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LIEBHERR COLD STORAGE PERFORMANCE
ENERGY & TEMPERATURE PERFORMANCE, UNIVERSITY OF BRISTOL

ANDY EVANS - GREEN LIGHT LABORATORIES LTD

LIEBHERR COLD STORAGE PERFORMANCE

INTRODUCTION

Cold storage is commonplace in a variety of lab types. Liebherr has recently released a number of new models of fridges and freezers. These units have been examined at the Learning and Research Centre University of Bristol. Units were examined to quantify their energy consumption and temperature performance.



Figure 1. SRFvH4011 with probes positioned in the top compartment and middle compartment.

TESTING THE UNITS

All units were tested at the Learning and Research Centre, University of Bristol. The laboratory space used was air conditioned with an ambient of 23C (+/-1.5C). This case study used the Logically Wireless Monitoring system utilizing their energy monitors, temperature probes and online platform to record all the data. In each compartment a UKAS calibrated PT1000 probe was placed in the centrepoint of each shelf. In each unit tested the probe located in the centrepoint of the top compartment was always 14cm from the top of the chamber. A sample representative probe (PT1000 probe immersed in 5ml of glycol) was also placed in the centrepoint of the unit (figure 1). The energy monitors employed had an accuracy of +/-1%.

The criteria used during the testing are defined in figure 2.

Pull Down Time	The time taken in minutes for the last probe in the chamber/compartment to reach the mean temperature measured when the unit is empty with no door openings and at the desired set temperature,
Doopr Opening Recovery Time	The time taken in minutes following a door opening or series of door openings for the unit to recover to the mean temperature for tht setpoint.
Energy Consumption	The energy consumed by the fridge or freezer at a set temperature. The energy consumption data is measured in kWh/day and stadardised to Watts Per Litre Per Day (W/L/Day). This is calculated using the following equation (kWh/day/Net Litre Capacity)*1000. Both the kWh/day and W/L/Day data is reported.
Warm Up Time	The time taken in minutes for each probe in the chamber/compartment to reach the specific threshold temperature after the unit is switched off, during this time the doors remain closed.

Figure 2. Cold storage performance criteria.

The fridges were examined first.

FRIDGE RESULTS

Four fridges were examined. All units had an in-chamber fan, 2 units had glass door, 2 units had solid doors. The energy consumption, temperature data and door opening recovery times are shown in figure 3.

	Liebherr	Liebherr	Liebherr	Liebherr
Manufacturer	Liebherr	Liebherr	Liebherr	Liebherr
Model	SRFvg3511	SRFvg400120B	SRFvh400120A	SRFvh4011
Net Capacity (L)	260	298	298	297
Fan/Convection	Fan	Fan	Fan	Fan
Door Type	Glass	Solid	Solid	Glass
PERFORMANCE DATA				
kWh/Day at 4C Set Point	0.964	1.097	0.849	1.002
Energy - W/L/Day	3.71	3.68	2.85	3.37
Top Comp. Mean Air Temp(Lowest/Highest)[Pull Down Time]	3.7C(3.2C/5.0C)[43 minutes]	3.4C(2.6C/4.8C)[30 minutes]	3.6C(3.0C/4.5C)[24 minutes]	3.3C(2.5C/5.0C)[31 minutes]
Mid Comp. Mean Air Temp(Lowest/Highest)[Pull Down Time]	3.5C(2.9C/4.8C)[42 minutes]	3.0C(1.8C/4.6C)[28 minutes]	3.3C(2.7C/4.3C)[23 minutes]	3.2C(2.6C/4.7C)[30 minutes]
Mid Comp. Mean Sample Temp(Lowest/Highest)	3.8C(3.5C/4.5C)	3.0C(2.6C/4.1C)	3.4C(3.1C/3.9C)	3.2C(2.9C/4.1C)
Bottom Comp. Mean Air Temp(Lowest/Highest)[Pull Down Time]	4.2C(3.6C/5.4C)[53 minutes]	4.4C(3.9C/5.1C)[69 minutes]	4.1C(3.5C/5.0C)[37 minutes]	3.8C(3.1C/5.3C)[31 minutes]
WARM UP TIME TO 10C				
Top Compartment	51 minutes	77 minutes	75 minutes	47 minutes
Middle Compartment	70 minutes	91 minutes	94 minutes	69 minutes
Middle Compartment Sample	75 minutes	97 minutes	100 minutes	77 minutes
Bottom Compartment	71 minutes	90 minutes	88 minutes	68 minutes

Figure 3. Liebherr fridge energy and temperature performance.

Units were then subjected to two timed door openings (figure 4).



Liebherr Cold Storage

Manufacturer	Liebherr	Liebherr	Liebherr	Liebherr
Model	SRFvg3511	SRFvg400120B	SRFvh400120A	SRFvh4011
Net Capacity (L)	260	298	298	297
Door Type	Glass	Solid	Solid	Glass
PERFORMANCE DATA				
A. Single 60 Second Door Opening				
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	3.3C(9.2C/5.9C)[10 minutes]	2.7C(9.5C/6.8C)[10 minutes]	4.2C(10.0C/5.8C)[13 minutes]	2.9C(10.2C/7.3C)[10 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	3.0C(10.1C/7.1C)[10 minutes]	1.9C(8.3C/6.4C)[10 minutes]	3.9C(10.3C/6.4C)[13 minutes]	2.8C(9.6C/6.8C)[10 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	3.6C(6.6C/3.0C)[34 minutes]	2.6C(6.2C/3.6C)[12 minutes]	3.6C(6.5C/2.9C)[28 minutes]	3.2C(5.7C/2.5C)[23 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	3.9C(6.1C/2.2C)[8 minutes]	4.0C(6.9C/2.9C)[11 minutes]	4.6C(6.4C/1.8C)[12 minutes]	3.5C(5.3C/1.8C)[10 minutes]
B. Single 90 Second Door Opening				
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	3.3C(10.9C/7.6C)[14 minutes]	3.5C(12.0C/8.5C)[11 minutes]	3.9C(12.2C/8.3C)[16 minutes]	3.4C(11.5C/8.1C)[12 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	3.1C(11.5C/8.4C)[13 minutes]	2.9C(9.2C/6.3C)[12 minutes]	3.7C(11.3C/7.6C)[15 minutes]	3.4C(11.9C/8.5C)[13 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	3.7C(7.5C/3.8C)[37 minutes]	2.8C(6.7C/3.9C)[12 minutes]	3.4C(7.2C/3.8C)[31 minutes]	3.4C(6.4C/3.0C)[36 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	3.8C(7.0C/3.2C)[15 minutes]	4.4C(13.0C/8.6C)[15 minutes]	4.5C(7.0C/2.5C)[15 minutes]	3.9C(5.6C/1.7C)[12 minutes]
Door Opening Energy Cost (A+B)	0.014 kWh	0.023 kWh	0.007 kWh	0.011 kWh

Figure 4. Fridge door opening recovery times and energy consumed from carrying out a 60 second and 90 second door opening.

Next, all units were subjected to 3 different frequencies of 60 second door openings. Each sequence of door openings was carried out over an 8-hour period to reflect a working day of operation. The door opening recover times were measured following the final door opening of each sequence. The energy consumed by carrying out each door opening sequence was also recorded (figure 4).

Manufacturer	Liebherr	Liebherr	Liebherr	Liebherr
Model	SRFvg3511	SRFvg400120B	SRFvh400120A	SRFvh4011
Net Capacity (L)	260	298	298	297
Door Type	Glass	Solid	Solid	Glass
C. OCCASIONAL DOOR OPENINGS PERFORMANCE DATA				
Number of 60 Second Door Openings	17			
Interval Between Door Openings	30 minutes			
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	4.1C(8.5C/4.4C)[18 minutes]	2.7C(9.1C/6.4C)[8 minutes]	3.1C(8.8C/5.7C)[11 minutes]	3.2C(8.4C/5.2C)[8 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	3.8C(8.3C/4.5C)[9 minutes]	1.9C(8.5C/6.6C)[7 minutes]	2.8C(7.9C/5.1C)[10 minutes]	3.0C(8.6C/5.6C)[11 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	3.9C(5.8C/1.9C)[36 minutes]	2.6C(5.1C/2.5C)[10 minutes]	3.2C(6.1C/2.9C)[26 minutes]	3.1C(5.1C/2.0C)[23 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	4.6C(6.0C/1.4C)[5 minutes]	3.9C(3.2C/5.0C)[6 minutes]	3.7C(6.4C/2.7C)[9 minutes]	3.8C(5.2C/1.4C)[5 minutes]
Occasional Door Openings Energy Consumption	0.110 kWh	0.100 kWh	0.065 kWh	0.083 kWh
D. REGULAR DOOR OPENINGS PERFORMANCE DATA				
Number of 60 Second Door Openings	25			
Interval Between Door Openings	20 minutes			
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	4.0C(8.5C/4.5C)[22 minutes]	4.1C(9.2C/5.1C)[6 minutes]	3.0C(9.0C/6.0C)[12 minutes]	3.1C(8.4C/5.3C)[8 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	3.9C(9.0C/5.1C)[11 minutes]	3.9C(8.9C/5.0C)[6 minutes]	2.7C(8.4C/5.7C)[11 minutes]	3.0C(8.7C/5.7C)[10 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	4.3C(6.6C/2.3C)[37 minutes]	3.5C(6.2C/2.7C)[9 minutes]	3.2C(6.1C/2.9C)[27 minutes]	3.1C(5.9C/2.8C)[23 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	4.4C(6.5C/2.1C)[10 minutes]	4.6C(6.0C/1.4C)[5 minutes]	3.6C(6.4C/2.8C)[10 minutes]	3.7C(6.1C/2.4C)[5 minutes]
Regular Door Openings Energy Consumption	0.147 kWh	0.170 kWh	0.092 kWh	0.125 kWh
D. REGULAR DOOR OPENINGS PERFORMANCE DATA				
Number of 60 Second Door Openings	33			
Interval Between Door Openings	15 minutes			
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	3.5C(8.9C/5.4C)[19 minutes]	3.7C(9.6C/5.9C)[8 minutes]	3.7C(9.7C/6.0C)[12 minutes]	2.9C(8.6C/5.7C)[10 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	3.2C(9.4C/6.2C)[9 minutes]	3.3C(9.0C/5.7C)[7 minutes]	3.4C(8.4C/5.0C)[11 minutes]	2.8C(9.5C/6.7C)[12 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	3.6C(7.3C/3.7C)[37 minutes]	3.5C(6.7C/3.2C)[10 minutes]	3.6C(6.5C/2.9C)[17 minutes]	3.0C(6.6C/3.6C)[34 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	4.1C(7.3C/3.2C)[11 minutes]	4.6C(7.1C/2.5C)[6 minutes]	4.1C(6.5C/2.4C)[10 minutes]	3.5C(6.8C/3.3C)[8 minutes]
Regular Door Openings Energy Consumption	0.188 kWh	0.240 kWh	0.152 kWh	0.165 kWh

Figure 5. Fridge temperature and energy performance data from carrying out three different frequencies of door openings over an 8-hour period.

FREEZER DATA

Two freezers were examined. The energy consumption, temperature data and door opening recovery times are shown in figure 6.

	Liebherr	Liebherr
Manufacturer	SRFvg3511	SRFvg400120B
Model		
Net Capacity (L)	257	394
PERFORMANCE DATA		
kWh/Day at -20C Set Point	1.265	1.148
Energy - W/L/Day	4.92	2.91
Top Comp. Mean Air Temp(Lowest/Highest)[Pull Down Time]	-18.8C(-19.3C/-17.2C)[141 minutes]	-19.7C(-20.2C/-18.9C)[122 minutes]
Middle Comp. Mean Air Temp(Lowest/Highest)[Pull Down Time]	-20.9C(-21.4C/-20.6C)[142 minutes]	-20.1C(-20.3/-19.7C)[121 minutes]
Middle Comp. Mean Sample Temp(Lowest/Highest)	-21.1C(-21.5C/-21.1C)	-20.3C(-20.5C/-20.3C)
Bottom Comp. Mean Air Temp(Lowest/Highest)[Pull Down Time]	-20.0C(-20.5C/-19.4C)[53 minutes]	-22.4C(-23.3C/-21.2C)[91 minutes]
WARM UP TIME TO -9C		
Top Compartment	151 minutes	132 minutes
Middle Compartment	182 minutes	111 minutes
Middle Compartment Sample	186 minutes	122 minutes
Bottom Compartment	164 minutes	114 minutes

Figure 6. Liebherr freezer energy and temperature performance.

Units were then subjected to two timed door openings (figure 7).

	Liebherr	Liebherr
Manufacturer	SRFvg3511	SRFvg400120B
Model		
Net Capacity (L)	260	298
PERFORMANCE DATA		
A. Single 60 Second Door Opening		
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-18.9C(-10.2C/8.7C)[35 minutes]	-19.9C(-17.5C/2.4C)[19 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-20.8C(-20.2C/0.6C)[11 minutes]	-20.0C(-18.6C/1.4C)[24 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-21.1C(-20.7C/0.4C)[11 minutes]	-20.3C(-19.6C/0.7C)[34 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-20.2C(-16.5C/3.7C)[22 minutes]	-23.2C(-18.1C/5.1C)[8 minutes]
B. Single 90 Second Door Opening		
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-18.8C(-5.1C/13.7C)[39 minutes]	-20.1C(-15.8C/4.3C)[14 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-20.8C(-19.5C/1.3C)[14 minutes]	-20.0C(-17.4C/2.6C)[22 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-21.0C(-20.1C/0.9C)[39 minutes]	-20.3C(-18.7C/1.6C)[37 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-20.2C(-14.7C/5.5C)[25 minutes]	-23.2C(-14.8C/8.4C)[17 minutes]
Door Opening Energy Cost (A+B)	0.093kWh	0.086 kWh

Figure 7. Freezer door opening recovery times and energy consumed from carrying out a 60 second and 90 second door opening.

Next, both units were subjected to 3 different frequencies of 60 second door openings. Each sequence of door openings was carried out over an 8-hour period to reflect a working day of operation. The door

opening recover times were measured following the final door opening of each sequence. The energy consumed by carrying out each door opening sequence was also recorded (figure 4).

Manufacturer	Liebherr	
Model	SRFvg3511	SRFvg400120B
Net Capacity (L)	260	298
C. OCCASIONAL DOOR OPENINGS PERFORMANCE DATA		
Number of 60 Second Door Openings	17	
Interval Between Door Openings	30 minutes	
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-19.7C(-8.7C/11.0C)[17 minutes]	-19.1C(-17.6C/1.5C)[16 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-21.3C(-19.1C/2.2C)[6 minutes]	-19.3C(-18.2C/1.1C)[14 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-21.8C(-20.3C/1.5C)[0 minutes]	-19.8C(-19.4C/0.4C)[0 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-20.3C(-15.6C/4.7C)[14 minutes]	-21.3C(-16.9C/4.4C)[8 minutes]
Occasional Door Openings Energy Consumption	0.633 kWh	0.840 kWh
D. REGULAR DOOR OPENINGS PERFORMANCE DATA		
Number of 60 Second Door Openings	25	
Interval Between Door Openings	20 minutes	
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-18.6C(-4.4C/14.2C)[35 minutes]	-18.9C(-16.2C/2.7C)[20 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-20.5C(-16.8C/3.7C)[8 minutes]	-19.8C(-17.8C/2.0C)[18 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-20.8C(-18.0C/2.8C)[0 minutes]	-20.0C(-18.8C/1.2C)[0 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-19.7C(-13.0C/6.7C)[5 minutes]	-21.3C(-17.6C/3.7C)[2 minutes]
Regular Door Openings Energy Consumption	0.801 kWh	0.987 kWh
D. REGULAR DOOR OPENINGS PERFORMANCE DATA		
Number of 60 Second Door Openings	33	
Interval Between Door Openings	15 minutes	
Top Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-18.7C(-3.6C/15.1C)[32 minutes]	-19.6C(-15.6C/4.0C)[20 minutes]
Middle Comp. Start Air Temp(Peak/Rise)[Recovery Time]	-20.5C(-16.0C/4.5C)[9 minutes]	-19.9C(-16.9C/3.0C)[15 minutes]
Middle Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-20.7C(-17.3C/3.4C)[0 minutes]	-20.3C(-18.1C/2.2C)[0 minutes]
Bottom Comp. Start Sample Temp (Peak/Rise)[Recovery Time]	-19.6C(-11.7C/7.9C)[10 minutes]	-22.0C(-17.0C/5.0C)[4 minutes]
Regular Door Openings Energy Consumption	1.221 kWh	1.323 kWh

Figure 8. Freezer temperature and energy performance data from carrying out three different frequencies of door openings over an 8-hour period.

It must be noted that on some occasions the freezer door opening recovery times for the glycol probes were 0 minutes. This was because prior to and following the final door opening of a sequence the probe temperature was already colder than the mean temperature which was used to measure door opening recovery (figures 9 and 10). One explanation for this is the compressors being on more frequently because of the numerous door openings. The refrigerated cold air cascades down with the solid drawers helping to retain the cold air. The configuration of the refrigeration system inside the chamber appears to be highly effective in minimizing temperature spikes following door openings. This would also explain the increasing energy consumption of each door opening sequence. The frequent door opening sequence resulted in the SRFvg400120B consuming an extra 1.323kWh of energy. However, this energy is effectively expended resulting in temperatures no warmer than -15.6C being recorded with a maximum door opening recovery time of 20 minutes.

The case is very similar with the SRFvg3511 with the exception being in its top compartment. This compartment does not have a solid drawer and therefore cold air is not retained, resulting in higher temperature rises. Both freezers only had wire drawers in their bottom compartments. However, these compartments were also resilient to temperature spikes and had short door opening recovery times, probably because of the cold air falling from the above chambers.

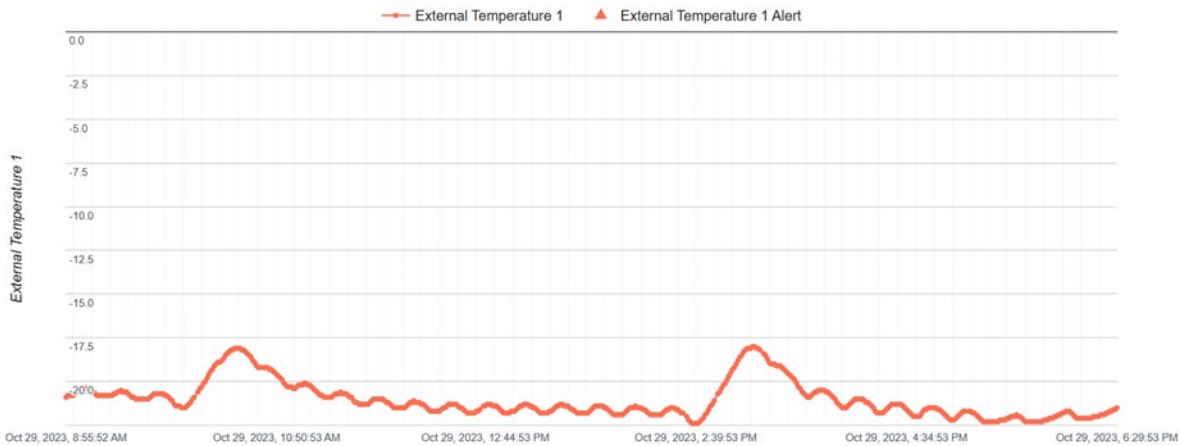


Figure 9. SRFvg3511 sample presentative probe temperatures during regular door opening sequence. Note that the two temperature peaks are recovered prior to the final door opening of the sequence.

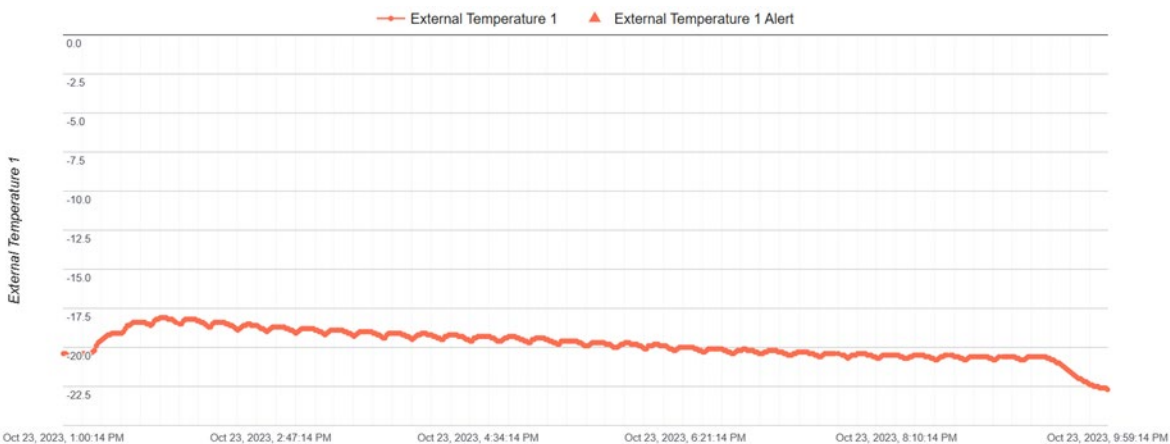


Figure 10. SRFvg400120B sample presentative probe temperatures during frequent door opening sequence.



CONCLUSION

The data for both the fridges and freezers indicates that the Liebherr units are capable of withstanding heavy usage. Temperature rises following door openings are quickly recovered. In the case of fridges, even following the frequent door opening sequence of testing (33 one-minute door openings carried out in 8 hours) all probe temperatures recover in ≤ 37 minutes. The freezers have their refrigerated airflow unit positioned in the ceiling of their chamber. This positioning ensures that following any door opening cold air is focused directly down into each compartment, minimizing temperature rises during door openings and hastening the door opening recovery times.

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