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DOOR OPENING PERFORMANCE STUDY

FRIDGES AND FREEZERS, UNIVERSITY OF BRISTOL

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INTRODUCTION

Fridges and freezers are widespread throughout scientific research and teaching. They are found in molecular sciences, life sciences, chemistry and stores departments throughout the UK. A range of models are available and lab operators may choose from a selection of units which will vary in their price & performance. With labs aiming to minimize their running costs, highlighting the models with the lowest running costs is a useful exercise. However, energy consumption values alone would not be serving end user requirements. This study aimed to highlight some of the data and criteria which should be considered when selecting the most sustainable solution based on the specific needs of the researcher, their laboratory and the materials they are storing.

Figure 1. The three fridges and three freezers examined at the Learning and Research Centre, University of Bristol.

SET POINT PERFORMANCE

Typically, fridges are used to store their contents at the set point of 4C whilst the set point of -20C is commonly used for storage in freezers. . Scientific Laboratory Supplies Ltd (S.L.S.) & Liebherr commissioned this study to investigate the differences in performance between well-known brands of under bench units widely supplied to the UK market. The units were selected based on having similar capacities, refrigerant type and volume and having spark reduced or spark free interiors. The units (Figure 1) were tested under controlled conditions at the Learning and Research Centre, University of Bristol. Southmead.

The fridges were monitored at the 4C set point and the freezers monitored at the -20C set point. Their temperature performance, energy consumption and door opening recovery times recorded. It must be noted that energy monitor for the Labcold Freezer was damaged during shipping and therefore energy data for this unit was not captured.

MEASURING TEMPERATURE AND ENERGY

This case study used the Logicall Wireless Monitoring system utilizing their energy monitors, temperature probes and online platform to record all the data. One difference that must be highlighted in terms of monitoring is the **pull down time.** Traditionally, the pull down time is measured by placing one probe inside the unit and measuring the time taken for the probe to reach the average chamber temperature. This study employed a more representative method. Whereby the pull down time is defined as the time taken for **each compartment to reach its average temperature** (accurate to 0.1C) measured at the 4C/-20C set point with no door openings over a 24 hour period. Door opening recovery times were also measured by recording the time taken for each compartment to reach its average temperature as described above.

Both the fridges and freezers were monitored using 3 temperature probes, each placed in the centre of their respective compartment. The middle compartment was monitored using a sample probe which was 10ml of glycerol (figure 2).

Figure 2. Sample probe was placed on the middle compartment of each unit. Central to the photo is the sample representative probe. Above this the probe in the top compartment can be seen.

The performance data collected for each unit concerning pull down time, energy consumption and timed door openings is shown in figures 3 & 4.

Manufacturer	Liebherr	Lec	Labcold
Model	LKUexv1610	LSFSR158UK	RLPR0517
Net Capacity	141	154	150
Energy Consumption kWh/day at 4C Set Point	0.669	0.434	0.889
W/L/Day at 4C	4.74	2.82	5.93
Temperature Performance at 4C			
Top Compartment mean (highest/lowest)[Pull Down Time]	3.9C(5.7C/3.7C)[78 mins]	4.1C(4.9C/3.5C)[79 mins]	6.7C(7.3C/6.3C)[110 mins]
Middle (Sample) Compartment mean (highest/lowest)[Pull Down Time]	3.0C(4.3C/-2.8C)[91 mins]	2.9C(3.3C/2.6C)[116 mins]	6.2C(6.6C/6.0C)[140 mins]
Bottom Compartment mean (highest/lowest)[Pull Down Time]	4.2C(6.3C/4.0C)[78 mins]	2.1C(3.6C/0.9C)[57 mins]	7.2C(7.8C/6.9C)[415 mins]
60 Second Door Opening Data			
Top Compartment Recovery Time (Start Temp)[Temp Rise]	16 mins (3.8C)[3.1C]	22 mins (4.0C)[5.8C]	37 mins (7.0C)[4.1C]
Middle (Sample) Compartment Recovery Time (Start Temp)[Temp Rise]	10 mins (3.0C)[0.5C]	55 mins (2.7C)[2.6C]	83 mins (6.4C)[1.7C]
Bottom Compartment Recovery Time (Start Temp)[Temp Rise]	15 mins (4.1C)[2.5C]	13 mins (2.2C)[2.3C]	38 mins (7.5C)[2.0C]
90 Second Door Opening Data			
Top Compartment Recovery Time (Start Temp)[Temp Rise]	24 mins (3.9C)[4.6C]	28 mins (3.6C)[7.6C]	38 mins (6.6C)[5.5C]
Middle (Sample) Compartment Recovery Time (Start Temp)[Temp Rise]	26 mins (2.9C)[2.5C]	68 mins (2.7C)[3.3C]	67 mins (6.1C)[2.2C]
Bottom Compartment Recovery Time (Start Temp)[Temp Rise]	16 mins (4.3C)[2.5C]	17 mins (1.5C)[4.3C]	41 mins (7.1C)[2.7C]
120 Second Door Opening Data			
Top Compartment Recovery Time (Start Temp)[Temp Rise]	26 mins (3.7C)[6.1C]	31 mins (3.6C)[8.2C]	64 mins (7.1C)[5.9C]
Middle (Sample) Compartment Recovery Time (Start Temp)[Temp Rise]	32 mins (2.8C)[2.8C]	66 mins (2.7C)[4.2C]	94 mins (6.4C)[2.9C]
Bottom Compartment Recovery Time (Start Temp)[Temp Rise]	18 mins (4.0C)[4.0C]	18 mins (1.1C)[5.8C]	64 mins (7.6C)[3.2C]

Figure 3. Fridge performance data recorded at ambient condition of 21C (+/-1.5C)

Model	Liebherr LGUex1500	Labcold RLVF0417	Biocold BIO130FRSS
Net Capacity (Litres)	130	120	130
Energy Consumption (-20C) kWh/day	0.669		0.368
W/L/Day at -20C	5.15		2.83
Temperature Performance at -20C			
Top Compartment mean (highest/lowest)[Pull Down Time]	-21.2C(-18.8C/-23.5C)[78 mins]	-18.3C(-17.4C/-19.4C)[108 mins]	-19.6C(-19.0C/-20.2C)[74 mins]
Middle (Sample) Compartment mean (highest/lowest)[Pull Down Time]	-21.7C(-20.5C/-22.7C)[89 mins]	-19.2C(-18.9C/-19.6C)[198 mins]	-20.2C(-19.9C/-20.4C)[138 mins]
Bottom Compartment mean (highest/lowest)[Pull Down Time]	-16.5C(-15.6C/-17.2C)[95 mins]	-20.2C(-18.9C/-21.6C)[106 mins]	-20.0C(-19.4C/-20.5C)[89 mins]
60 Second Door Opening Data			
Top Compartment Recovery Time (Start Temp)[Temp Rise]	18 mins (-19.8C)[5.8C]	34 mins (-18.5C)[12.3C]	29 mins (-19.2C)[2.3C]
Middle (Sample) Compartment Recovery Time (Start Temp)[Temp Rise]	25 mins (-21.3C)[2.6C]	74 mins (-19.3C)[6.5C]	30 mins (-19.9C)[0.6C]
Bottom Compartment Recovery Time (Start Temp)[Temp Rise]	27 mins (-15.9C)[3.0C]	33 mins (-20.0C)[7.1C]	12 mins (-19.7C)[1.6C]
90 Second Door Opening Data			
Top Compartment Recovery Time (Start Temp)[Temp Rise]	22 mins (-22.7C)[7.4C]	39 mins (-18.9C)[18.0C]	35 mins (-19.6C)[5.9C]
Middle (Sample) Compartment Recovery Time (Start Temp)[Temp Rise]	29 mins (-21.6C)[2.5C]	81 mins (-19.5C)[8.8C]	66 mins (-20.4C)[2.3C]
Bottom Compartment Recovery Time (Start Temp)[Temp Rise]	30 mins (-16.7C)[3.0C]	39 mins (-20.5C)[9.9C]	34 mins (-20.0C)[3.5C]
120 Second Door Opening Data			
Top Compartment Recovery Time (Start Temp)[Temp Rise]	22 mins (-23.0C)[8.2C]	45 mins (-19.0C)[24.1C]	51 mins (-20.2C)[7.0C]
Middle (Sample) Compartment Recovery Time (Start Temp)[Temp Rise]	29 mins (-22.5C)[3.9C]	87 mins (-19.7C)[10.4C]	108 mins (-20.5C)[2.8C]
Bottom Compartment Recovery Time (Start Temp)[Temp Rise]	30 mins (-16.9C)[7.9C]	43 mins (-21.7C)[12.3C]	51 mins (-20.5C)[4.3C]

Figure 4. Freezer performance data recorded at ambient condition of 21C (+/-1.5C)

DOOR OPENINGS VERSION 2.0

Although timed door openings are a great way to highlight differences in temperature performance they may not fully reflect lab usage. Therefore three different series of door openings were carried out, each series consisted of 12 door openings, each door opening being for 60 seconds. The intervals between each door opening were either, 30 minutes, 20 minutes or 15 minutes (figure 5). The graphs depicting each door opening type for each model follows. Please note that the series of door openings begin from the 1st hour as shown in figures 6 & 7. The mean temperature displayed was calculated using the temperature reading from the first door opening through to 60 minutes after the last of the 12 door openings.

Opening Type	Door Openings	Interval Between Openings
Occasional	12 x 60 seconds	30 minutes
Regular	12 x 60 seconds	20 minutes
Frequent	12 x 60 seconds	15 minutes

Figure 5. Door openings with increasing regularity.

Door Opening Type	Fridge Model & Compartment	Liebherr LKUexv1610			Lec LSFSR158UK			Labcold RLPR0517		
		Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
OCCASIONAL	Peak Temperature	6.5C	4.1C	6.2C	9.8C	5.1C	4.7C	11.4C	9.0C	9.8C
	Recovery Time (Mins)	15	5	5	60	63	14	40	86	41
	Mean Temperature	4.2C	2.9C	4.3C	6.0C	4.0C	1.8C	8.2C	7.8C	8.2C
REGULAR	Peak Temperature	6.5C	3.8C	6.3C	9.9C	5.4C	4.4C	11.5C	8.8C	9.4C
	Recovery Time (Mins)	16	5	6	60	64	11	36	64	59
	Mean Temperature	4.4C	2.9C	4.3C	6.7C	4.6C	1.7C	8.3C	7.5C	7.8C
FREQUENT	Peak Temperature	6.9C	4.9C	6.7C	11.5C	8.0C	6.5C	11.7C	9.2C	9.3C
	Recovery Time (Mins)	26	31	23	37	81	22	19	63	11
	Mean Temperature	4.6C	3.1C	4.5C	8.0C	5.8C	3.1C	8.3C	7.5C	7.7C

Figure 6. Effect of increasing door opening frequencies on fridges.

Door Opening Type	Freezer Model & Compartment	Liebherr LGUex1500			Labcold RLVF0417			Biocold BIO130FRSS		
		Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
OCCASIONAL	Peak Temperature	-16.9C	-19.8C	-13.5C	-2.4C	-10.3C	-12.4C	-14.9C	-18.5C	-17.6C
	Recovery Time (Mins)	11	4	12	37	80	35	71	114	26
	Mean Temperature	-21.6C	-22.2C	-16.5C	-12.1C	-13.2C	-15.8C	-18.1C	-19.4C	-19.3C
REGULAR	Peak Temperature	-18.0C	-19.5C	-13.6C	-0.9C	-7.2C	-8.4C	-15.0c	-18.2C	-17.6C
	Recovery Time (Mins)	6	3	4	43	90	42	14	187	31
	Mean Temperature	-22.1C	-22.6C	-17.1C	-9.3C	-10.1C	-12.3C	-17.3C	-19.0C	-19.1C
FREQUENT	Peak Temperature	-16.2C	-19.3C	-12.1C	3.6C	-2.0C	-2.4C	-14.7C	-17.6C	-17.5C
	Recovery Time (Mins)	11	12	15	55	248	54	133	218	32
	Mean Temperature	-20.9C	-21.7C	-15.7C	-5.7C	-6.6C	-8.5C	-17.0C	-19.0C	-19.1C

Figure 7. Effect of increasing door opening frequencies on freezers.

DISCUSSION: FRIDGES

When considering the pull down times the Liebherr unit had the fastest pull down time ≤ 91 minutes. Second was the Lec (≤ 116 minutes), last was the Labcold (≤ 415 minutes)

The Liebherr unit was also observed to recover the fastest from all durations of door openings (60, 90 and 120 seconds), recovering **sample** temperature in well under half the time of the other units. For example, the door opening recovery time for the sample probe in the Liebherr fridge took 10 minutes to recover from a 60 second door opening, the Lec unit took 55 minutes, and the Labcold took 83 minutes.

The mean sample probe temperatures in the Liebherr and Lec unit were similar, 3.0C and 2.9C respectively. In the Labcold unit the mean sample temperature was warmer at 6.2C.

The Liebherr fridge was best able to cope with all frequencies of door openings. During those door openings the temperatures measured in the Liebherr unit were the coldest, never exceeding 6.9C whilst the warmest temperatures were observed in the Labcold unit (≤ 11.7C).

During the testing the sample probe in the Liebherr unit largely remained colder than 4C, with the temperature only exceeding this during an automatic defrost cycle; these occur every 6 hours. The Labcold fridge maintained the sample probe temperature at ≤8C during door openings, this was also the case with the Lec fridge however the temperatures recorded appeared to progressively increase with the last 4 door openings.

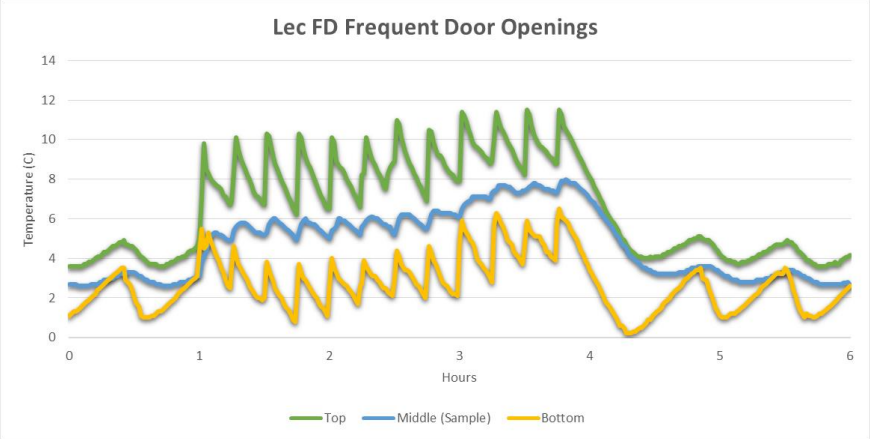

Figure 8. Frequent door openings of the Lec fridge.

In short, the **Lec** unit used the least amount of energy (2.82 W/L/Day). Temperatures in the Lec were also the coldest due to the lower temperatures observed in the bottom compartment. However, the door opening recovery times were considerably longer and peak temperature rises observed during the frequent door openings were a close second (11.5C).

The **Liebherr** unit came second for energy efficiency (4.74 W/L/Day) however it had mean temperatures not exceeding 4.2C and was the fasted to pull down to temperature. Its door opening recovery times were over double the speed of the other models. The temperatures observed during periods of door openings were the coldest in the Liebherr unit.

The **Labcold** unit used the most energy (5.93 W/L/Day). Temperatures were warmest inside the Labcold unit with the bottom compartment having a mean temperature of 7.2C (3C warmer than the Liebherr, 5C warmer than the Lec). The pull down time was the longest and door opening recovery times were longest when looking at the sample probes. The warmest temperatures during door openings were overserved in the Labcold unit (11.7C)

DISCUSSION: FREEZERS

When considering the pull down times the Liebherr unit had the fastest pull down time ≤ 95 minutes. Second was the Biocold (≤ 138 minutes), last was the Labcold (≤ 198 minutes)

The Liebherr unit was also observed to recover the fastest from all durations of door openings (60, 90 and 120 seconds). When the door openings were longer than 60 seconds recovering Liebherr unit recovered sample temperature is under half the time compared to the other units. For example, the door opening recovery time for the sample probe in the Liebherr freezer took 29 minutes to recover from a 90 second door opening, the Biocold unit took 66 minutes, and the Labcold took 81 minutes.

The mean sample probe temperatures in the Liebherr was the coldest at -21.3C. The Biocold unit was the next coldest with the mean temperature being -19.9C

The Liebherr and Biocold units was best able to cope with all frequencies of door openings. Their peak temperatures were similar, however the warmest temperature recorded in the Liebherr unit was -12.1C whilst the warmest temperature in the Biocold unit was -14.7C. The Liebherr unit had the fastest recovery times for all frequencies of door openings taking no longer than 15 minutes to recover following any series of openings. The Labcold unit recorded the warmest temperatures during all door openings and during the frequent door openings temperatures peaked at 3.6C. This is a result of the unit not featuring drawers (Figure XX).

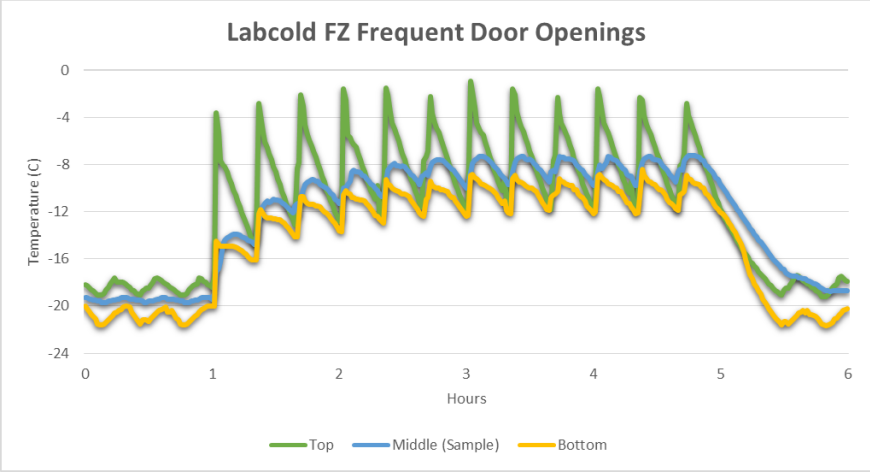

Figure 9. Frequent door openings of the Labcold freezers; the impact of no drawers.

In short, the **Biocold** unit used the least amount of energy (2.83 W/L/Day). Overall, temperatures in the Biocold were also the coldest due to the lower temperatures observed in the bottom compartment when compared to the Liebherr unit. However, the door opening recovery times were considerably longer ranging from twice to over ten times longer than those observed in the Liebherr unit.

The **Liebherr** unit came second for energy efficiency (5.15 W/L/Day). Temperatures were the coldest in the top and middle compartments, however, the bottom compartment mean temperature (-16.5C) meant that overall the Liebherr unit experienced the second warmest temperature peak (-12.1C) during the frequent door openings. The Liebherr unit was the fastest to recover from a door opening, particularly following a series of door openings whereby the unit was over 10 times faster than the other units.

The **Labcold** unit remains to have its energy consumption recorded. . With the door closed, mean temperatures inside the unit ranged from -18.3C to -20.2C. However, the temperature rises recorded

during all door opening procedures were significantly warmer in the Labcold unit due to the absence of any drawers. A single 60 second door opening resulted in a temperature rise of 12.3C, over double the observed rise is the other models. Following **regular** door openings sample temperatures were warmer than -10C, following **frequent** door openings sample temperatures were as warm as -2C.

CONCLUSION

The data collected has shown that in the case of the freezers **drawers** are essential for maintaining acceptable temperatures. Subsequent studies may include freezers with drawers only as this will allow for the drawers to be pulled out during the door opening phases of testing, which will better reflect laboratory usage and highlight any differences in performance between units. Furthermore the frequency of door openings can be increased to reflect an 8 hour working shift. Lastly, a rapid door opening procedure could be added to future case studies (door openings every 10 minutes) to highlight which units are most suited to heavy usage. It appears that the Liebherr units were the most robust when looking at temperature performance, especially when frequently accessed.

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