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EPPENDORF F740HI RACKING STUDY

ULT FREEZER TEMPERATURE PERFORMANCE. I.C.L.

ANDY EVANS - GREEN LIGHT LABORATORIES LTD

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INTRODUCTION

Ultra-Low Temperature (ULT) freezers are well known to be high consumers of energy. Holding set temperatures 90°C to 100°C colder than their environment will always require a significant amount of energy. One way to reduce ULT freezer energy consumption is to warm up the set temperature. By doing so energy consumption will be reduced from 18-34% depending on the model, age & condition of the freezer. When considering warming up their ULT freezers, some end users raise concerns that by taking such an action they may expose their samples/contents to unfavorable temperatures during their day to day operation.



Figure 1. The F740hi with probes positioned at the centre of each shelf. Furthermore, additional probes were positioned at the back of the top compartment (compartment 1) and the front of the bottom compartment (compartment 5). Compartment 3, the middle compartment, had its probes positioned to be exactly at the middle point of the cabinet.

USING RACKING AND DIFFERENT SET TEMPERATURES

Previous studies have shown the use of racking can reduce temperature rises during door openings and increase the warm up times. Those studies like this study were jointly commissioned by Scientific Laboratory Supplies Ltd and Eppendorf UK, with racking kindly provided by Wesbart Ltd. This study set out to measure the temperature performance of the F740hi freezer at four different set temperatures both with (figure 1) and without racking (figure 2.



Figure 2. The F740hi filled with aluminium, front opening racking.

MEASURING TEMPERATURE PERFORMANCE

This case study used the Logicall Wireless Monitoring system utilizing their energy monitors, temperature probes and online platform to record all of the data. When measuring door opening recovery times this was determined when each individual probe returned to its mean temperature as measured at that temperature set point, door closed, over a 24-hour period. This is a more precise form of measurement which avoids warmer thresholds or average chamber temperatures to indicate recovery. In a similar way this was also the approach when measuring the warm up times to -50C, with each individual probe having its time to reach this threshold recorded. The probes were positioned as shown in figure 1. The middle compartment (compartment 3) was also fitted with a sample probe which was immersed in 5ml of glycerol. The freezer was tested at the set points of -80°C, -75°C, -70°C and -65°C. The results are shown in figures 3 to 6.

ULT Freezer Compartment	Temperature Performance (Celsius) at -80C Set Point								
	Highest	Lowest	Variance	Mean	60 Sec. D.O. Start Temp.	Peak Temp.	Temp.Rise	Recovery time (mins)	Warm Up to -50C (mins)
Compartment 1 Back Empty	-74.5	-76	1.5	-75.3	-74.5	-50.1	24.4	67	211
Compartment 1 Middle Empty	-74.7	-75.9	1.2	-75.4	-75.8	-50.5	25.3	89	254
Compartment 2 Middle Empty	-77.2	-78	0.8	-77.7	-77.9	-60.9	17	128	293
Compartment 3 Middle Empty	-78.2	-79.3	1.1	-78.8	-78.9	-60.3	18.6	122	278
Compartment 3 Sample Empty	-78.3	-78.9	0.6	-78.6	-78.8	-69.9	8.9	128	327
Compartment 4 Middle Empty	-78.4	-79.4	1	-78.9	-79.2	-66.5	12.7	68	340
Compartment 5 Middle Empty	-76.6	-78	1.4	-77.2	-77.9	-61.8	16.1	52	355
Compartment 5 Front Empty	-75.8	-77	1.2	-76.4	-76.5	-60.9	15.6	54	367
Compartment 1 Back Racked	-73.5	-73.9	0.4	-73.6	-73.6	-70.8	2.8	142	458
Compartment 1 Middle Racked	-73.4	-73.6	0.2	-73.5	-73.5	-69.8	3.7	183	533
Compartment 2 Middle Racked	-76.5	-76.7	0.2	-76.6	-76.6	-73.9	2.7	278	615
Compartment 3 Middle Racked	-78.4	-78.6	0.2	-78.5	-78.5	-76.1	2.4	257	617
Compartment 3 Sample Racked	-78	-78.2	0.2	-78.1	-78.1	-76	2.1	289	641
Compartment 4 Middle Racked	-79.1	-79.5	0.4	-79.3	-79.3	-77.9	1.4	36	782
Compartment 5 Middle Racked	-77.5	-77.7	0.2	-77.6	-77.6	-78.1	-0.5	NA	822
Compartment 5 Front Racked	-77.7	-77.8	0.1	-77.8	-77.8	-78	-0.2	NA	826

Figure 3. F740hi performance at -80°C with and without racking.

ULT Freezer Compartment	Temperature Performance (Celsius) at -75C Set Point								
	Highest	Lowest	Variance	Mean	60 Sec. D.O. Start Temp.	Peak Temp.	Temp.Rise	Recovery time (mins)	Warm Up to -50C (mins)
Compartment 1 Back Empty	-71.3	-72.8	1.5	-72.1	-71.5	-48.2	23.3	60	150
Compartment 1 Middle Empty	-71.2	-72.5	1.3	-71.9	-71.6	-47.7	23.9	83	191
Compartment 2 Middle Empty	-72.7	-73.6	0.9	-73.2	-73.1	-58.1	15	124	235
Compartment 3 Middle Empty	-73.4	-74.4	1	-73.9	-73.8	-57.3	16.5	123	219
Compartment 3 Sample Empty	-73.7	-74.3	0.6	-74	-74	-66.1	7.9	130	266
Compartment 4 Middle Empty	-73.2	-74.2	1	-73.8	-73.6	-61.8	11.8	55	282
Compartment 5 Middle Empty	-71.5	-72.6	1.1	-72	-72.2	-58.7	13.5	52	276
Compartment 5 Front Empty	-70.3	-71.1	0.8	-70.8	-70.7	-56.7	14	52	283
Compartment 1 Back Racked	-70.2	-70.5	0.3	-70.3	-70.4	-67.2	3.2	123	323
Compartment 1 Middle Racked	-69.9	-70.1	0.2	-70	-70	-66.1	3.9	156	398
Compartment 2 Middle Racked	-72	-72.2	0.2	-72.1	-72.1	-69	3.1	249	478
Compartment 3 Middle Racked	-73.5	-73.7	0.2	-73.6	-73.6	-71.3	2.3	252	482
Compartment 3 Sample Racked	-73.5	-73.6	0.1	-73.5	-73.6	-71.4	2.2	279	504
Compartment 4 Middle Racked	-74.2	-74.7	0.5	-74.5	-74.6	-73	1.6	28	644
Compartment 5 Middle Racked	-72.3	-72.5	0.2	-72.4	-72.3	-72.4	-0.1	NA	686
Compartment 5 Front Racked	-72.1	-72.2	0.1	-72.2	-72.1	-72.5	-0.4	NA	694

Figure 4. F740hi performance at -75°C with and without racking.

ULT Freezer Compartment	Temperature Performance (Celsius) at -70C Set Point								
	Highest	Lowest	Variance	Mean	60 Sec. D.O. Start Temp.	Peak Temp.	Temp.Rise	Recovery time (mins)	Warm Up to -50C (mins)
Compartment 1 Back Empty	-66.5	-68.2	1.7	-67.3	-68.1	-44.3	23.8	62	99
Compartment 1 Middle Empty	-66.2	-68.1	1.9	-67.1	-68	-44.6	23.4	80	143
Compartment 2 Middle Empty	-67.7	-69.1	1.4	-68.2	-68.7	-52.1	16.6	122	188
Compartment 3 Middle Empty	-68.7	-70.1	1.4	-69.1	-69.5	-55.1	14.4	121	160
Compartment 3 Sample Empty	-68.8	-70	1.2	-69.1	-69	-60	9	126	209
Compartment 4 Middle Empty	-67.9	-69.7	1.8	-68.5	-68.1	-53.4	14.7	39	223
Compartment 5 Middle Empty	-65.9	-67.5	1.6	-66.2	-66.1	-52.3	13.8	30	216
Compartment 5 Front Empty	-65.4	-66.7	1.3	-65.7	-65.6	-51.1	14.5	32	230
Compartment 1 Back Racked	-65.2	-65.4	0.2	-65.3	-65.3	-62.2	3.1	117	195
Compartment 1 Middle Racked	-65.2	-65.3	0.1	-65.2	-65.3	-61.1	4.2	149	266
Compartment 2 Middle Racked	-67.1	-67.3	0.2	-67.2	-67.2	-64.1	3.1	247	342
Compartment 3 Middle Racked	-68.6	-68.9	0.3	-68.7	-68.7	-66.3	2.4	243	344
Compartment 3 Sample Racked	-68.6	-68.8	0.2	-68.6	-68.6	-66.3	2.3	253	370
Compartment 4 Middle Racked	-68.4	-68.5	0.1	-68.5	-68.5	-67.5	1	14	508
Compartment 5 Middle Racked	-68	-68.1	0.1	-68.1	-68.1	-68.1	0	NA	551
Compartment 5 Front Racked	-67.9	-68	0.1	-68	-68	-68.2	-0.2	NA	560

Figure 5. F740hi performance at -70°C with and without racking.

ULT Freezer Compartment	Temperature Performance (Celsius) at -65C Set Point								
	Highest	Lowest	Variance	Mean	60 Sec. D.O. Start Temp.	Peak Temp.	Temp.Rise	Recovery time (mins)	Warm Up to -50C (mins)
Compartment 1 Back Empty	-63.2	-65.5	2.3	-64.5	-64.2	-41	23.2	44	55
Compartment 1 Middle Empty	-63	-65	2	-64.1	-63.9	-41.3	22.6	69	72
Compartment 2 Middle Empty	-63.8	-65.1	1.3	-64.5	-64	-47.4	16.6	107	109
Compartment 3 Middle Empty	-64.1	-65.3	1.2	-64.8	-64.4	-49.4	15	111	106
Compartment 3 Sample Empty	-64.5	-65.3	0.8	-65	-64.8	-56.1	8.7	117	154
Compartment 4 Middle Empty	-63.1	-64.5	1.4	-63.9	-63.4	-48.3	15.1	129	168
Compartment 5 Middle Empty	-61.3	-61.9	0.6	-61.7	-61.4	-48.1	13.3	127	160
Compartment 5 Front Empty	-60.3	-60.8	0.5	-60.6	-60.5	-46.3	14.2	133	175
Compartment 1 Back Racked	-61.3	-61.6	0.3	-61.5	-61.6	-58.7	2.9	109	142
Compartment 1 Middle Racked	-61	-61.2	0.2	-61.1	-61.1	-57.4	3.7	145	213
Compartment 2 Middle Racked	-62.2	-62.4	0.2	-62.3	-62.3	-59.5	2.8	230	292
Compartment 3 Middle Racked	-63.2	-63.5	0.3	-63.3	-63.6	-61.5	2.1	234	295
Compartment 3 Sample Racked	-63.4	-63.5	0.1	-63.4	-63.5	-61.7	1.8	237	222
Compartment 4 Middle Racked	-63.8	-64.4	0.6	-64.1	-64.2	-62.9	1.3	23	356
Compartment 5 Middle Racked	-61.4	-61.8	0.4	-61.7	-61.8	-61.9	-0.1	NA	407
Compartment 5 Front Racked	-61	-61.2	0.2	-61.1	-61.4	-61.7	-0.3	NA	414

Figure 6. F740hi performance at -65°C with and without racking.

DISCUSSION

From the data collected a number of observations can be made regarding the impact of racking. Firstly, adding racking alters the observed temperatures in each compartment. As shown in figures 3-6, when racking is added to the freezer the temperatures in the top 3 compartments become 1-2°C warmer, whilst the temperatures in the bottom two compartments decreases by 1-2°C. The second effect of adding racking is the temperature variance inside each compartment is greatly reduced. This is reduced from 1.5-2.0°C to a maximum of 0.6°C with racking.

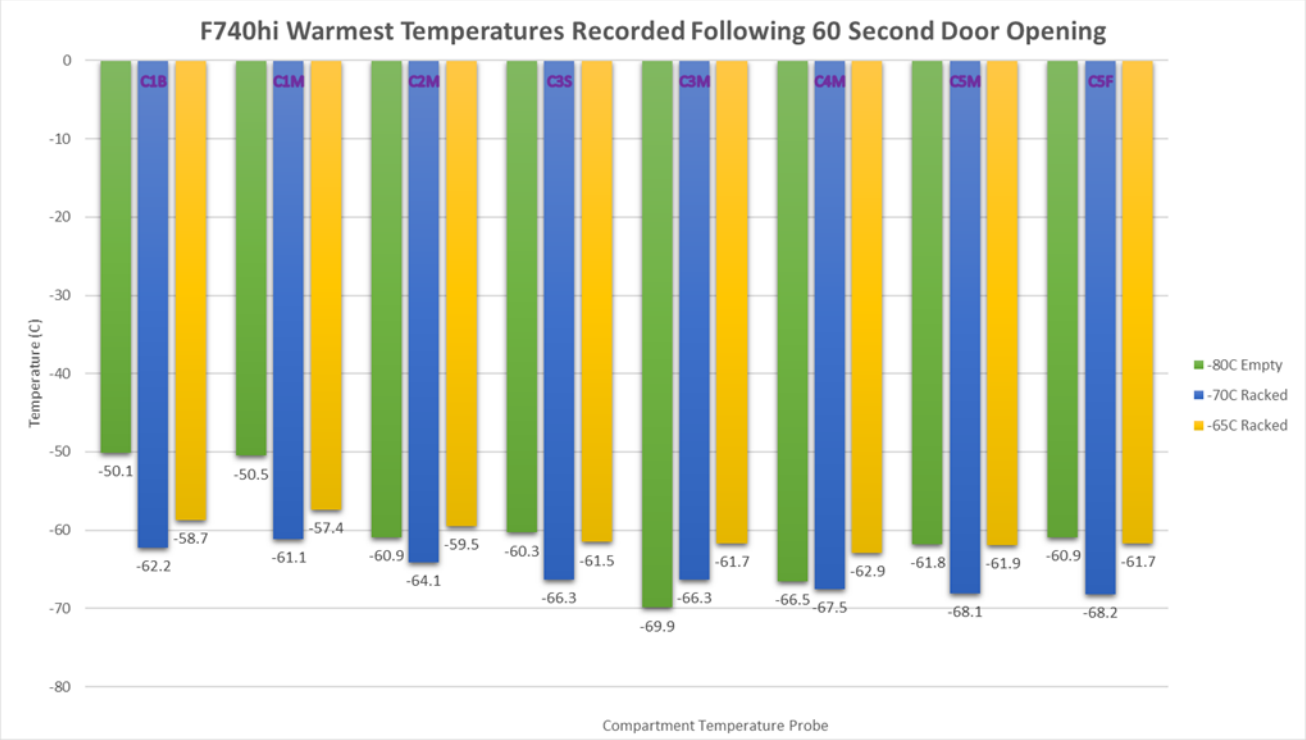


Figure 7. Warmest temperatures measured in the empty freezer set to -80°C (green) versus the racked unit which is at set temperatures 10°C warmer (blue) and 15°C warmer (yellow).

Door Openings

Racking also had a significant impact on the warmest (peak) temperatures recorded following a 60 second door opening. In the empty ULT freezer, at all the set points above -80°C a door opening resulted in temperatures warmer than -50°C being reached (see figures 4-6). However, when adding racking, the temperature rises following a door opening were greatly reduced. Racking reduced the temperature rise following a door opening to a maximum of 4.0°C whilst in the non-racked units' temperatures would rise by more than double this number in their *'best compartments'* and over six times this number in the compartments most impacted by door openings (the top compartments). This impact is perhaps best summarized above in figure 7.

As shown in figure 7, warming the freezer up by 10°C and adding racking resulted in all but one compartments being colder following a door opening when compared to the -80C (empty) data. When the freezer is empty and at -80°C the top compartment probes came very close to breaching the -50°C threshold following a door opening. When testing the racked units, even at the -65°C set point those measured temperatures following a door opening were over 8C°C colder compared to the empty unit at -80°C.

Door Opening Recovery Times

The door opening recovery times in the empty freezer were generally faster compared to the racked unit. The exception being the bottom compartments of the racked units which, following a door opening actually fell in temperature due to the cold air cascading down from the upper compartments. These compartments aside, it is clear that for all compartments to recover from a door opening the racked unit will require ≥ double the time compared to the non-racked unit.

Warm Up Times

Similar to the door opening recovery times it was observed that with the exception of one probe at the -70C set point, that the warm up times to -50°C are double or longer with the addition of racking (figure 8). The impact of racking on warm up times is clear when comparing the warm up times from the unit tested at **-80°C empty** to the **racked unit tested at -70°C** where the warm up times were between **30% to 98% longer.**

Set Temperature	Empty ULT Freezer	Racked ULT Freezer
	Range of Warm Up Times to -50C	
-80C Set Point	211 - 367 minutes	458 - 826 minutes
-75C Set Point	150 - 283 minutes	323 - 694 minutes
-70C Set Point	99 - 230 minutes	195 - 560 minutes
-65C Set Point	55 - 175 minutes	142 - 414 minutes

Figure 8. Warm up times for the F740hi with and without racking at different set temperatures.

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