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ULT FREEZER RACKING STUDY – PART II

IMPACT OF DIFFERENT METALS USED FOR ULT RACKING UPON PERFORMANCE, UNIVERSITY OF OXFORD

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INTRODUCTION

Ultra Low Temperature (ULT) freezers are a predominantly used in life sciences for the long term storage of valuable samples and products. The use of racking can vary between organizations with some ULT freezers being completely racked (figure 1) whilst others are devoid of any racking whatsoever. Racking can be made of aluminium or stainless steel. This study completes the case study from October 2018 by repeating the procedure using the same conditions, location and freezer unit, this time using stainless steel racking. This study now compares the impact of different types of metal racking upon the temperature and energy performance of a ULT freezer at the -80C set point.

Figure 1. ULT freezer fully racked with temperature loggers in place.

TESTING THE IMPACT OF RACKING

The data was collected over a three week period at the Department of Plant Sciences, University of Oxford. The Eppendorf ULT freezer (F570h) tested was supplied for the study by Scientific Laboratory

Supplies Ltd and the racking was supplied by Wesbart UK Ltd. The racking was in the format of front opening outers designed to house standard cryoboxes. The total weight of the aluminium racking used was 90kg, the total weight of the steel racking used was 145kg. The unit was tested in an air conditioned laboratory where the ambient temperature was recorded at 19C (+/-1C). The ULT freezer had a temperature logger placed at the centre point of each of its shelf, with a further two loggers placed at the centre front and centre back points of the centre shelf (Compartment 3). This temperature logger recorded the internal temperature every minute, accurate to 0.1C. The temperature loggers used were MadgeTech Cryotemp Data Loggers, supplied by Wessex Power. Compartments were numbered in descending order meaning that the top compartment was labelled as compartment 1 and the bottom compartment is compartment 5. The energy monitors used had a kWh reading variance of +/- 1%. The ULT freezer was subjected to a number of tests. The tests measuring temperature and energy performance at the -80C set point without any door openings are summarized in Figure 1. Please note that a different method has been employed to measure pull down times. In this case study, the pull down time has been calculated for **each freezer compartment**. The pull down time is measured as when the compartment reaches its **exact** average temperature at the -80C set point (measured over a 24 hour period), meaning it was measured to the tenth of a degree Celsius. Most existing methods of measuring pull down times are not measured so precisely, relying on a single probe in many cases.

Measurement	Empty F570h ULT Freezer	Aluminium Racked F570h ULT Freezer	Steel Racked F570h ULT Freezer
Energy Consumption	7.57 kWh	7.20 kWh	7.77 kWh
Compartment 1 Average Temperature (Pull Down Time)	-78.6C (5 Hours 24 Minutes)	-78.9C (9 Hours 31 Minutes)	-76.7C (9 Hours 29 Minutes)
Compartment 2 Average Temperature (Pull Down Time)	-79.9C (6 Hours 38 Minutes)	-79.3C (12 Hours 31 Minutes)	-78.6C (10 Hours 29 Minutes)
Compartment 3 Back Avg. Temperature (Pull Down Time)	-81.5C (3 Hours 34 Minutes)	-80.5C (13 Hours 19 Minutes)	-79.3C (20 Hours 59 Minutes)
Compartment 3 Middle Avg. Temperature (Pull Down Time)	-80.2C (4 Hours 57 Minutes)	-79.4C (15 Hours 32 Minutes)	-78.9C (20 Hours 59 Minutes)
Compartment 3 Front Avg.Temperature (Pull Down Time)	-80.4C (4 Hours 36 Minutes)	-79.5C (18 Hours)	-78.6C (19 Hours 27 Minutes)
Compartment 4 Average Temperature (Pull Down Time)	-79.2C (3 Hours 44 Minutes)	-79.2C (15 Hours 12 Minutes)	-77.9C (17 Hours 59 Minutes)
Compartment 5 Average Temperature (Pull Down Time)	-76.7C (3 Hours 39 Minutes)	-77.4C (19 Hours 43 Minutes)	-75.3C (7 Hours 28 Minutes)
Compartment 1 Warm Up Time To -50C	4 Hours 19 Minutes	8 Hours 44 Minutes	8 Hours 11 Minutes
Compartment 2 Warm Up Time To -50C	5 Hours 12 Minutes	11 Hours 4 Minutes	11 Hours 1 Minute
Compartment 3 Back Warm Up Time To -50C	5 Hours 55 Minutes	13 Hours 11 Minutes	13 Hours 8 Minutes
Compartment 3 Middle Warm Up Time To -50C	5 Hours 54 Minutes	13 Hours 5 Minutes	13 Hours 30 Minutes
Compartment 3 Front Warm Up Time To -50C	5 Hours 49 Minutes	13 Hours 2 Minutes	13 Hours 15 Minutes
Compartment 4 Warm Up Time To -50C	6 Hours 10 Minutes	14 Hours 23 Minutes	14 Hours 36 Minutes
Compartment 5 Warm Up Time To -50C	6 Hours 10 Minutes	14 Hours 24 Minutes	14 Hours 24 Minutes

Figure 2. ULT Temperature and energy performance at -80C set point, empty and racked.

A number of timed door openings were also carried out. All doors were opened to a 90 degree angle and then closed within the allotted time. Figure 3 shows the temperature changes following a 60 second door opening. Please note that when reading the legend all data with the prefix E is from the empty freezer and data with the prefix R is from the racked freezers.

In total there were 4.5 minutes of door openings carried out on each unit configuration during those two weeks of testing. In the empty ULT freezer these door openings used 0.78 kWh of electricity whilst in the aluminium racked unit these door openings used 1.27 kWh of electricity. When steel racking was used these door openings used 1.47 kWh of electricity.

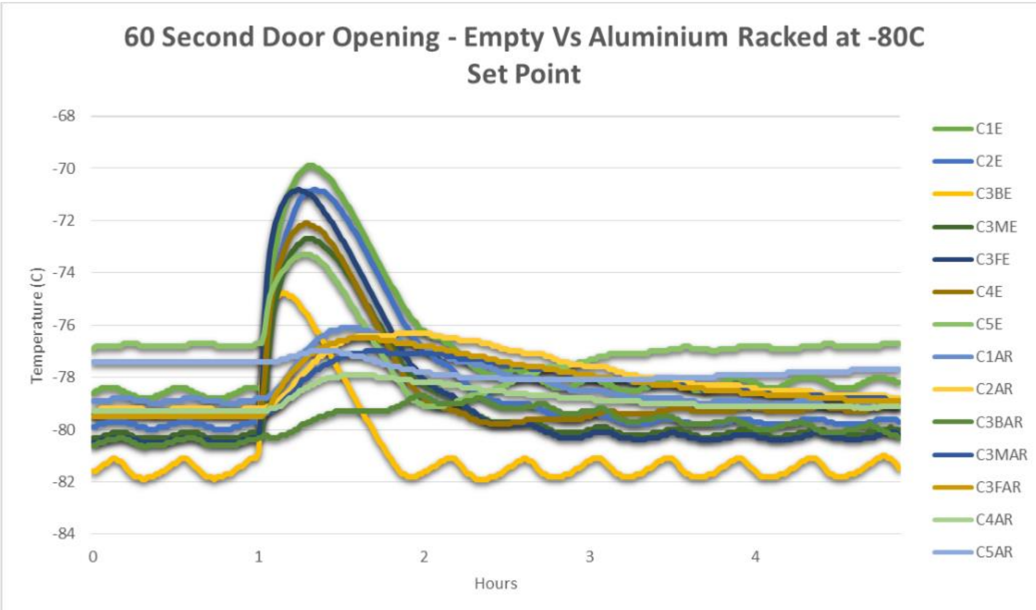

Figure 3. Effects of a 60 second door opening on ULT freezer compartment temperatures (aluminium racked Vs empty)

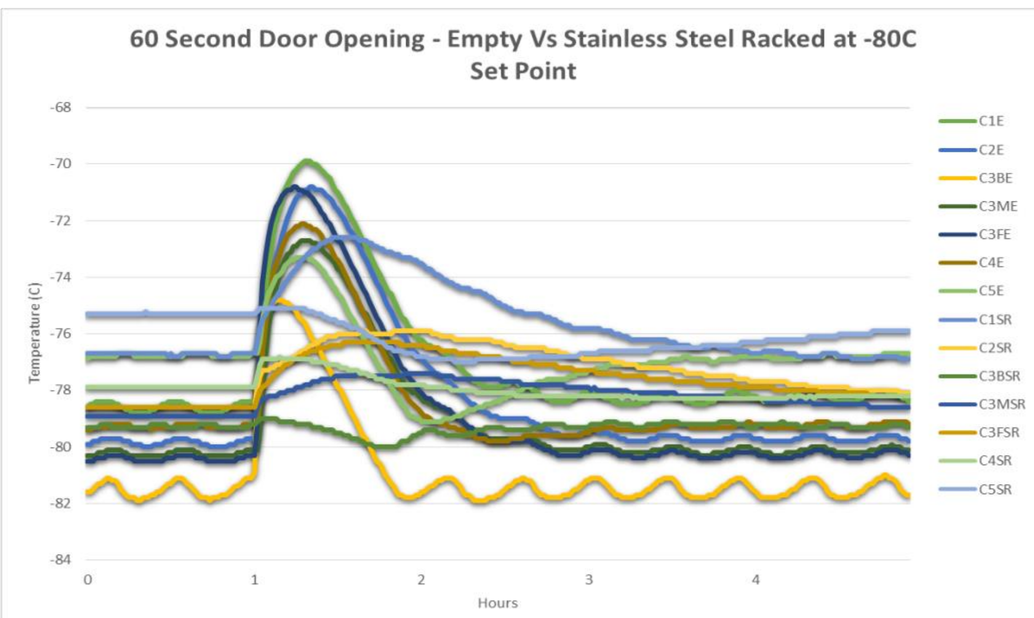

Figure 4. Effects of a 60 second door opening on ULT freezer compartment temperatures (stainless steel racked Vs empty)

F570h ULT Freezer Compartment	Warmest Temperature Following: 60 Second Door Opening	90 Second Door Opening	120 Second Door Opening
Empty Unit, Compartment 1	-69.9C	-66.1C	-63.1C
Empty Unit, Compartment 2	-70.8C	-66.9C	-64.1C
Empty Unit, Compartment 3, Back	-74.8C	-71.9C	-69.9C
Empty Unit, Compartment 3, Middle	-72.7C	-69.3C	-66.6C
Empty Unit, Compartment 3, Front	-70.8C	-66.3C	-63.0C
Empty Unit, Compartment 4	-72.1C	-68.8C	-66.5C
Empty Unit, Compartment 5	-73.4C	-71.6C	-70.3C
Aluminium Racked Unit, Compartment 1	-76.1C	-74.4C	-72.7C
Aluminium Racked Unit, Compartment 2	-76.3C	-74.6C	-73.3C
Aluminium Racked Unit, Compartment 3, Back	-78.7C	-77.6C	-76.8C
Aluminium Racked Unit, Compartment 3, Middle	-77.0C	-75.4C	-74.4C
Aluminium Racked Unit, Compartment 3, Front	-76.5C	-74.8C	-73.7C
Aluminium Racked Unit, Compartment 4	-77.9C	-76.5C	-75.9C
Aluminium Racked Unit, Compartment 5	-77.0C	-76.5C	-76.4C
Steel Racked Unit, Compartment 1	-72.6C	-70.7C	-69.1C
Steel Racked Unit, Compartment 2	-75.9C	-73.8C	-71.9C
Steel Racked Unit, Compartment 3, Back	-79.0C	-77.6C	-76.6C
Steel Racked Unit, Compartment 3, Middle	-77.4C	-75.7C	-74.5C
Steel Racked Unit, Compartment 3, Front	-76.3C	-74.5C	-73.2C
Steel Racked Unit, Compartment 4	-76.8C	-75.8C	-75.0C
Steel Racked Unit, Compartment 5	-75.1C	-74.4C	-73.9C

Figure 5. Effect of timed door openings on ULT freezer compartment temperatures.

It was also observed that in the case of the steel racked ULT freezer, to recover temperature following a timed door opening was as follows 60 seconds = 5 hours 59 minutes, 90 seconds = 6 hours 52 minutes 120 seconds = 7 hours 51 minutes. In the empty ULT freezer, to recover temperature following a timed door opening was as follows 60 seconds = 2 hours 2 minutes, 90 seconds = 2 hours 30 minutes, and 120 seconds = 3 hours 30 minutes. In the racked unit these recovery times double.

DISCUSSION

Although it was observed that the racked units took longer to recover from a door opening those units remained significantly colder than the non-racked unit. After a 60 second door opening temperatures in a racked unit will be as much as 6C colder than the empty ULT freezer.

With longer door openings of 90 and 120 seconds these temperatures can be up to 7C and 10C colder respectively. The temperatures recorded in the aluminium and steel racked ULT freezer after a 120 second door opening were **colder** than those recorded in the empty ULT freezer following a 60 second door opening. The racking was able to absorb the heat following a door opening resulting in the lower rises in temperature. With the racked units containing 90kg (aluminium) and 145kg (steel) more metal than the empty unit the recovery times are subsequently longer.

The effect of the aluminium racking (figure 2) also resulted in the warmer temperatures observed in the empty ULT freezer (Compartments 1 and 5) being **colder** in the aluminium racked unit; there was a more even distribution of temperature. In the case of the steel racking all temperatures compared to the empty ULT freezer.

There was no significant difference between the warm up times observed in the aluminium and steel racked units. Although the racked units, more so the steel racked unit, had observed increases in average compartment temperatures racking also resulted in at least a doubling of the warm up times to -50C. In some compartments this warm up time was **137% longer**. This would give end users longer to manage the safe transfer of samples following a loss of power/failure. Also, although door openings were compared during this study it must be noted that when a ULT freezer is racked keeping an inventory and therefore locating contents is easier and faster. Therefore in a racked unit door openings would logically be shorter compared to that of an equally full non-racked ULT freezer. The impact of this in the racked ULT freezer would be even smaller rises in internal temperatures and a lower cost in electricity associated with accessing samples (providing end users were employing a proper inventory).

Furthermore, to save energy end users could fully rack a ULT freezer and operate it at warmer temperatures (-75C or -70C). The racking would greatly decrease the impact of a door opening ensuring that samples always remained at an acceptable temperature. This will be further explored in future case studies.

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