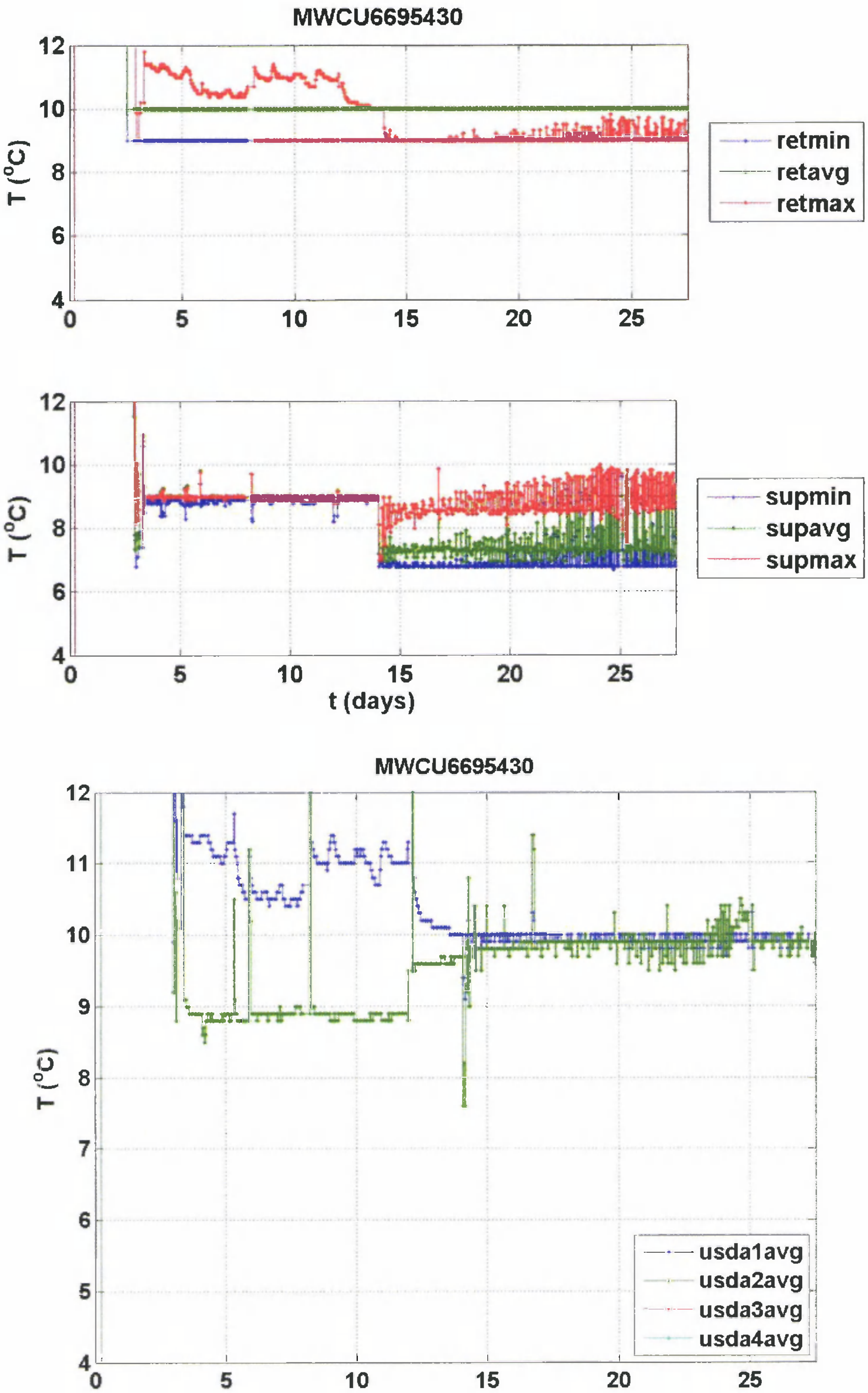

Figure 7 Temperature readings for the test1 container

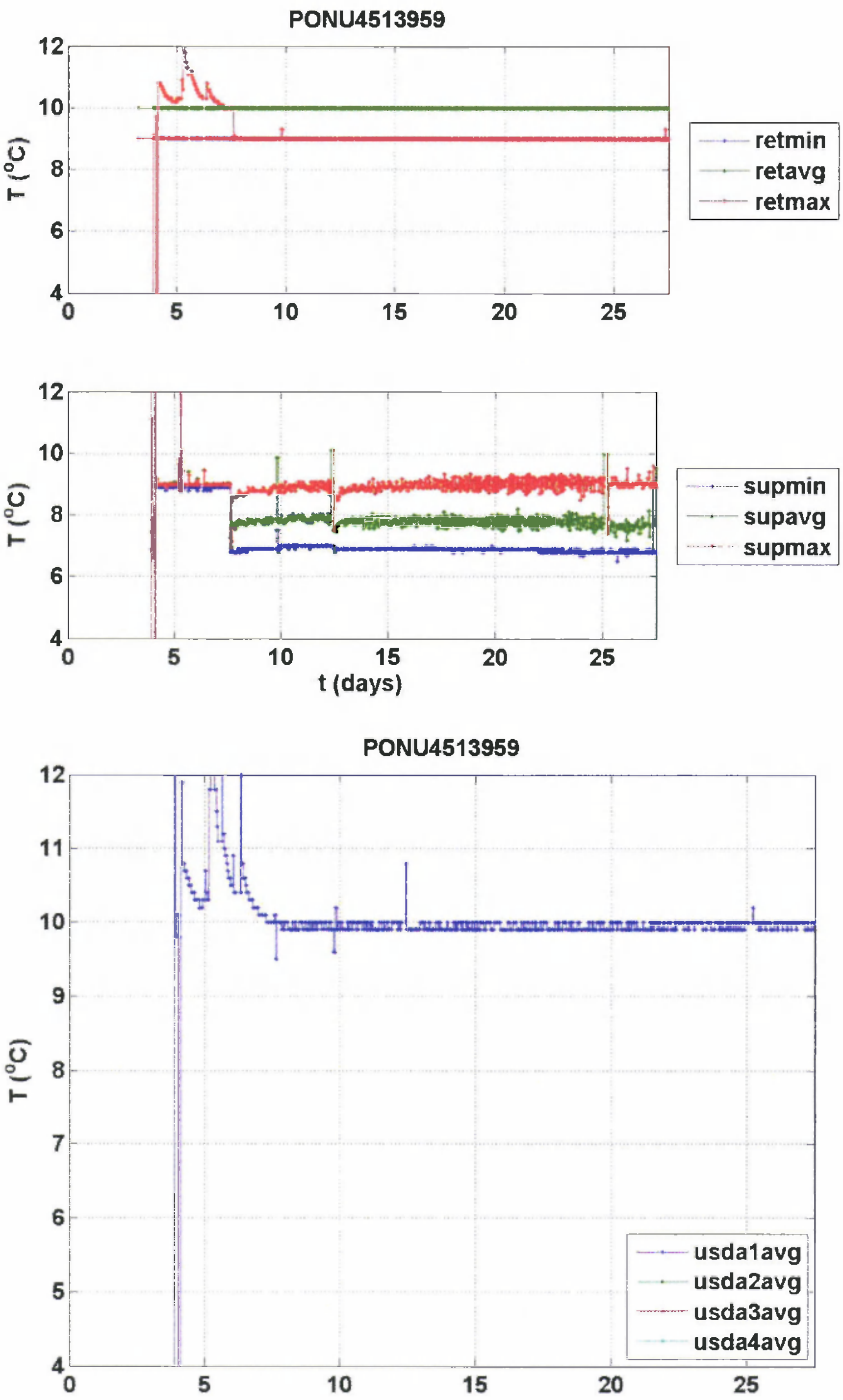

Figure 8 Temperature readings for the test2 container

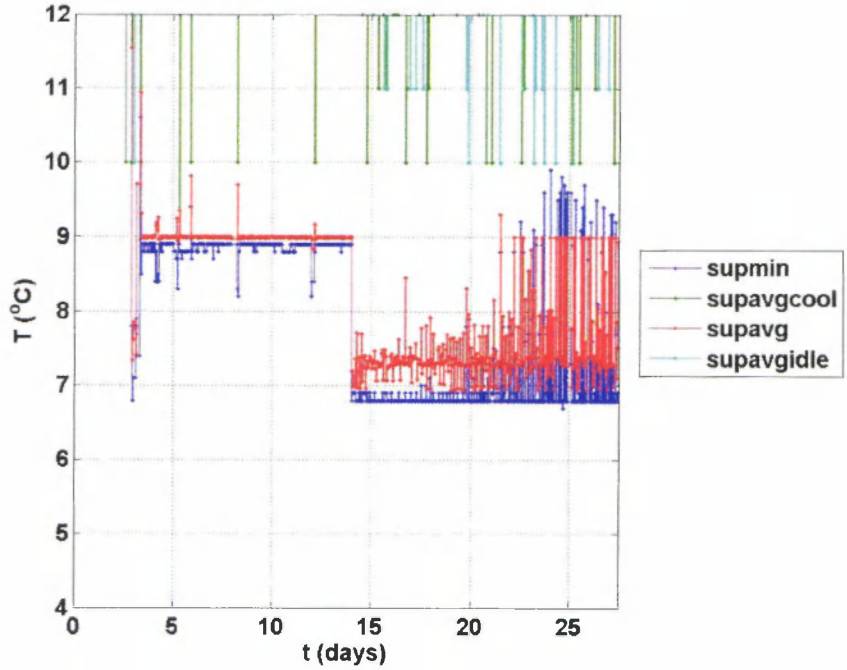

Figure 9 Supply temperatures for test1

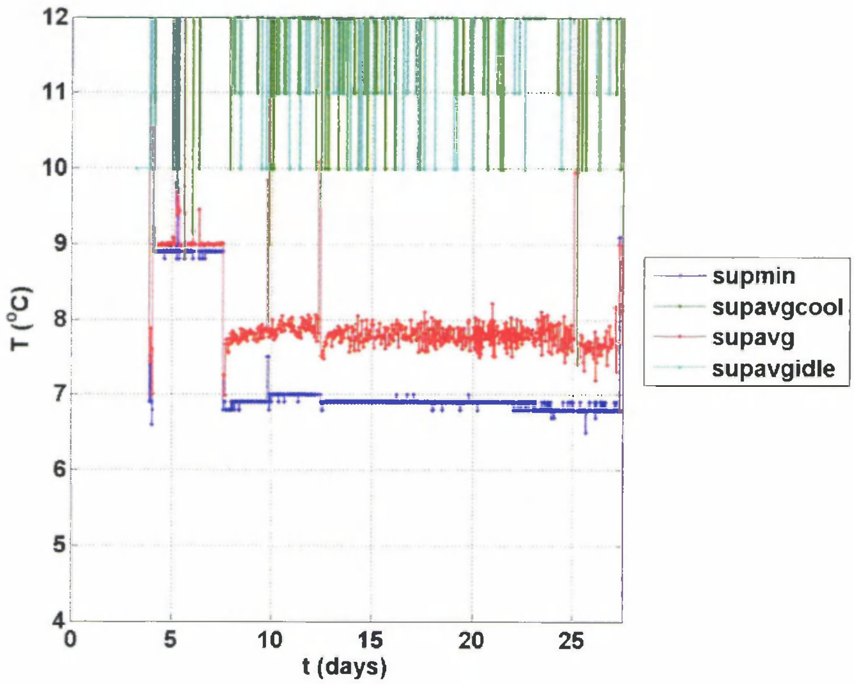

Figure 10 Supply temperatures for test2

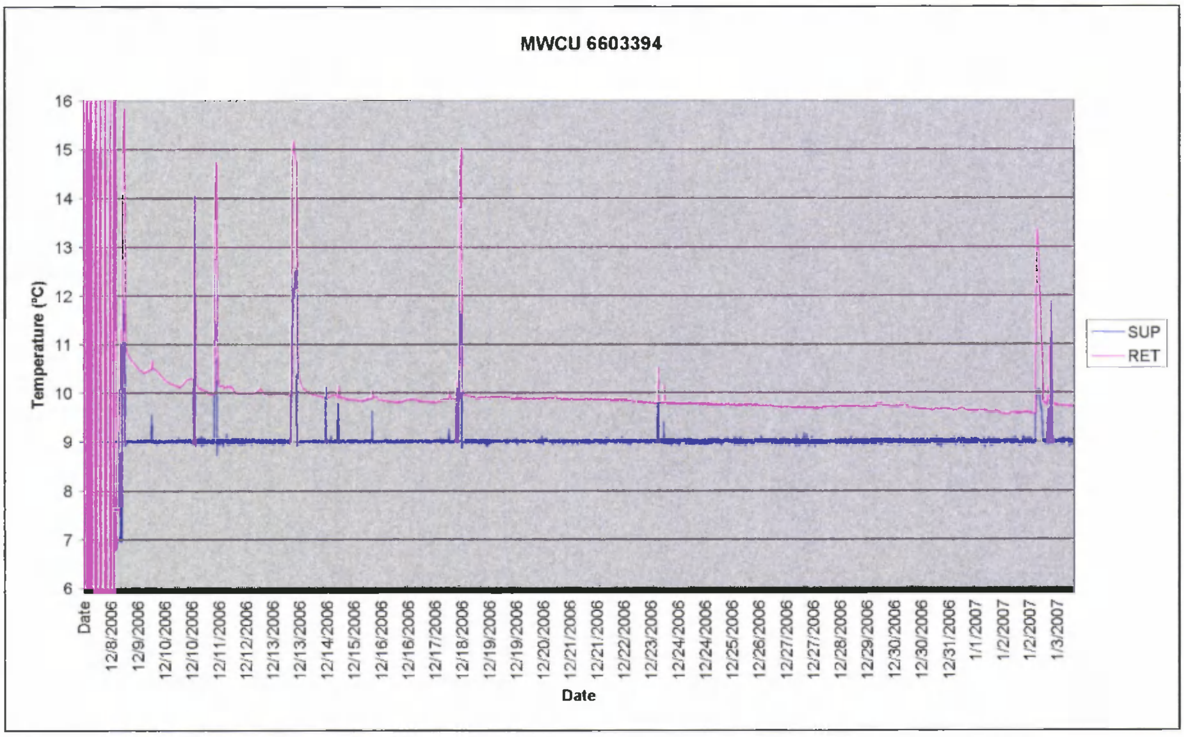

Figure 11 Temperature readings for ref1

Appendix III: Supply temperature error and cooling period graphs

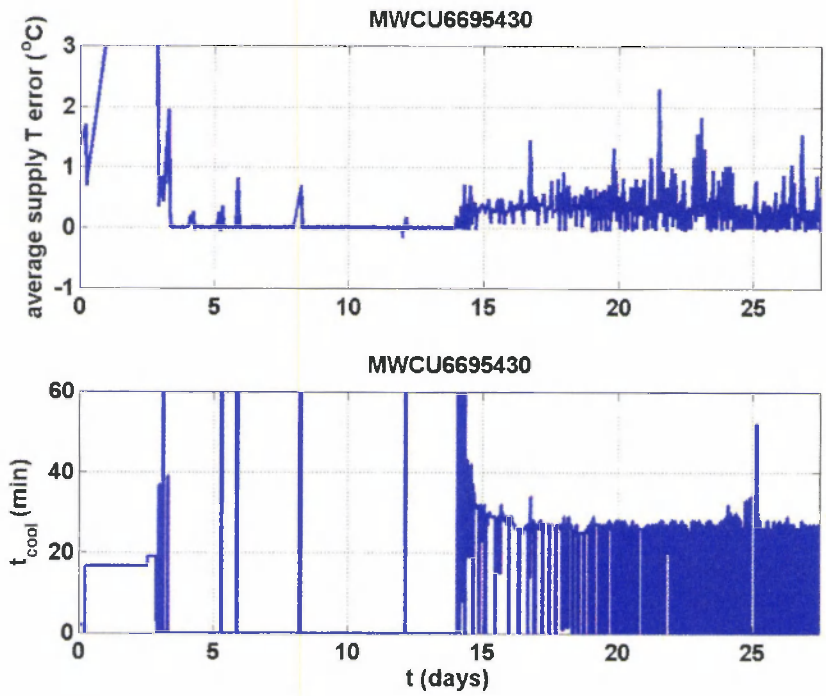

Figure 12 Supply temperature errors and cooling period lengths for test1

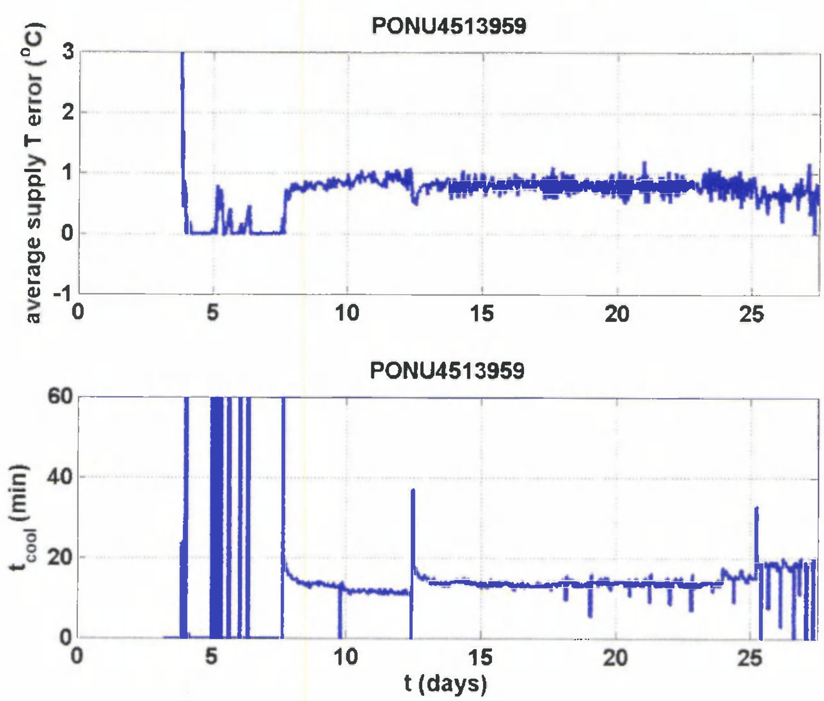

Figure 13 Supply temperature errors and cooling period lengths for test2

Appendix IV: Ambient temperatures

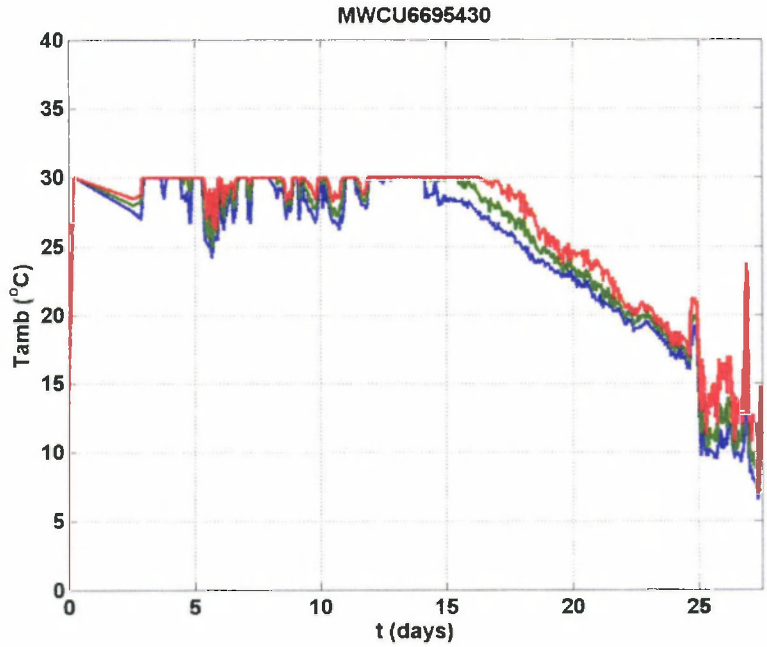

Figure 14 Ambient temperature readings from the unit of test1

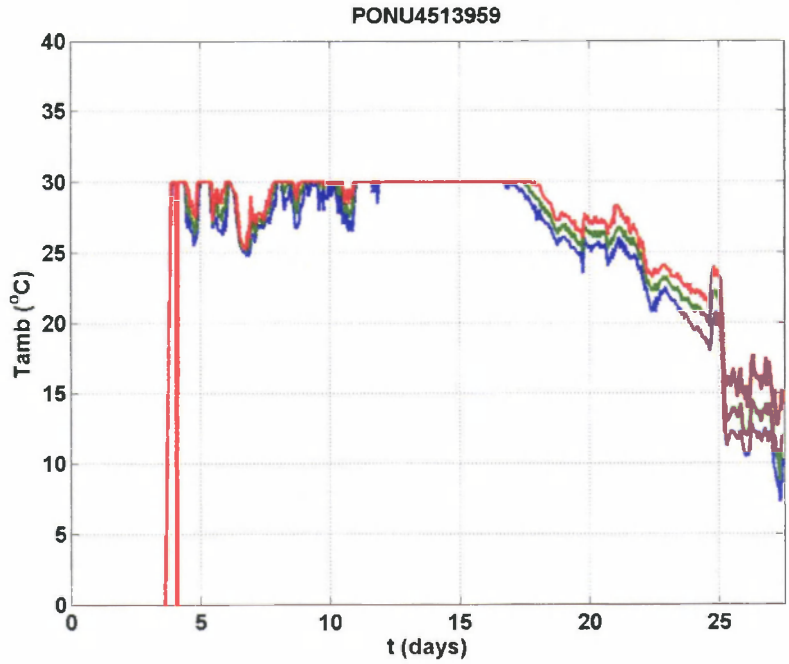

Figure 15 Ambient temperature readings from the unit of test2

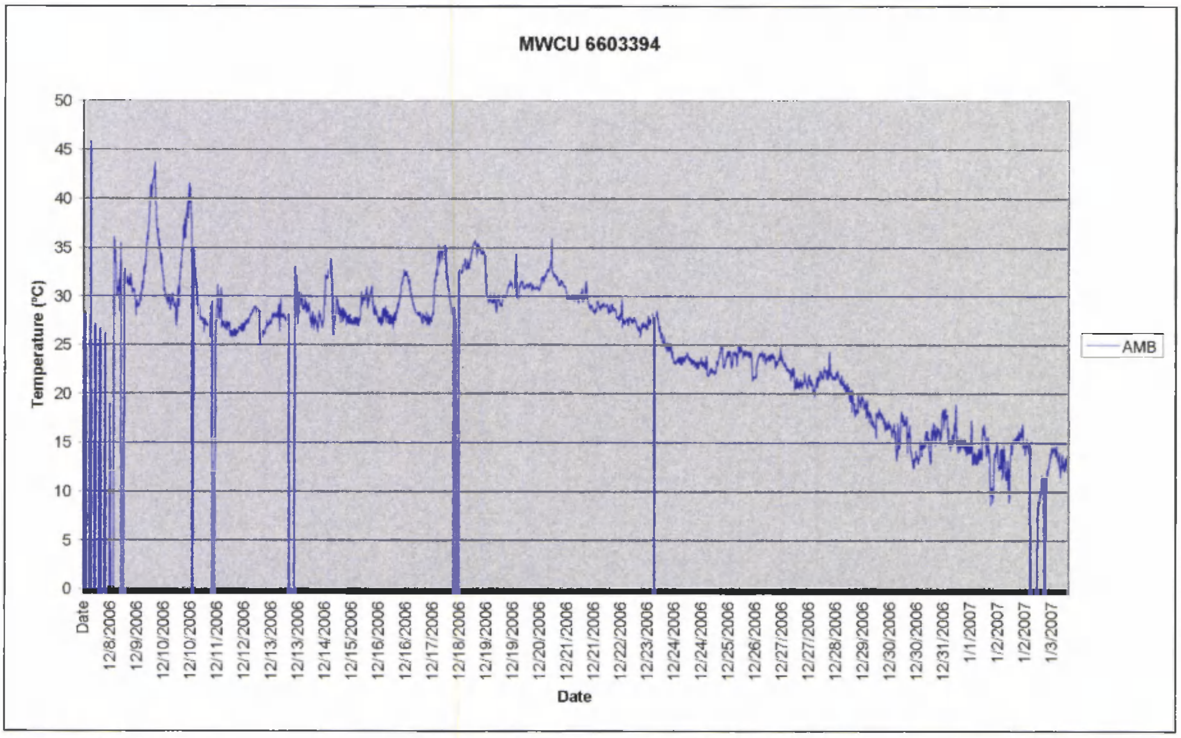

Figure 16 Ambient temperature readings from the unit of container ref1

Appendix V: Unit activity graphs

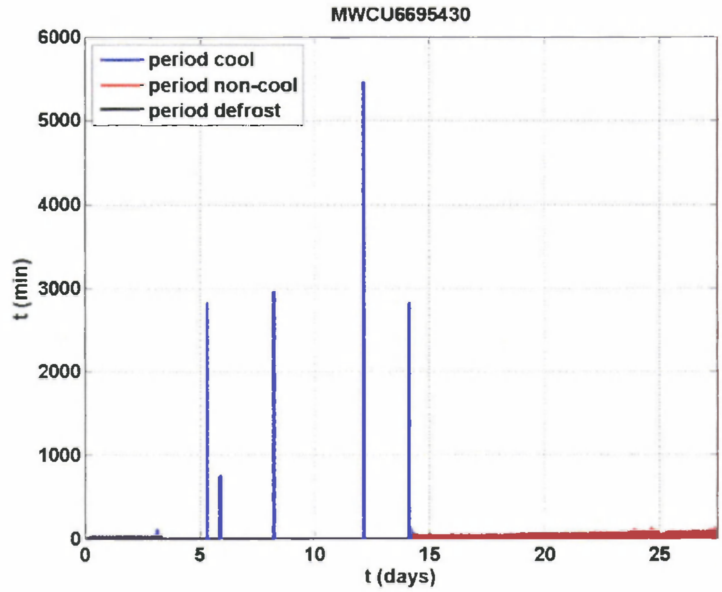

Figure 17 The number of minutes per cooling, non-cooling and defrost period as a function of time for test1. At each time instant during the voyage when a period is finished a bar is drawn with the number of minutes that that period has lasted. If the period is smaller then an hour, the bars turn into a line.

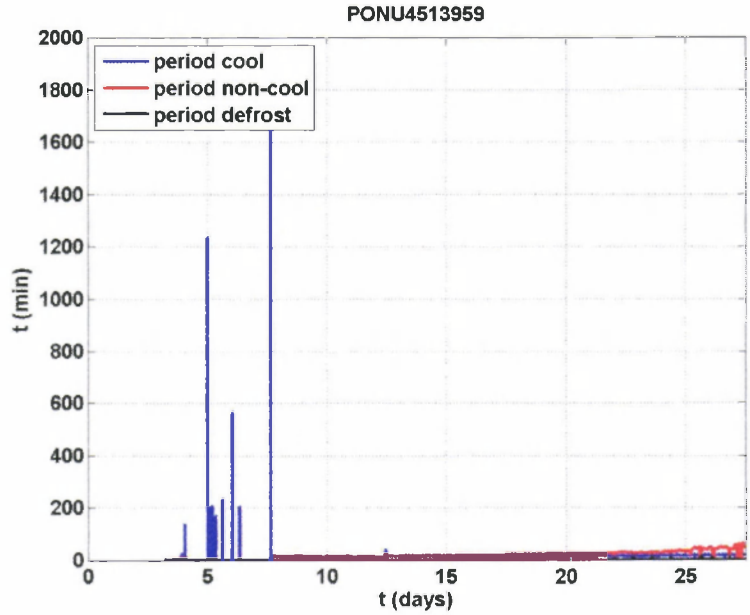

Figure 18 The number of minutes per cooling, non-cooling and defrost period as a function of time for test2. At each time instant during the voyage when a period is finished a bar is drawn with the number of minutes that that period has lasted. If the period is smaller then an hour, the bars turn into a line.

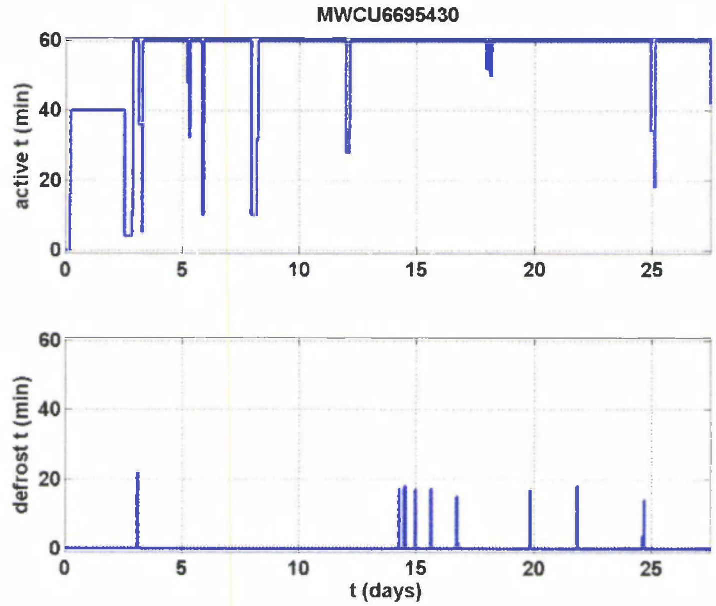

Figure 19 The number of minutes activity and defrosting as a function of time for test1. Every hour of the trip the number of minutes that was used for defrost was recorded. The number of minutes the unit was active was recorded as well, which is mostly 60 min/hour but sometimes less.

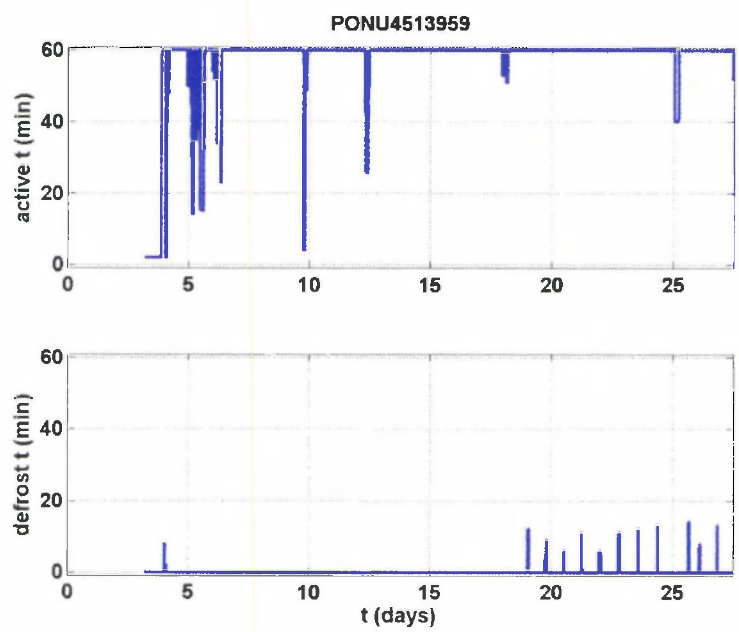

Figure 20 The number of minutes activity and defrosting as a function of time for test2. Every hour of the trip the number of minutes that was used for defrost was recorded. The number of minutes the unit was active was recorded as well, which is mostly 60 min/hour but sometimes less.

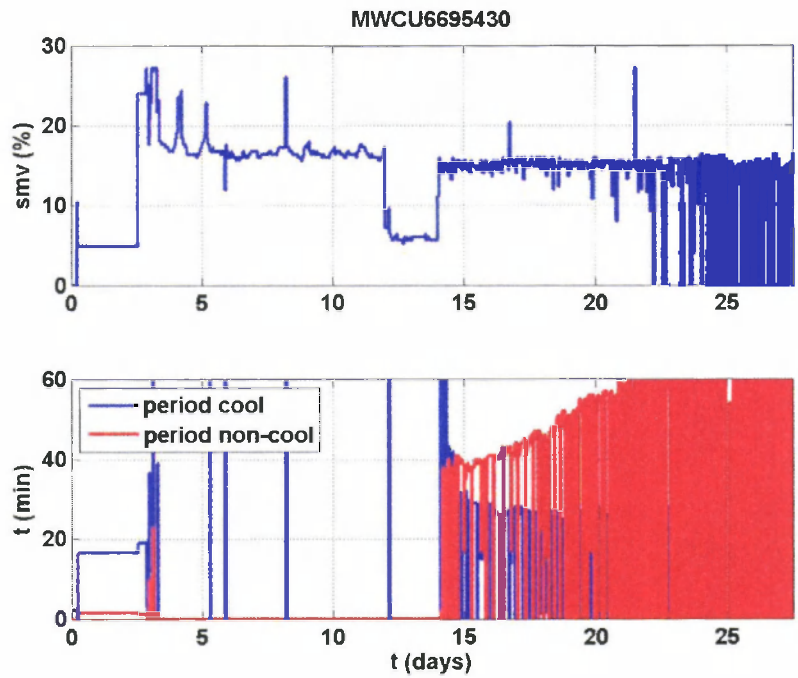

Figure 21 The smv opening (suction modulation valve) and number of minutes of cooling and non-cooling as a function of time for test1.

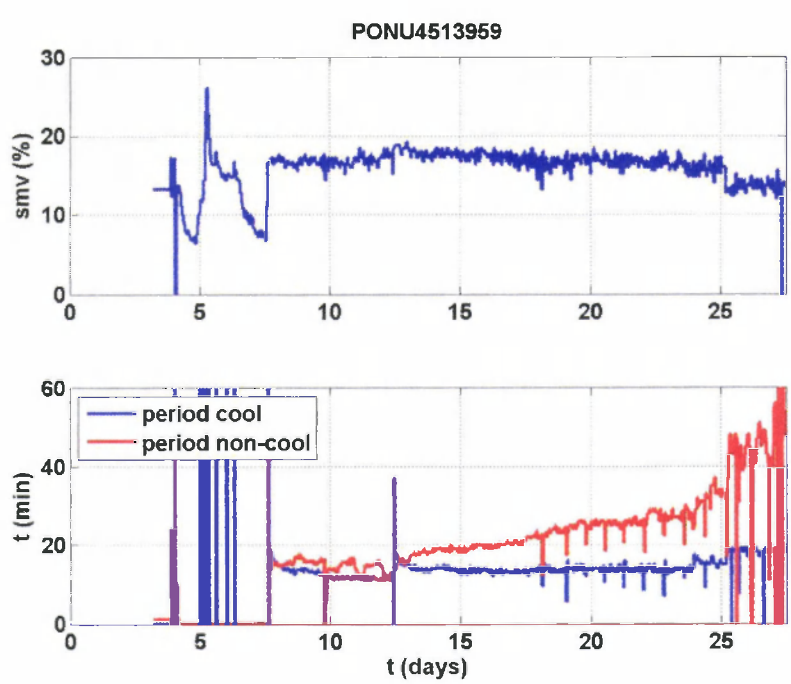

Figure 22 The smv opening (suction modulation valve) and number of minutes of cooling and non-cooling as a function of time for test2.