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Eighth Quest Regular Trial Shipment

Pineapples from Ecuador to Spain

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Report 823

Abstract

The "Quest regular" system has been developed to reduce power consumption of reefer containers. The Quest Regular concept and corresponding CCPC software were tested in a real-life shipment of pineapples from Ecuador to Spain in December 2006. The goal of the trial shipment was to test the software and compare the power usage of 3 test containers (with the same settings for test1, test2 and test3) to a reference container, which was shipped simultaneously at original settings.

Including the pull down phase, savings over the whole trip are 33%. Power savings during cycling are approximately 55%.

One of the test containers showed difficulty to reach its setpoint for a few days and multiple alarm codes, until handling in Balboa. The reason remains unclear. Otherwise, supply air temperatures of the test containers reach their required setpoint.

The return air temperatures during cycling are satisfactory. One test container only starts to cycle during the last day of the trip. The performance could be improved by choosing a less conservative limit for the start of cooling at the low supply air setpoint.

Acknowledgements

This eighth 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.

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

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.

Finally, our thanks go to Terra Sol, whose fruit was transported and who made quality inspection possible after transport.

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 trial with mangoes, apples, mandarins, bananas, melons and pineapples it has been tested for long shipments of bananas, pineapples and mangoes in December 2006. In order to determine the amount of power reduction, a comparison was made with a standard controlled reefer container. All four 40ft. containers were loaded with pineapples from the same origin and transported on the same vessels (Maersk Rosario and Jeppesen Maersk). The shipment was from Ecuador (Guayaquil) to Spain (Algeciras). The transport time was 17 days to Algeciras.

Three test containers, TRLU 1880470 (test1), PONU 4831899 (test2) and MWCU 6720019 (test3), were equipped with and controlled by the "Quest Regular" software, also referred to as CCPC (Compressor-Cycle Perishable Cooling). Container PONU 4989800 (ref1) served as reference container. During the shipment power consumption of all containers was measured using externally added KWH-meters. The temperature distribution of test1 and ref1 were measured using 18 sensors per container and logging the actual temperature every 30 minutes. At arrival a quick quality inspection was performed by Philip Pailes, see the MMS report for details.

2 Material and methods

2.1 Product

The pineapple variety was MD-2. The pineapples originated from the Santa Domingo area in Ecuador. The fruit was exported by Terra Sol. The initial temperature of the pineapples was approximately 8 °C.

Figure 1 MD-2 pineapple

Figure 2 MD-2 pineapple open

2.2 Packaging and stowage

The pineapples are packed in cardboard boxes. The carton size is 600x400 mm, stacked 15 boxes high (5 on a layer). In total 4 containers with 1500 cartons are packed, placed on 20 pallets. The pallets used were wooden industrial pallets size 1200x1000 mm. 20 pallets were fitted in the container cross stacked.

2.3 Unit settings

All four 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 pineapple. The test containers were running in CCPC mode.

The reference container settings were:

◊ Supply setpoint	8.0 °C = 46.4 F
◊ Fan setting	High
◊ Vent setting	30 m^3/hr

The CCPC settings were:

◊ Supply setpoint	6.0 °C = 42.8 F
◊ Return Air Pulldown Low Limit	8.0 °C = 46.4 F
◊ Return Air Low Limit	8.0 °C = 46.4 F
◊ Return Air High Limit	9.0 °C = 48.2 F
◊ Fan setting	Alternating
◊ Vent setting	30 m^3/hr

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.

2.4 Voyage schedule

From December 6th to 9th the containers were loaded with pineapples. Subsequently, the containers were taken to the harbour of Guayaquil. The setup is shown in Table 2.

Table 2 Container setup

Container nr	Setup mode	Stuffing date	Commodity
TRLU 1880470	CCPC (test1)	6/12/2006	Pineapple
PONU 4989800	NORMAL (ref1)	8/12/2006	Pineapple
PONU 4831899	CCPC (test2)	7/12/2006	Pineapple
MWCU 6720019	CCPC (test3)	8/12/2006	Pineapple

All containers were loaded to the vessel (Maersk Rosario) on December 11th.

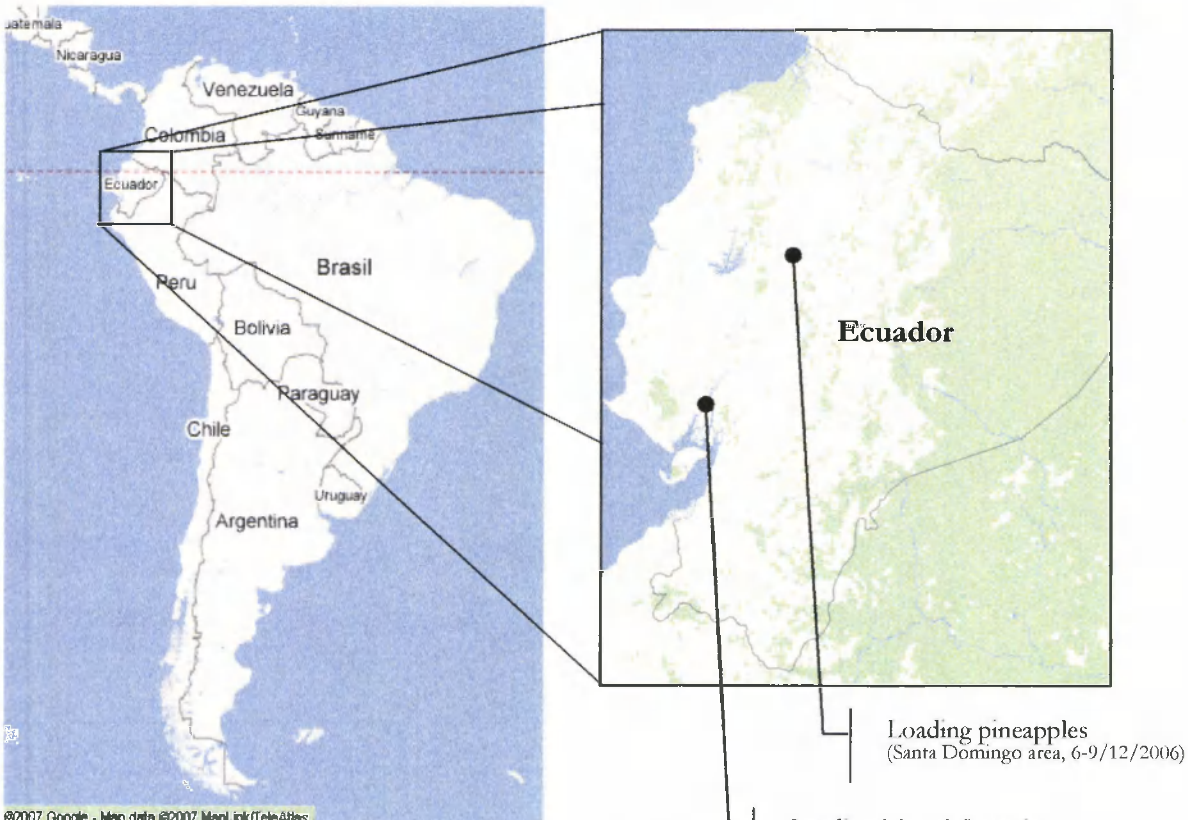

Figure 3 Map of loading and departure locations [1]

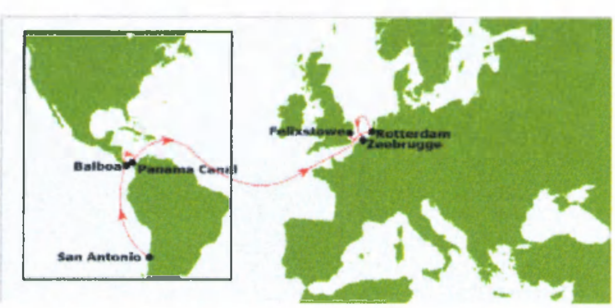

Figure 4 Map of the vessels' route (left Maersk Rosario[a], right Jeppesen Maersk) [2]

The containers arrived in Algeciras (Spain) on December 27th. Figure 7 and Figure 8 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 all units. The CCPC software installed on the containers included additional data logging, storing elaborate unit information every hour. In container test1 and ref1 temperatures were measured by TinyTags inside the cartons.

[a] *Guayaquil to Balboa*

3 Temperatures

Temperature data is available form the units and for test1 and ref1 from sensors placed inside the cartons. Because test1 did not start to cycle until the last day of the trip, a carton temperature comparison for Normal compared to CCPC mode can not be made. Instead, the unit data for test2 and test3 are used.

3.1 Temperature readings during pull down

Pull down was executed in CCPC mode for all test containers. The number of days for the return air to reach the high return air limit and the pull down limit are shown in Table 3. (The test containers start to cycle at reaching this pull down limit.) Container test1 takes a long time to pull down the return air temperature, other containers show relatively comparable values.

Table 3 Pull down times and carton temperatures at Tpdlim (t)

Container	Thlim (°C)	Tpdlim (°C)	Time to Thlim (days)	Time to Tpdlim (days)
Ref1	9	-	2	-
Test1	9	8	21	21
Test2	9	8	2	3
Test3	9	8	2	2

Test1 starts cycling very late, because until the last day of the trip, the return air stays just above the high return air limit. 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

During Quest Regular Mode, the test containers reach the low supply air temperature setpoint. The average supply temperature error during cooling lies between 0.5 and 0.8°C for these units.

When test2 reaches the return air high limit and should start to run at the low supply air setpoint, the unit behaves awkward for a few days. SMV reading is 100%, while it does not reach its setpoint. A number of alarms are given, concerning compressor (high pressure safety, circuit failure), current over limit and sensor failure. The unit starts to function normally when after being handled in Bilboa. After discussing with Carrier, it remains unclear what caused the unit to malfunction, it may have been the result of a software bug.

3.3 Return air readings during Quest Regular Mode

The return air flows of test2 and test3 have an average temperature of 8.5°C. This is the same as in the reference container. Test1, which is not cycling for most of the trip and therefore acts as if it were a reference container, has a higher mean return air temperature, namely 9.3°C.

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 5. Time axis is such that t = 0 starts at December 5th 2006 16:00.

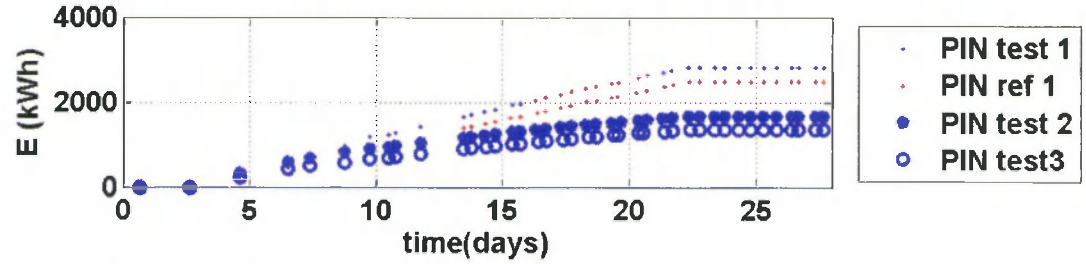

Figure 5 Energy readings as a function of time for the three container sets

On board the Jeppesen, test3 was running with a water cooled condenser, while the others had air cooling of the condenser, see Table 4. Also, test3 was stored on deck instead of in the cargo hold. This can also affects the power consumption of the reefers. The simultaneously shipped banana containers showed a 1 kW higher power consumption for air cooled instead of water cooled condensers.

Table 4 Type of condenser cooling of the reefers and ventilation setting at unloading

Container	Condenser cooling	Location	Mean Power (kW)
ref1	air cooled condenser	Deck	5.3
test1	air cooled condenser	Deck	6.0
test2	air cooled condenser	Deck	3.5
test3	water cooled condenser	Cargo Hold	2.9

The reference container (ref1) used 2493 kWh in 474 hour, a mean power usage of 5.3 kW.

The test containers (test1, test2 and test3) used 2822, 1676 and 1367 kWh in 473, 473 and 474 h, a mean power usage of 6.0, 3.5 and 2.9 kW, which is 13% more, 33% less and 45% less compared to the reference containers. Note that test1 did not cycle for most of the trip and test3's 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: 33 %. 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 6. Power savings during cycling are approximately 55%.

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 19 through Figure 25 in the appendix. (For comparison, also the active hours and defrost time of the units are shown.) Test1 only starts cycling during the last day of the trip. The compressor off time intervals then last about 2 hours, approximately 3 times as long as the compressor-on time interval. Compressor off time intervals for test2 last approximately 20 - 60 minutes, about 1.3 - 4 times as long as the compressor-on time intervals. Compressor off time intervals for test3 last approximately 30 - 100 minutes, about 1.5 - 5 times as long as the compressor-on time intervals. The compressor off periods become shorter when ambient temperature is higher. Compressor on time periods remain the same.

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 for test1 and test2 is AUTO[b], leaving the unit to learn from its measurement data how often a defrost action is necessary. As test1 is not cycling for most of the trip, it serves as a sort of reference unit defrosting about once a day, whereas defrost period of the test2 container increases to about once every 3 days. The defrost actions take approximately 16 minutes and 0.5 kWh), see Table 6 in the appendix. 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 1/2 to 1/3rd).

[b] *For ref1, defrost information is limited, because of the standard software version used. Test3 was set to a fixed defrost interval for most of the trip.*

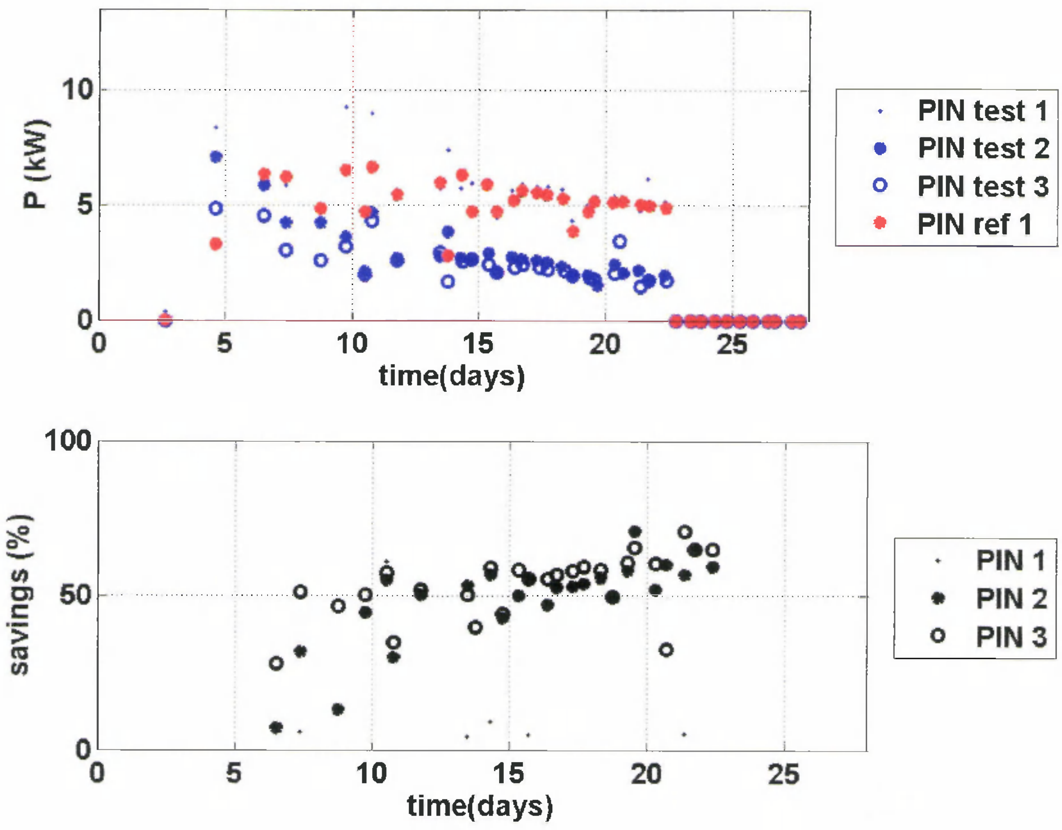

Figure 6 Power and savings as a function of time

5 Conclusions

5.1 Power savings

Taking into account the differences in condenser cooling and the fact that test1 did not cycle for most of the trip, the best estimation for the savings is 33%, i.e. test2 compared to ref1. This includes the pull down phase during which the unit is not cycling yet. Power savings during cycling are approximately 55%.

5.2 Temperatures

The test containers reach the low supply air temperature setpoint during cycling. The average supply temperature error during cooling lies between 0.5 and 0.8°C for test2 and test3. The return air temperatures of test2 and test3 are comparable to those of ref1.

Test1 starts cycling very late, because, until the last day of the trip, the return air stays just above the high return air limit. 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).

The test2 unit behaves awkward for a few days. The SMV reading is 100%, while it does not reach its setpoint. A number of alarms are given. The unit starts to function normally when after being handled in Bilboa. After discussing with Carrier, it remains unclear what caused the unit to malfunction.

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 Spain

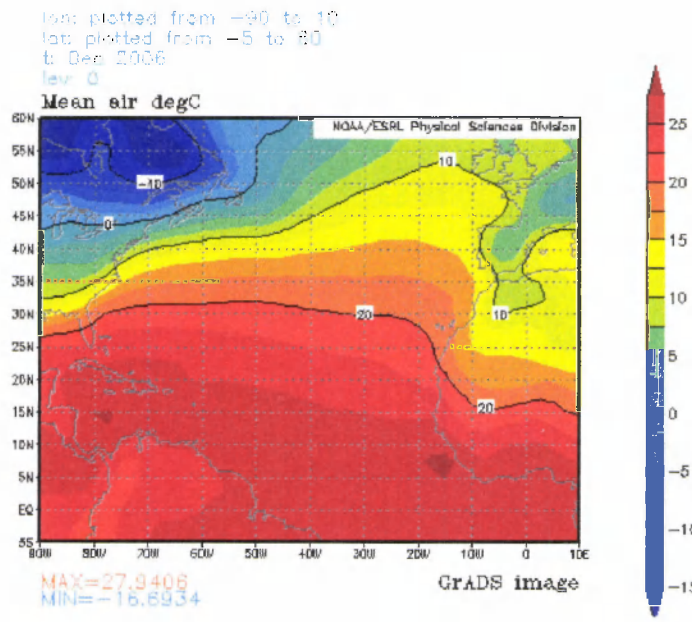

Figure 7 Mean December temperature between Ecuador and Spain [3]

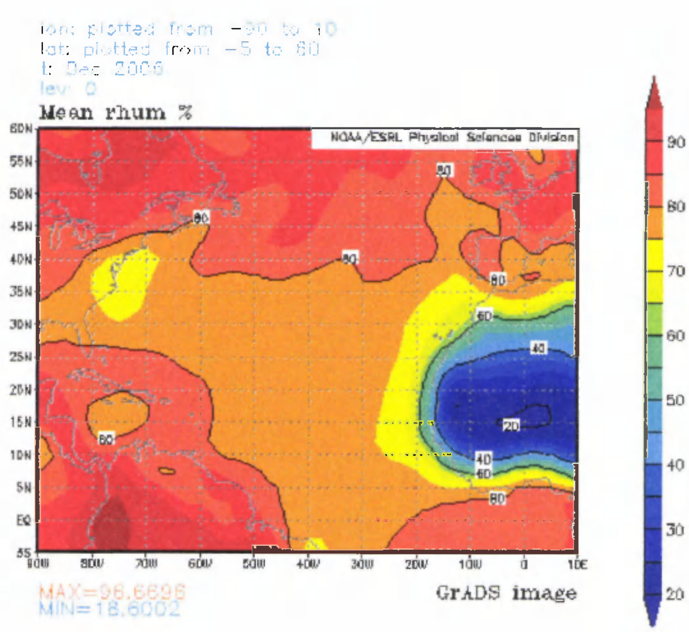

Figure 8 Mean December relative humidity between Ecuador and Spain [3]

Appendix II: Unloading and dcx file information

Table 5 Unloading and dcx temperature information

Container	usda	ret	Sup	superror
Ref1	Not available	To 9.3 in 1.5 days, 8.7 in 3 days to 8.5 final	8.1	NA
Test1	8.3 – 9.5 deg C, final hours: 7.3 to 8.1 (usda1) 8.0 to 9.1 deg C (usda2-4)	Mostly 9.1 to 9.6, final hours:7.9 to 9.0	Mostly 8.0, min 7.8, final hours: 5.8 to 8.9	0.1 deg C, Final hours: 0.1 to 0.6 deg C
Test2	None	First part: 8.0 to 9.6 deg C Second part: 8.0/8.5/9.0: ok	First part: 7.1 to 9.1 deg C, does not reach setpoint, although long cooling periods Second part: 6.0/8.5 to 8.0/9.3 degC	First part: 0.4 to 2.4 deg C, second part: 0.8 to 1.0 deg
Test3	Only usda1, mostly 8.4 deg C, 7.8 to 9.1	8.0/8.5/9.0: ok	5.7/8.2/9.2: ok	Mostly 0.6 deg C, -0.1 to 2.3 deg C

Table 6 DCX information, containers ref1, test1, test2 and test3

Container	Alarms from dcx files	cool limit max (Kmin)	clm trigger	Smv	deice	heat	dehum	cool period	non-cool period
Ref1	none	-	-	NA	Not available (NA)	(NA)	(NA)	-	-
Test1	None	160	none	4/7/26	0.5 kWh for 16 mins, total 13.9 kWh, freq down to once a day (auto)	no	no	60	130, only final hours of trip
Test2	32, 44, 49, 57- 59, 60-69, 71	First part: 60 to 320, second part: 20	none	100 -> 17	0.5 kWh for 16 mins, to 12 mins, total 5.5 kWh, freq down to once every 3 days (auto)	no	no	First part: 100 to 500 mins Second part: 14 mins	First part:50 to 100 mins Second part: 40 -> 20 -> 60 mins
Test3	none	Mostly 40, max 220	none	6/19/27	0.5 kWh for 17 mins, total 8.6 kWh, freq down to once a day (defrost interval 6, auto from 21/12)	no	no	Mostly 23 mins	60 to 100 mins

Appendix IV: Unit temperature readings as a function of time

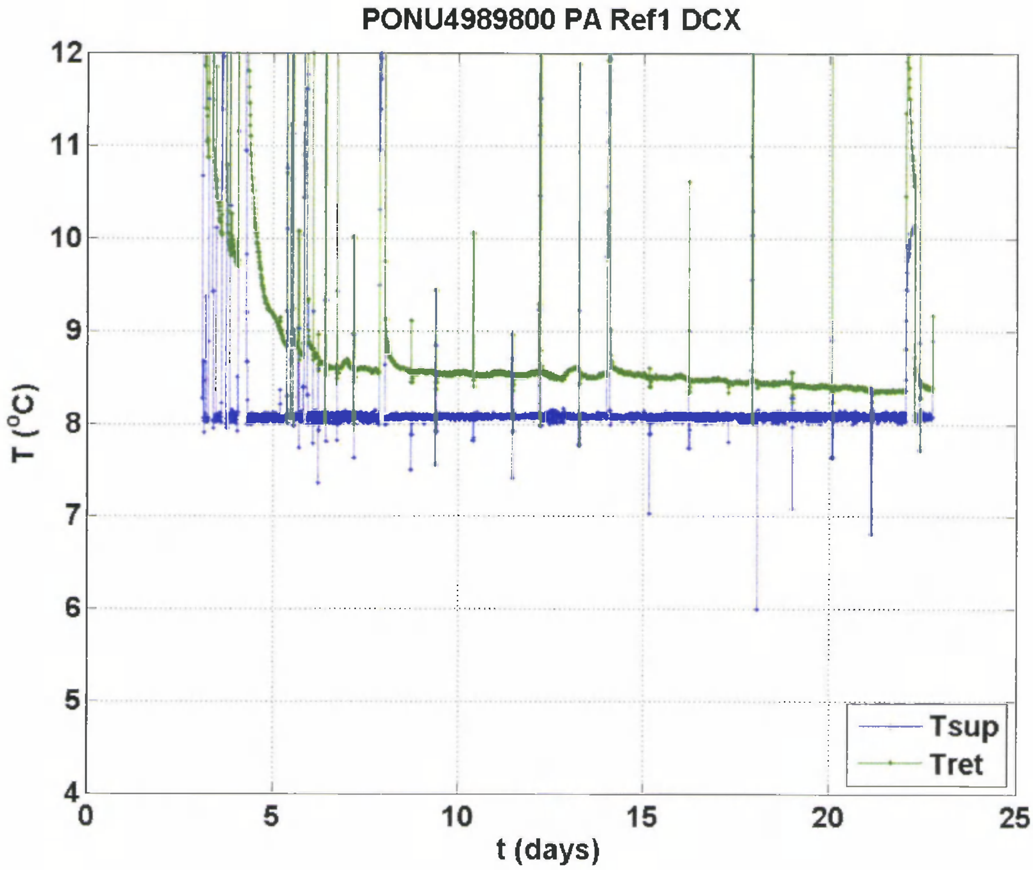

Figure 9 Temperature readings from the unit for ref1, 15 minute snapshot

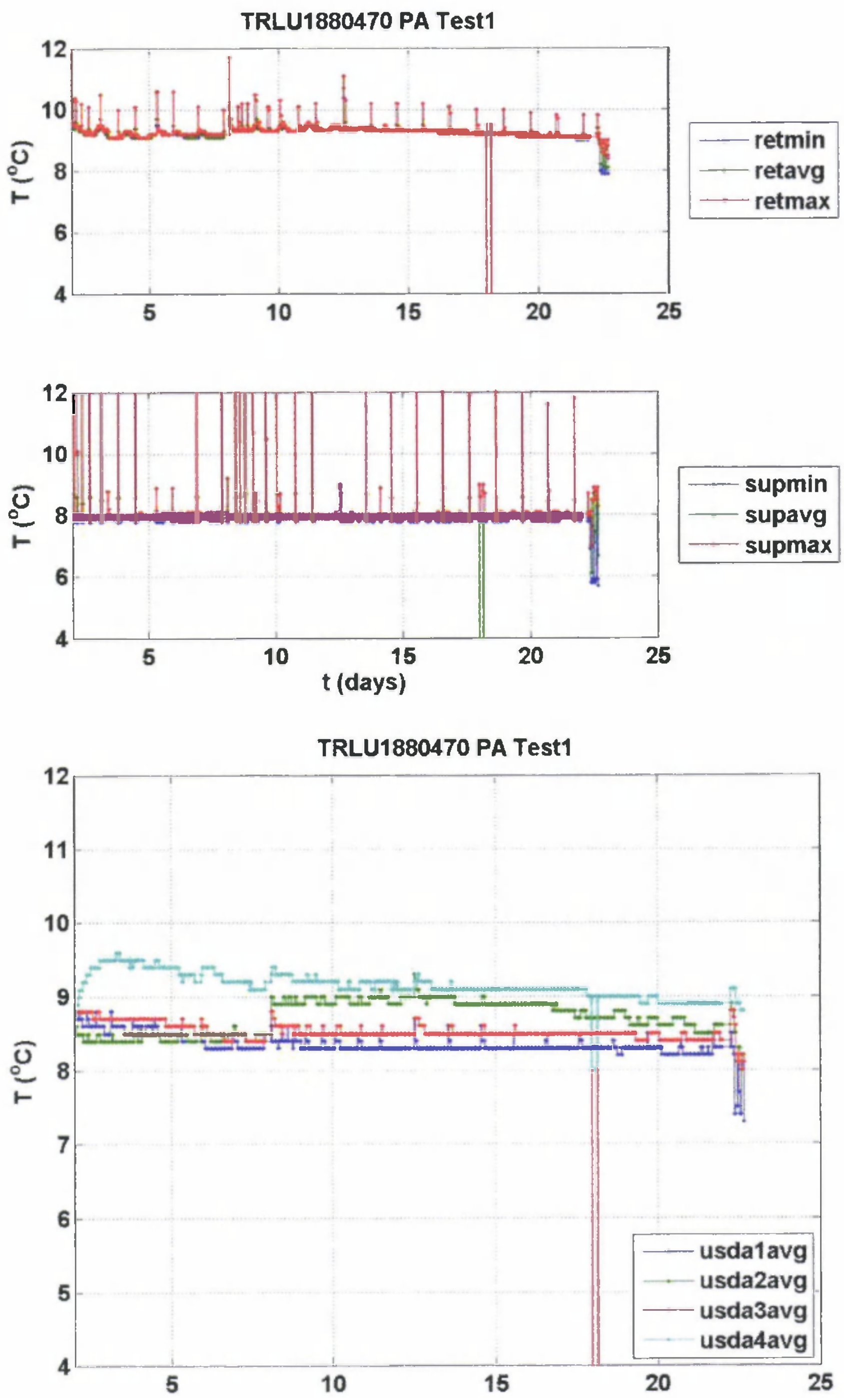

Figure 10 Temperature readings from the unit for test1

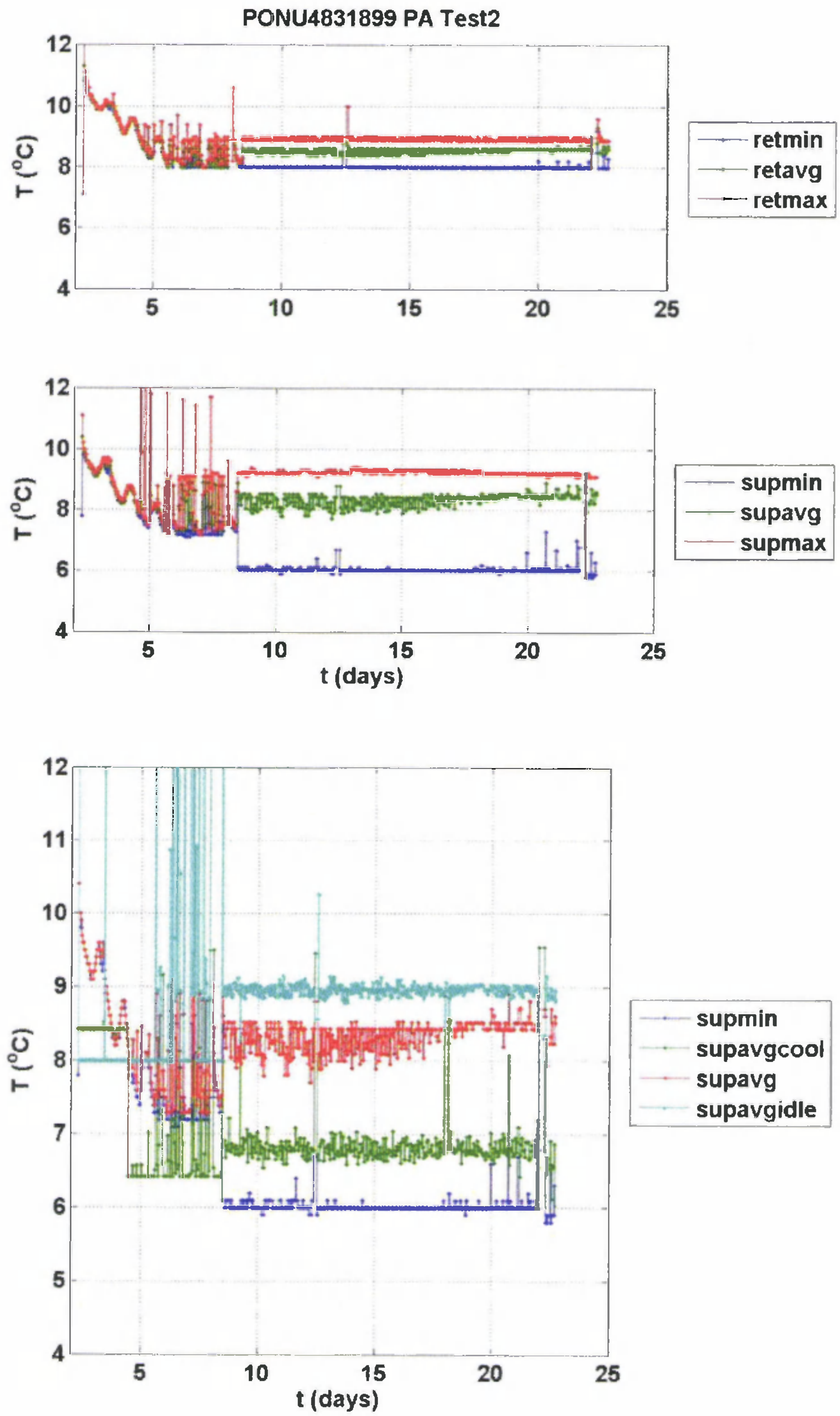

Figure 11 Temperature readings from the unit for test2

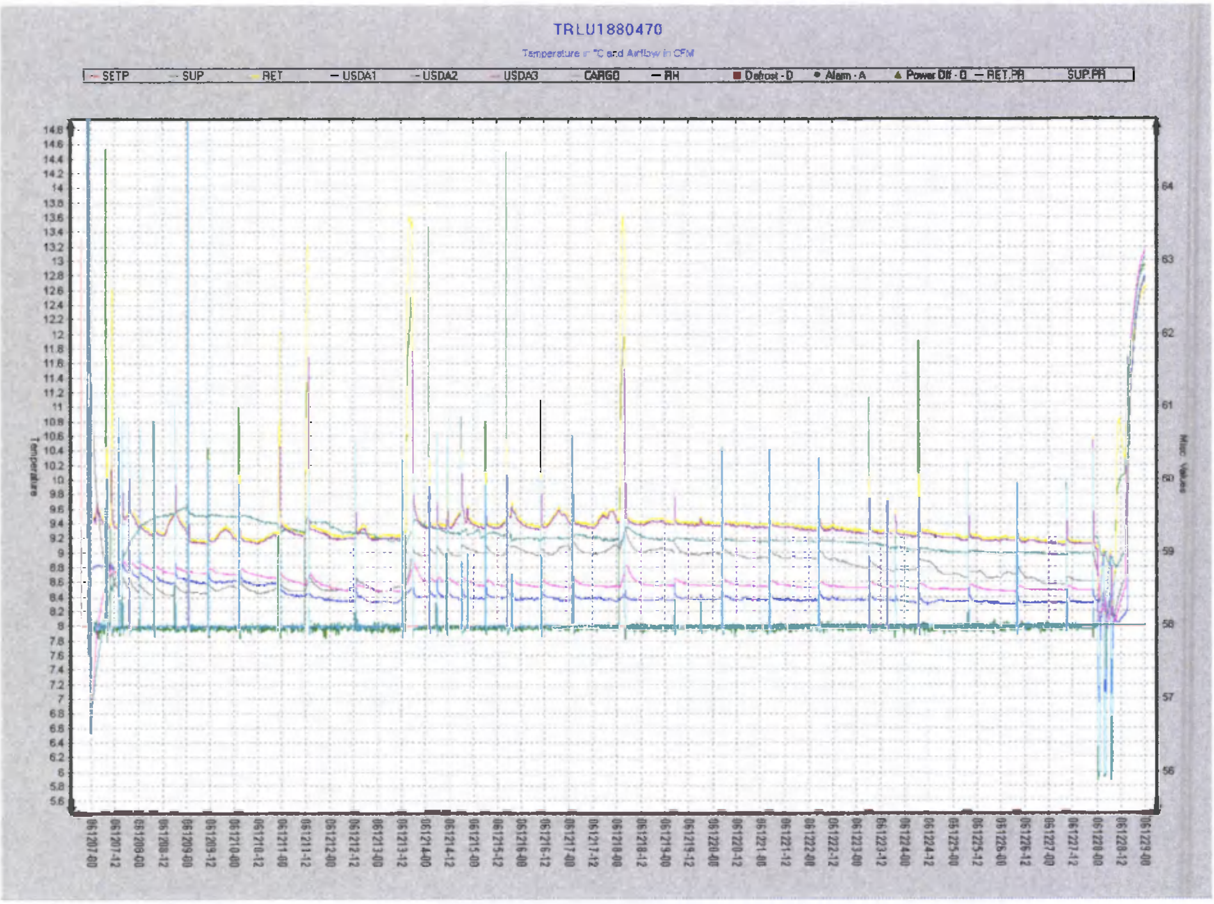

Figure 12 Temperature readings from the unit for test1, 15 minute interval data

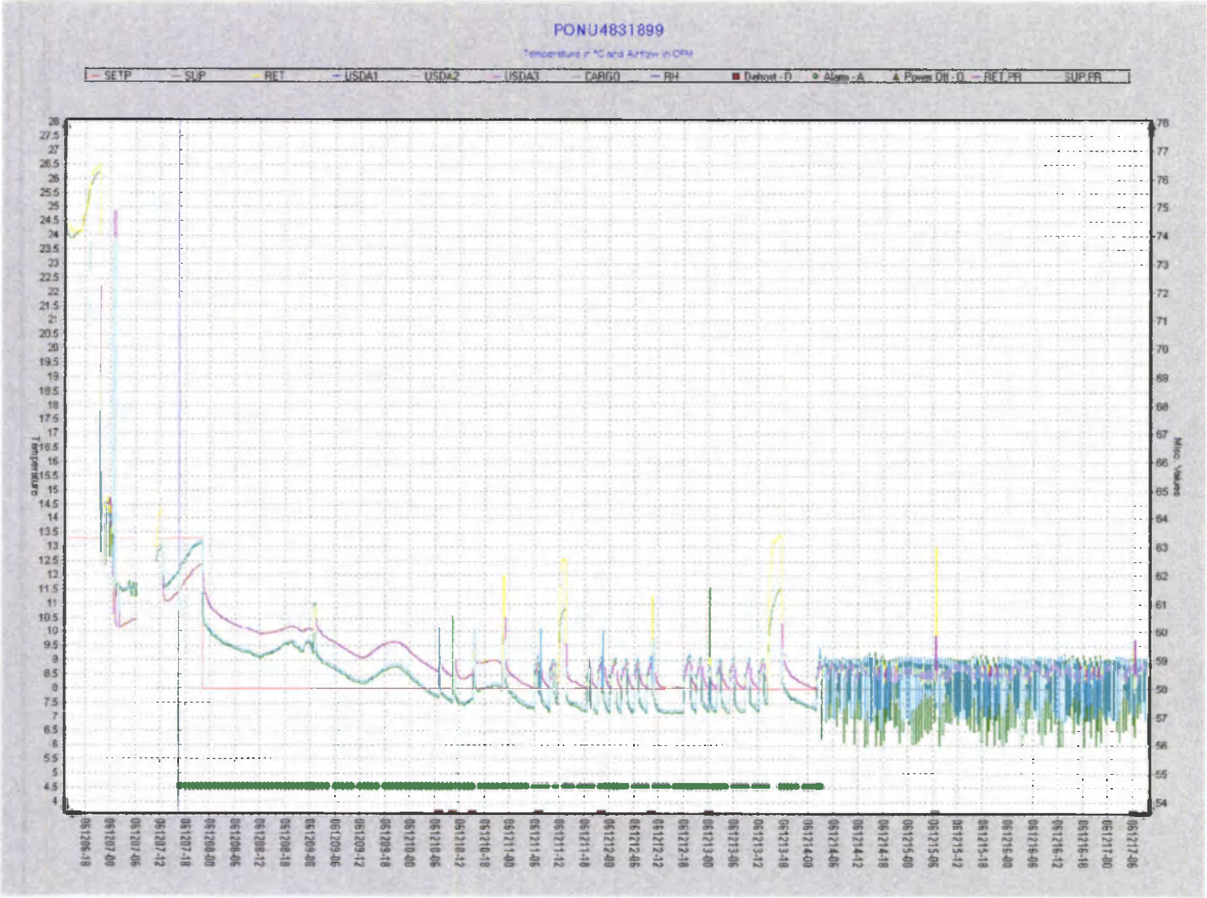

Figure 13 Temperature readings from the unit for test2, 15 minute interval data

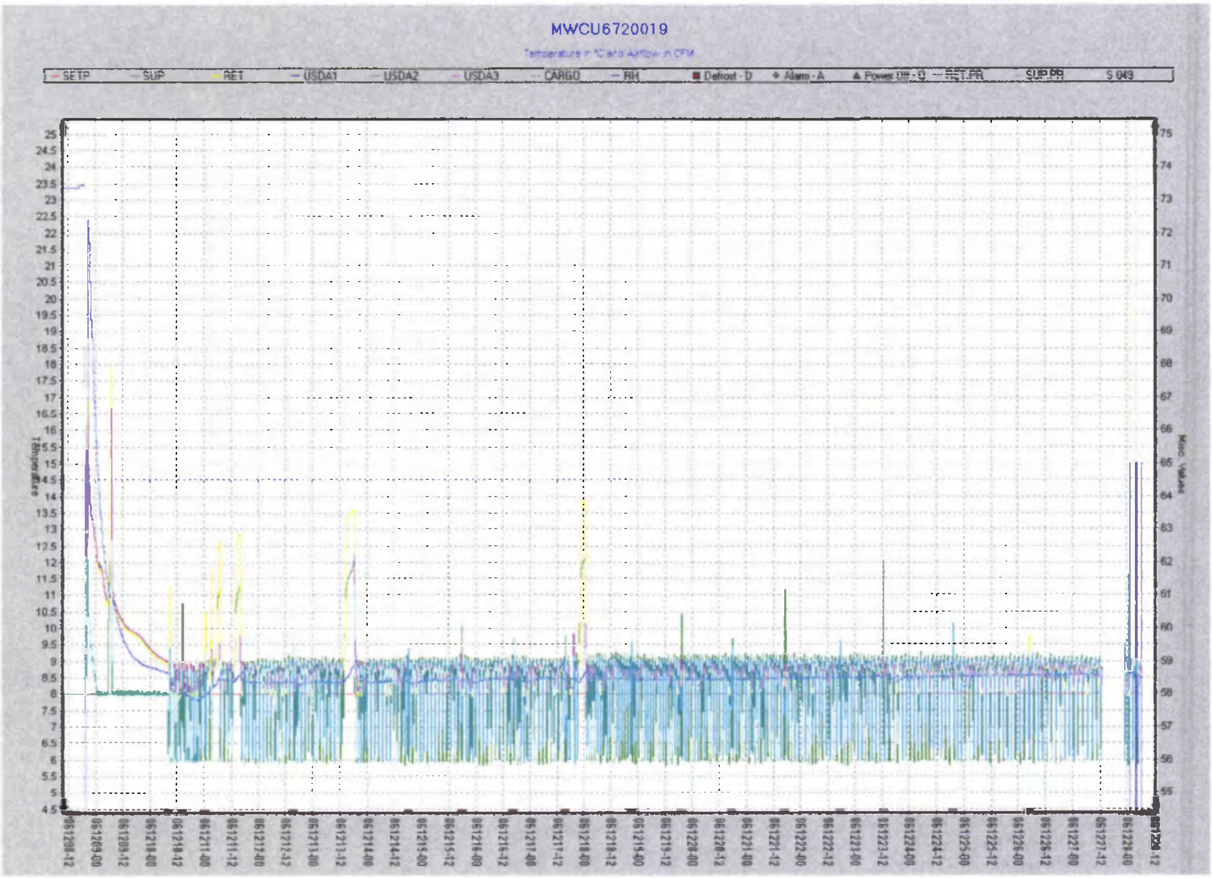

Figure 14 Temperature readings from the unit for test3, 15 minute interval data

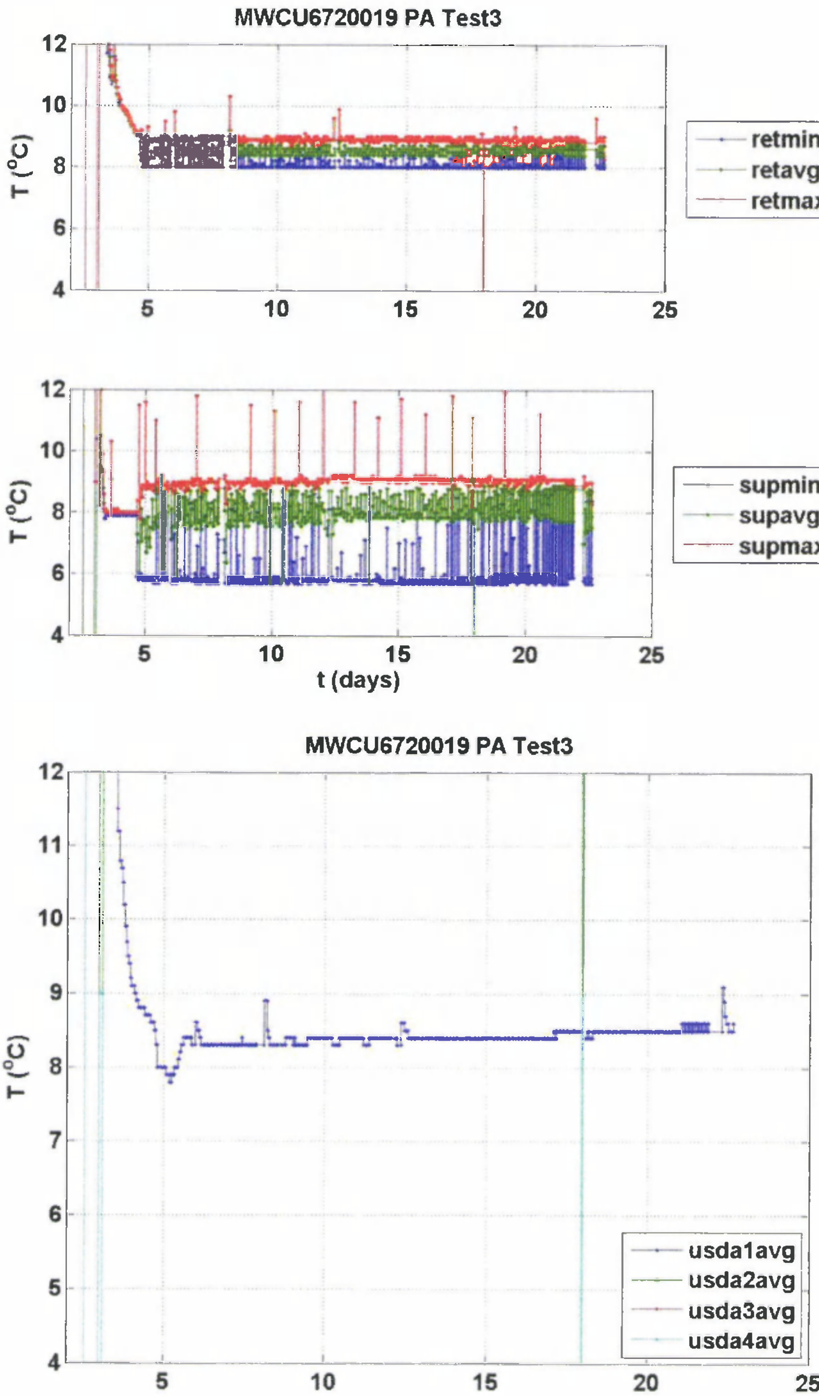

Figure 15 Temperature readings from the unit for test3

Appendix VI: Ambient temperatures

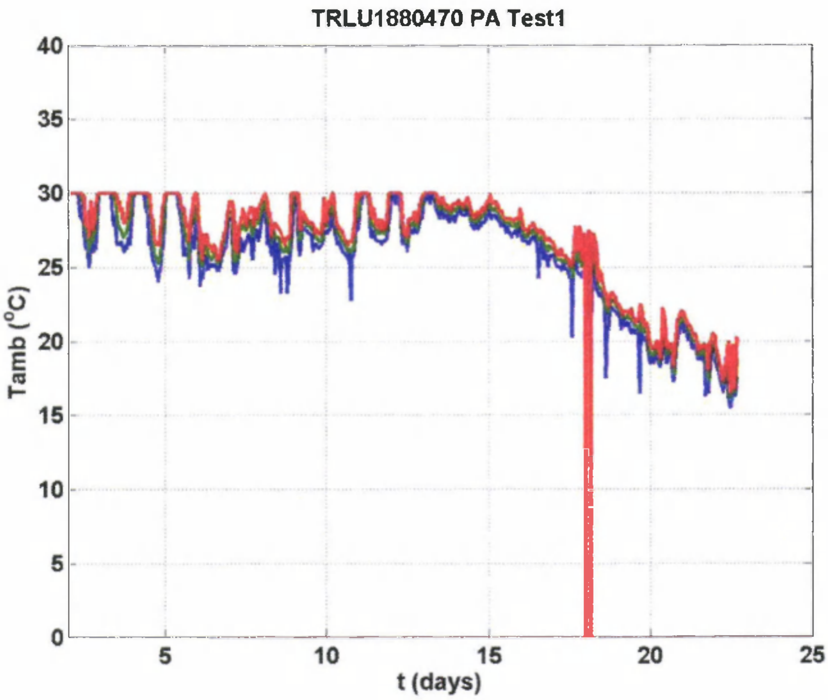

Figure 16 Ambient temperature readings from the unit of test1

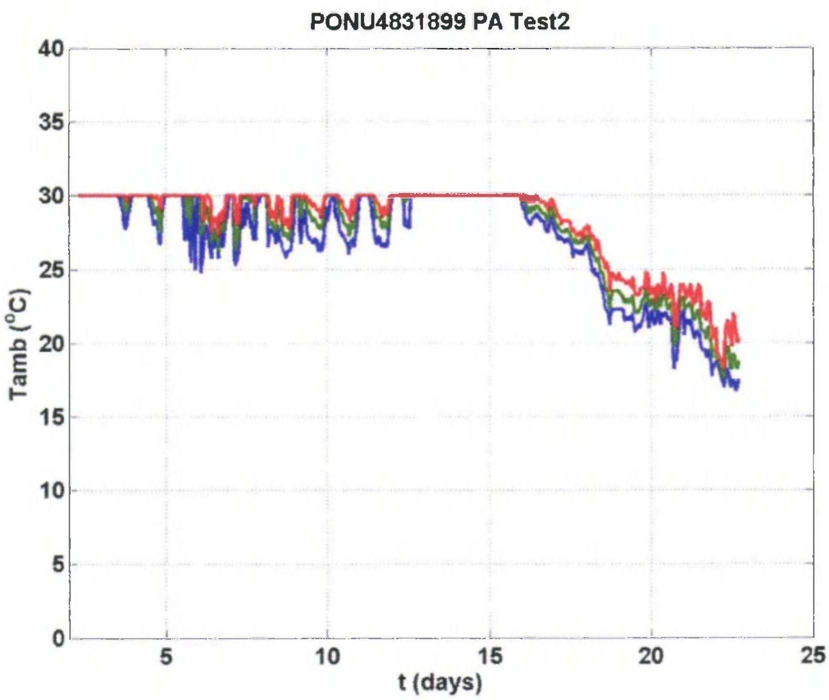

Figure 17 Ambient temperature readings from the unit of test2

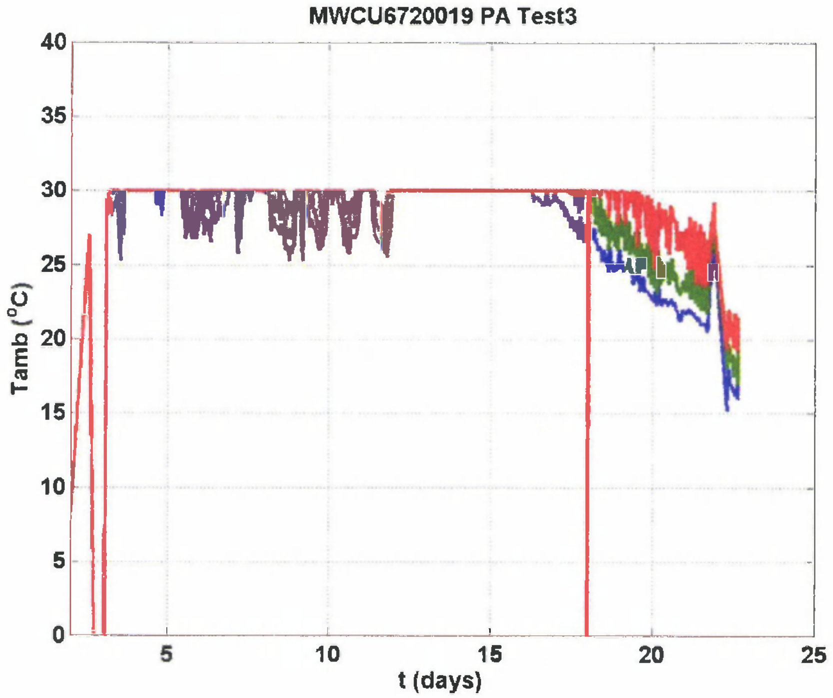

Figure 18 Ambient temperature readings from the unit of container test3

Appendix VII: Unit activity graphs

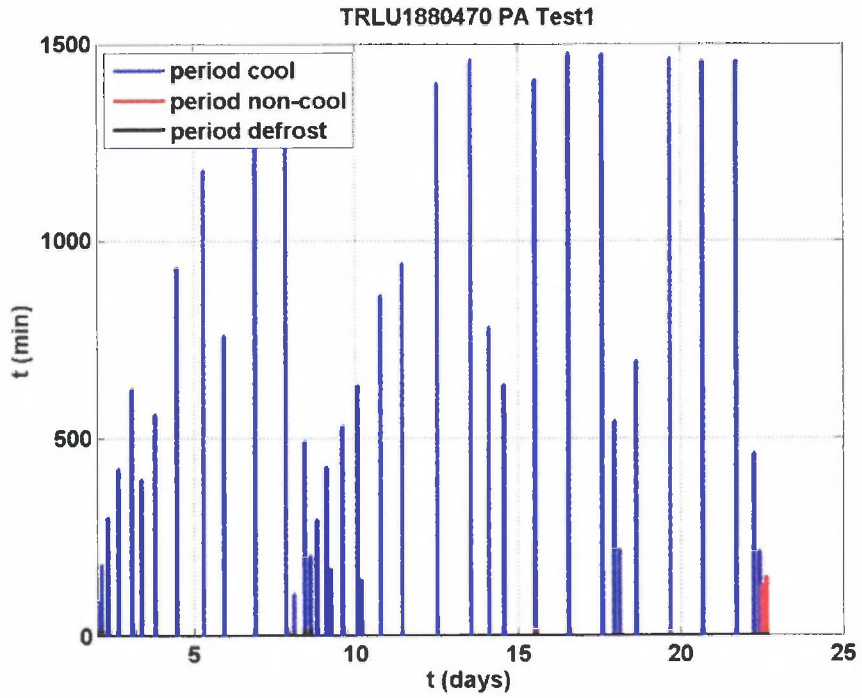

Figure 19 The number of minutes per cooling, non-cooling and defrost period as a function of time for test1. At each time instant during the voyage when a period is finished a bar is drawn with the number of minutes that that period has lasted. If the period is smaller then an hour, the bars turn into a line.

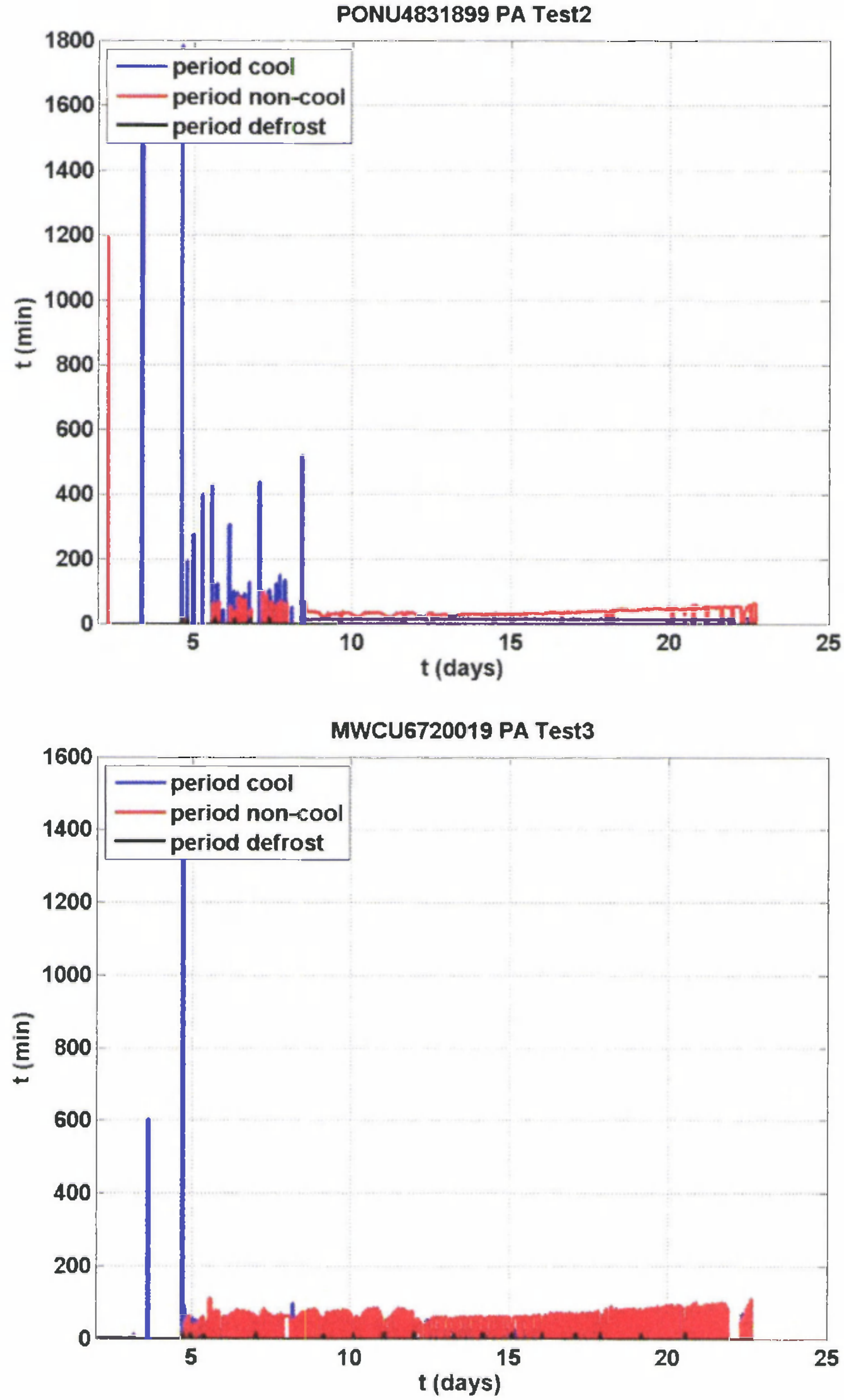

Figure 20 The number of minutes per cooling, non-cooling and defrost period as a function of time for the test2 and test3 containers. At each time instant during the voyage when a period is finished a bar is drawn with the number of minutes that that period has lasted. If the period is smaller then an hour, the bars turn into a line.

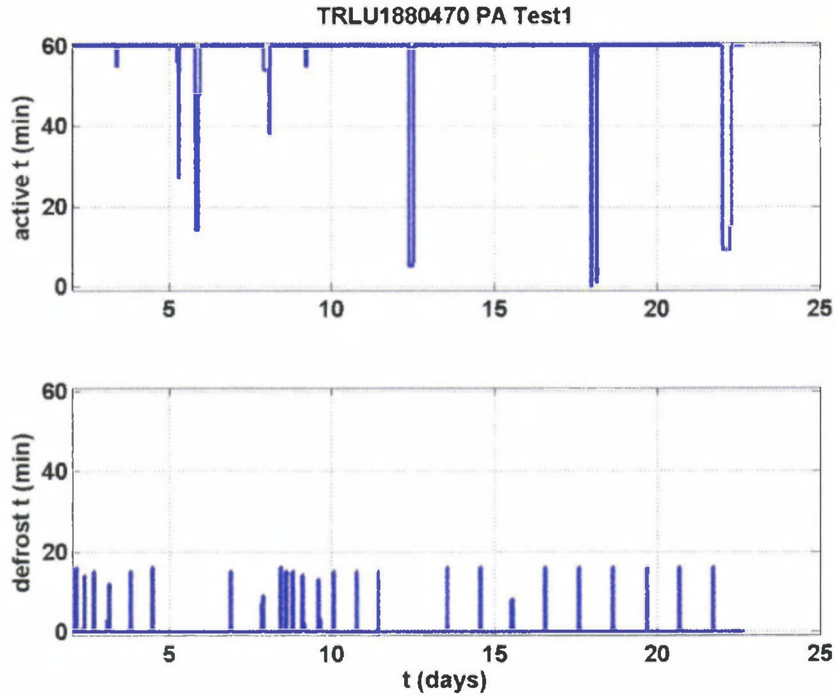

Figure 21 The number of minutes activity and defrosting as a function of time for test1. Every hour of the trip the number of minutes that was used for defrost was recorded. The number of minutes the unit was active was recorded as well, which is mostly 60 min/hour but sometimes less.

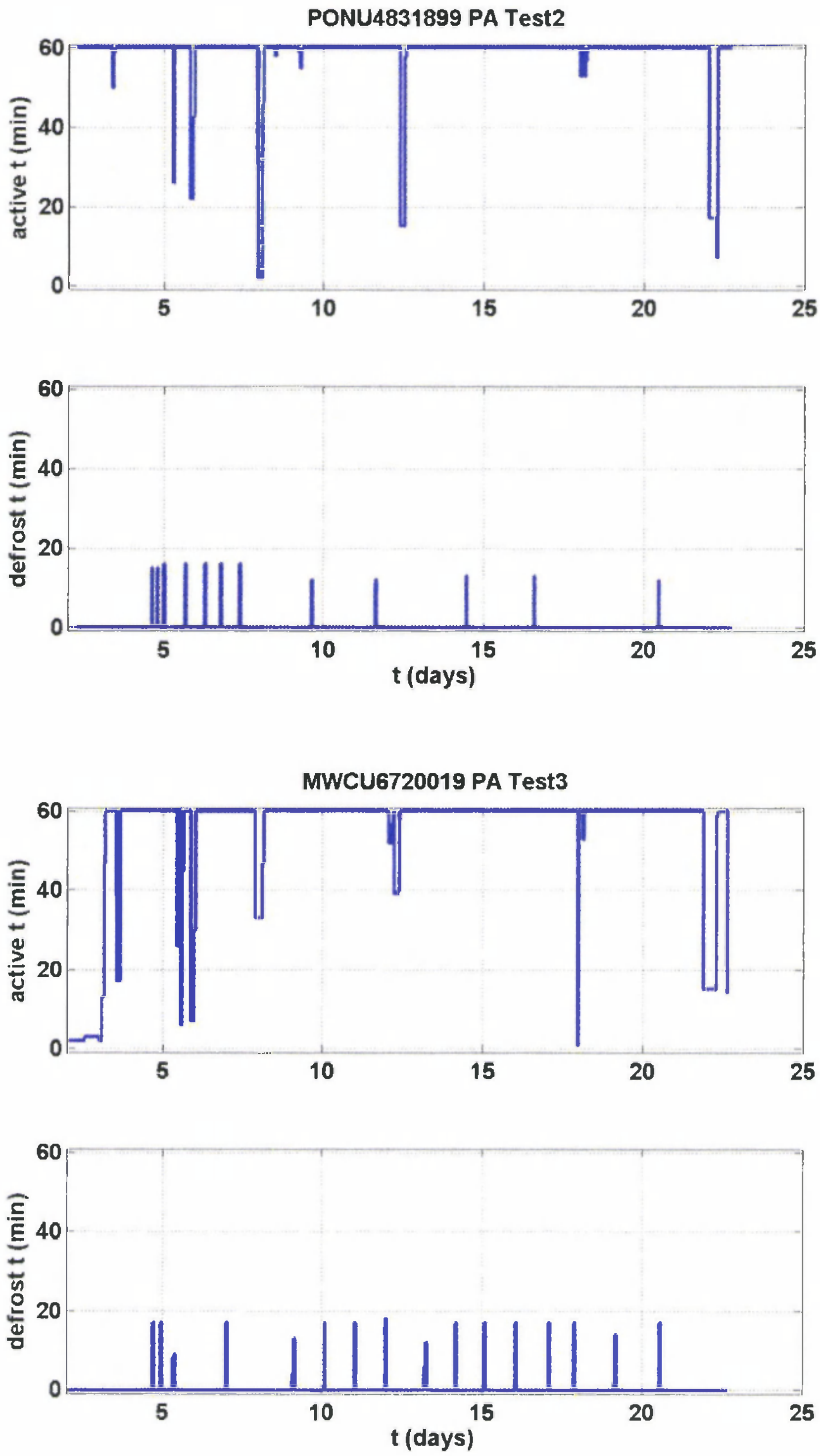

Figure 22 The number of minutes activity and defrosting as a function of time test2 and test3. Every hour of the trip the number of minutes that was used for defrost was recorded. The number of minutes the unit was active was recorded as well, which is mostly 60 min/hour but sometimes less.

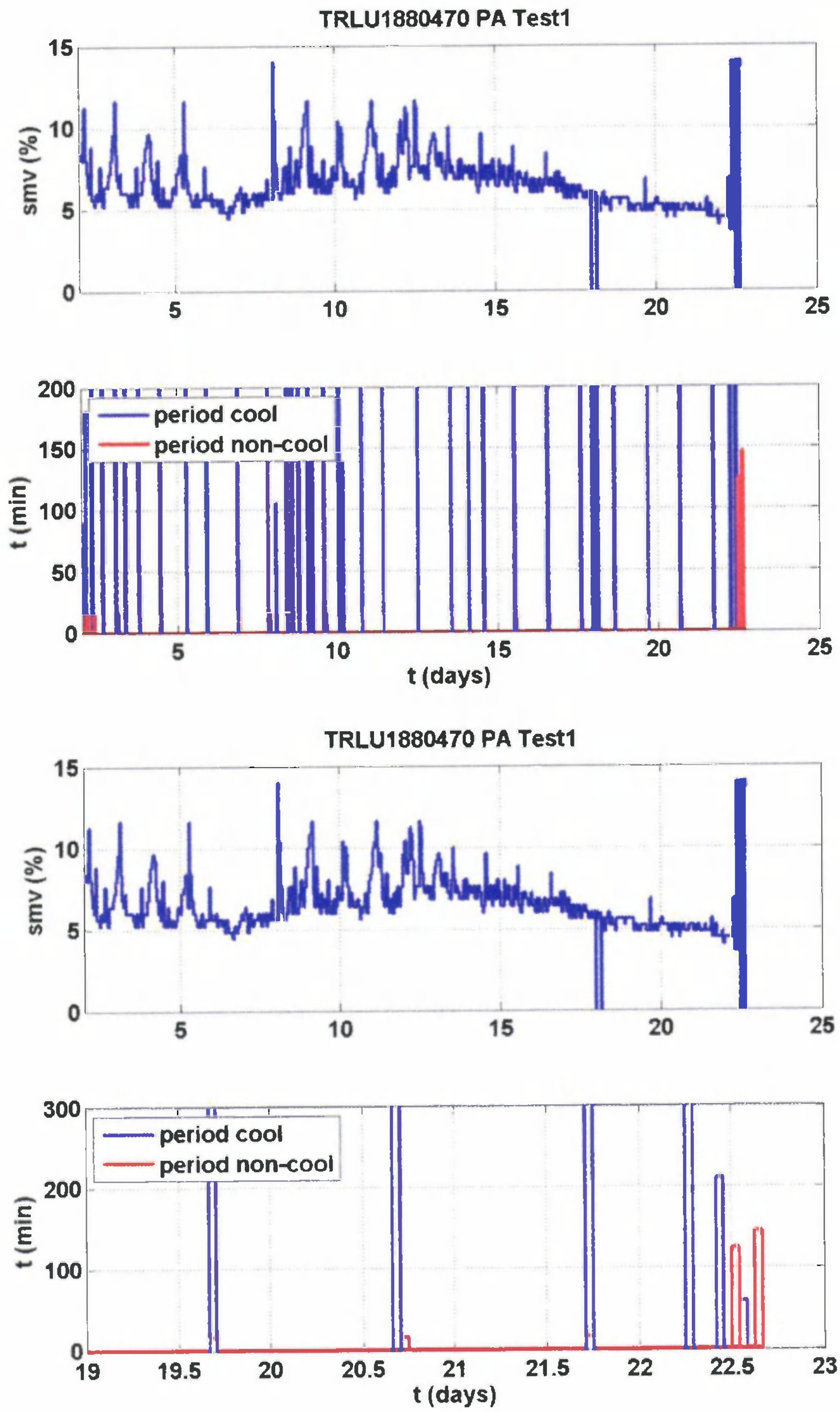

Figure 23 The smv opening (suction modulation valve) and number of minutes of cooling and non-cooling as a function of time for test1. Note that test1 was not cycling until the very last few hours of the trip.

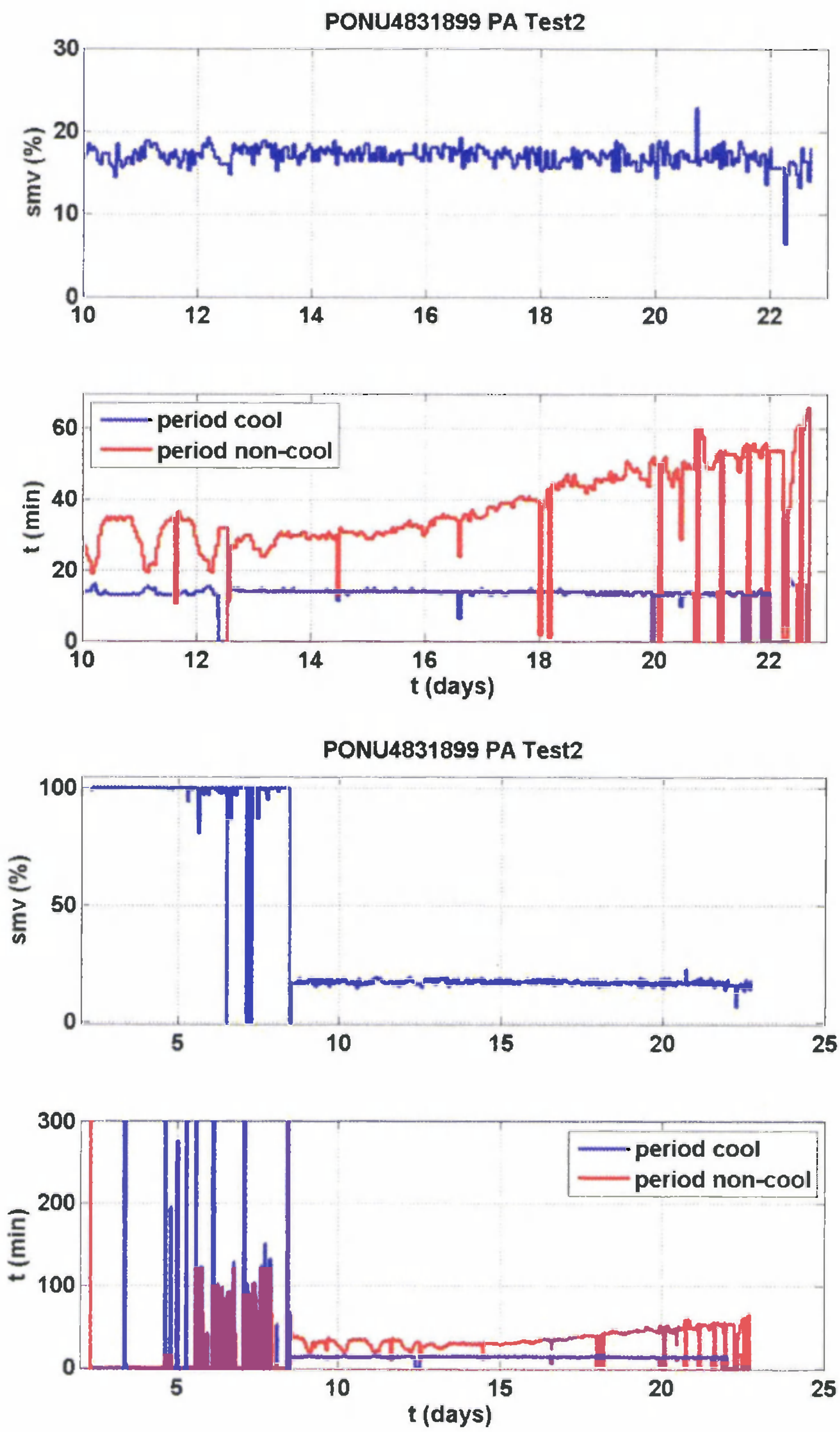

Figure 24 The smv (suction modulation valve) opening and number of minutes of cooling and non-cooling as a function of time for test2.

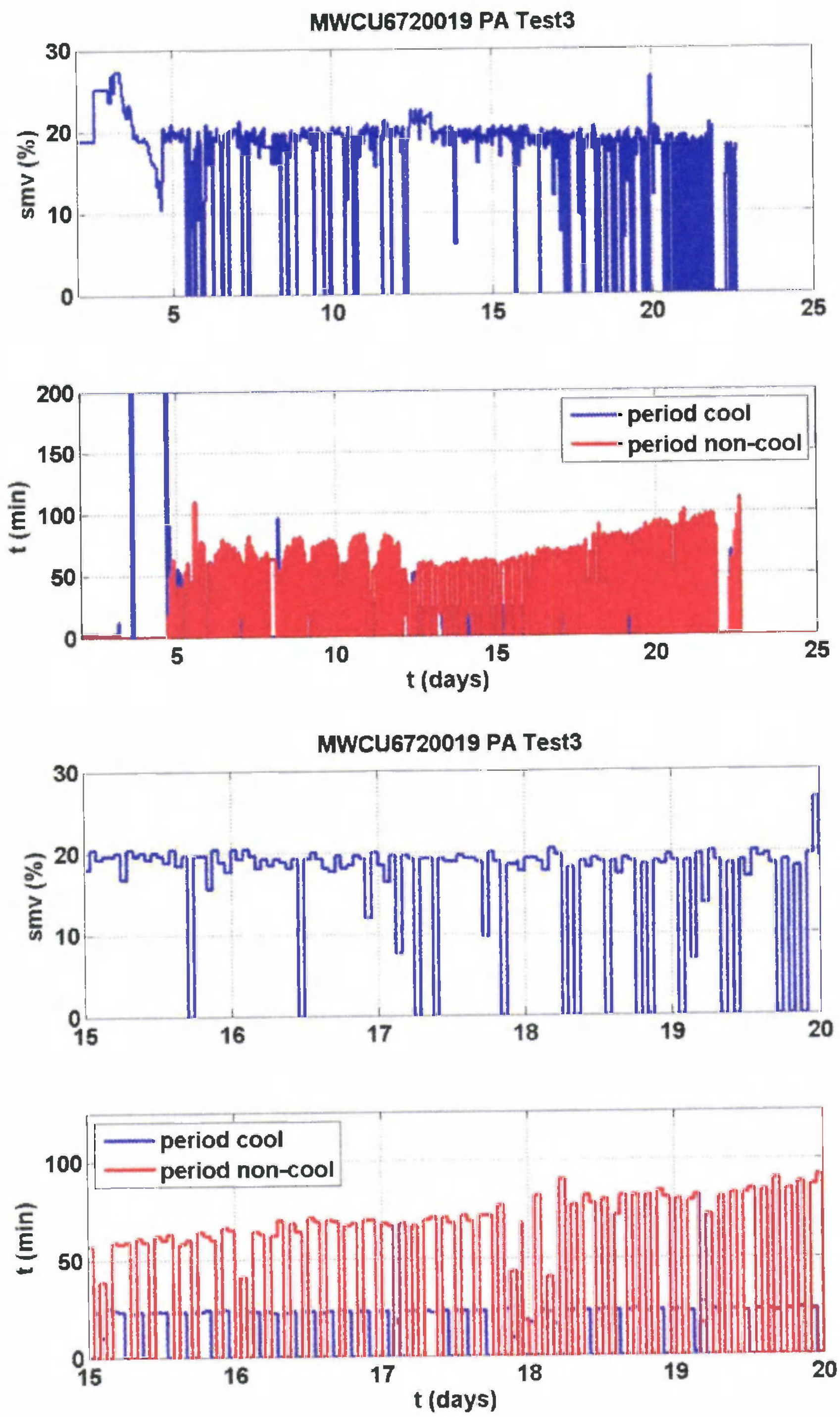

Figure 25 The smv (suction modulation valve) opening and number of minutes of cooling and non-cooling as a function of time for test3.

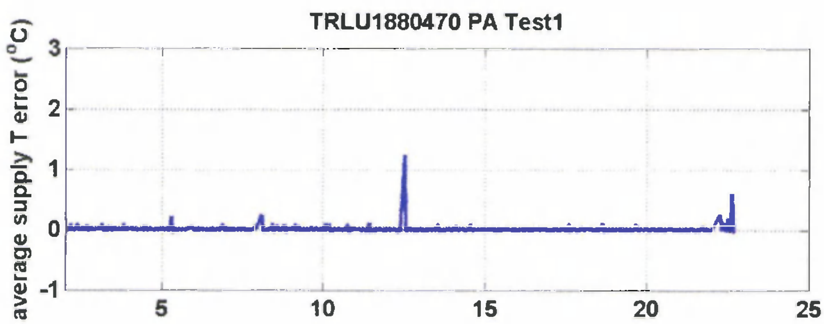

Figure 26 Supply air temperature error for test1

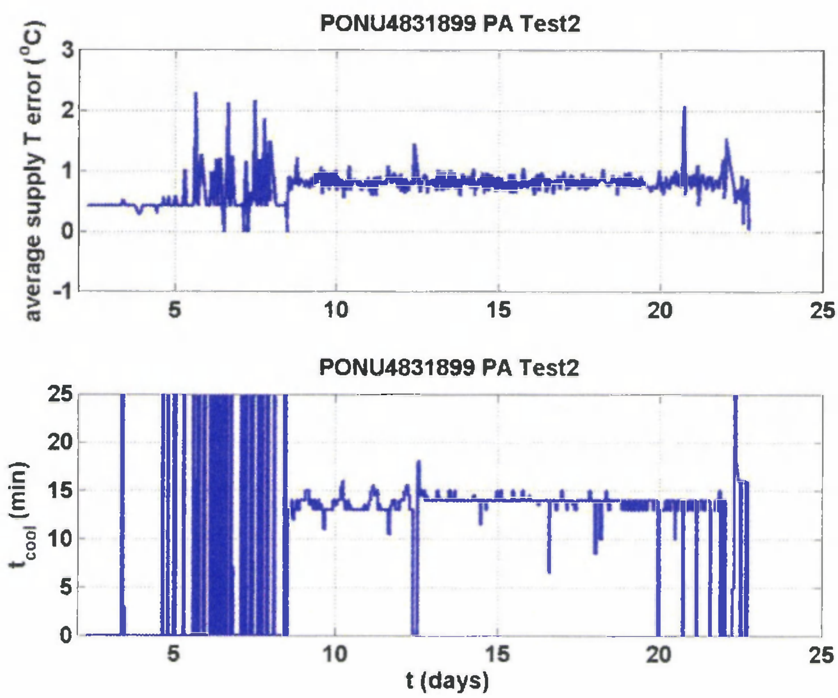

Figure 27 Supply air temperature error and cooling period lengths for test2

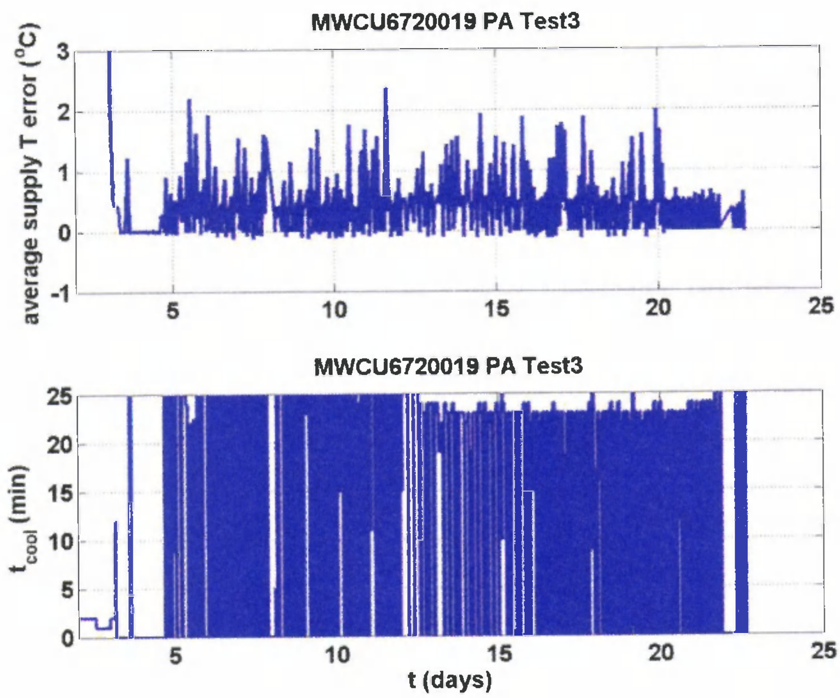

Figure 28 Supply air temperature error and cooling period lengths for test3