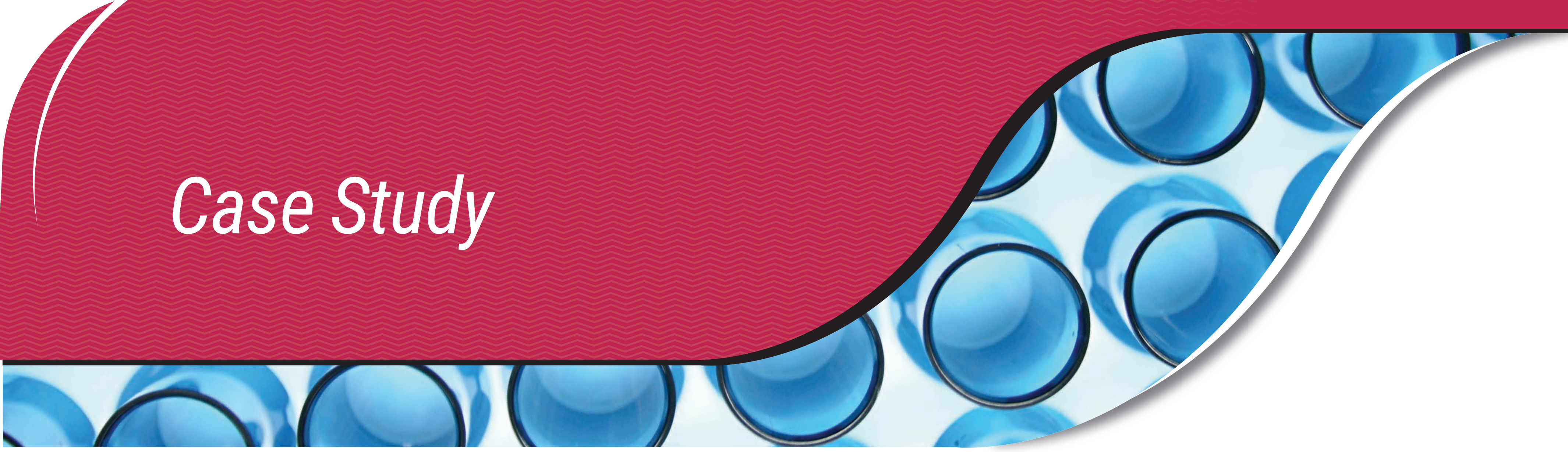

ULT freezer best practice: Eppendorf F570H performance, University of Bristol

Andy Evans - Green Light Laboratories Ltd

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. In recent months, the rises in energy costs has further placed emphasis upon lab equipment running costs and means by which energy can be conserved. ULT freezer best practice is often promoted by individual organisations, manufacturers, insurers and LEAF (the leading lab sustainability certification scheme). Although best practice is widely encouraged very little quantified data exists outside of changing the set temperature of the ULT freezer from -80°C to -70°C. By warming up, modern ULT freezer energy consumption will be reduced by 18-34% depending on the model, age & condition of the unit. However, the energy cost of bad practice has rarely been quantified.

Quantifying bad practice

Quantifying the impact of bad practice was carried out at the Learning and Research Centre, University of Bristol. The study was jointly commissioned by Scientific Laboratory Supplies Ltd (SLS) and Eppendorf UK. The ULT freezer tested was the Eppendorf F570h. The laboratory space used was air conditioned with an ambient of 23°C (+/-1.5°C). This case study used the Logicall Wireless Monitoring system utilising 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 centre point of each shelf (*Figure 1*).

Figure 1: The F570h fitted with PT1000 probes and energy monitor.

Furthermore, additional probes were positioned at the back of the top compartment (compartment 1) and the front of the bottom compartment (compartment 5). The F570h was first tested without any poor usage/conditions. This first step in testing provided the baseline data by which the impacts of bad practice could be measured against.

ULT freezer bad practice

There are multiple actions an end user can routinely carry out which are deemed beneficial to the running costs and lifespan of their ULT freezer. To measure the impact of such actions, the opposite action was taken. The impact was measured in terms of energy consumption and temperature performance. The first action of bad practice taken was not keeping a clean filter.

Blocked filter

The filter of the ULT freezer traps dust and particles that accompany air being drawn through the ULT freezer by the fan. The fan cools the condenser of the refrigeration system, essential for the operation of the ULT freezer. During operation of the ULT freezer the filter will become dirty, and as dirt accumulates it will increasingly block the filter (*Figure 2*).

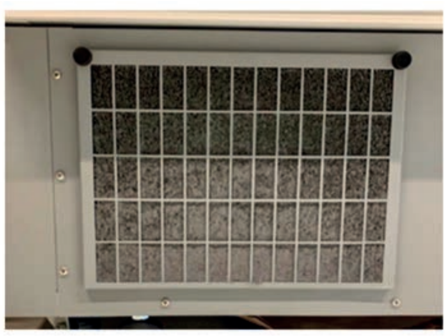

Figure 2: Dirty filter becoming increasingly blocked.

To simulate this during the case study the filter was blocked on both sides using card blocking 50% and 75% of the available filter area (*Figure 3*). To maintain adequate airflow through and around, the positioning, spacing, of a ULT freezer is also included in best practice.

Poor Spacing

Keeping a distance of ≥50cm at the sides and rear of the ULT freezer is another action an end user can take. Doing so provides the space for airflow, allowing the warm air ejected at the rear of the unit to rise and dissipate. To simulate poor spacing the rear of the ULT freezer was pushed flat against the wall with boxes and containers placed on top and on both sides of the freezer (*Figure 4*).

Figure 3: The filter with 75% of the surface area blocked.

Figure 4: On the left, poor spacing. Placing a ULT freezer back to back with another is another form of poor spacing was examined separately.

Back to back with another ULT freezer

Akin to poor spacing, placing the ULT freezer away from other heat sources allows for the efficient cooling of the refrigeration system. One example of what steps not to take is placing two ULT freezers back to back (*Figure 4*).

Door seal obstruction

Keeping the door seal clean, unobstructed and intact helps to keep the ULT freezer chamber at the desired set temperature and reduces the build up of ice. The action taken to obstruct the door seal is shown in *Figure 5*.

Figure 5: Left; securing the 45cm long ruler to the top left-hand side of the opened freezer created at 3.8mm gap (right) between the door seal and the freezer chamber. The obstructed seal spanned the entire height of the top freezer compartment (1) and ~50% of that of compartment 2.

To carry out the impact of each instance of poor practice the following steps were taken (*Figure 6*). The measurements taken and the unit dimensions used for to calculate the energy data are shown in *Figures 7 & 8*.

Action	Description
Step 1: Application	Action taken to simulate bad practice. Unit left to stabilize for ≥24 hours.
Step 2: Energy & Temperature Performance	Unit has their energy consumption measured and temperature peformance recorded for a period of ≥24 hours.
Step 3: Door Opening	A timed door opening of 60 seconds is carried out with the temperature rises and recovery times recorded. Unit left for ≥24 hours following the door opening.

Figure 6: Applying each type or combination of bad practice during the case study.

Usable Capacity	The measured internal capacity of the freezer where contents may be placed. Each compartment is individually measured as a vertical projection of the shelf area, providing that this space is accessible. The total of those compartments is the Internal Volume of the unit, expressed in litres rounded up to the nearest 0.1L.
Door Opening Recovery Times	The recovery time (in minutes) is the time taken following a timed door opening for the last probe in the freezer to either (1) recover to their mean temperature for that setpoint or (2) to recover to the desired setpoint temperature (-80°C).
Energy Consumption	The energy consumed by a freezer at a set temperature. The energy consumption data is measured in kWh/day and standardised to Watts Per Litre Per Day (W/L/Day). This is calculated using following equation (kWh/day/Usable Capacity Litres)*1000. Both the kWh/day and W/L/Day data is reported.

Figure 7: Definitions of the measurements taken during the study. Note that W/L/Day was calculated using the Usable Capacity as shown in Figure 8.

Capacity Data	
Manufacturer - Model	Eppendorf - F570h
Usable Capacity	508.62 Litres
Published Net Capacity	570 Litres
Unit Footprint	1694.2 Litres
Pub. Net Vs Usable Capacity	61.4 Litres Smaller
Pub. Vs U.C Difference	10.8% Smaller
U.C. as % of Footprint	30.0%

Figure 8: The space occupied and made available by the F570h.

The results of the testing upon temperature performance and door opening recovery times are shown in *Figure 9*. The impact of the different forms of bad practice upon energy consumption are shown in *Figure 10*.

Normal

Probe Location	Highest	Lowest	Variance	Mean	60 Sec D/O Start Temp.	Peak Temperature	Temperature Rise	60 Sec D/O Recovery (mins)
Compartment 1 Back	-76.5	-79.7	3.2	-78.1	-77.4	-57.8	19.6	45
Compartment 1 Middle	-75.7	-77.5	1.8	-76.7	-76.9	-54.2	22.7	74
Compartment 2 Middle	-77.8	-79	1.2	-78.4	-78.6	-66.5	12.1	104
Compartment 3 Middle	-78.1	-79.1	1	-78.7	-78.6	-65.1	13.5	104
Compartment 4 Middle	-77.7	-78.4	0.7	-78.1	-77.8	-69.9	7.9	44
Compartment 5 Middle	-74.9	-75.5	0.6	-75.2	-75.1	-68.9	6.2	35
Compartment 5 Front	-74.9	-75.2	0.3	-75	-74.9	-63	11.9	37

50% Filter Block

Probe Location	Highest	Lowest	Variance	Mean	60 Sec D/O Start Temp.	Peak Temperature	Temperature Rise	60 Sec D/O Recovery (mins)
Compartment 1 Back	-76.7	-79.1	2.4	-78	-78.7	-64.3	14.4	49
Compartment 1 Middle	-76	-77.4	1.4	-76.8	-77.3	-63.6	13.7	84
Compartment 2 Middle	-77.7	-78.8	1.1	-78.3	-78.6	-67.2	11.4	102
Compartment 3 Middle	-78.2	-79	0.8	-78.7	-78.9	-65.5	13.4	145
Compartment 4 Middle	-77.8	-78.4	0.6	-78.1	-78	-70	8	54
Compartment 5 Middle	-75.5	-75.9	0.4	-75.7	-75.5	-75.6	-69.2	44
Compartment 5 Front	-75.1	-75.5	0.4	-75.3	-75.1	-64.1	11	49

75% Filter Block

Probe Location	Highest	Lowest	Variance	Mean	60 Sec D/O Start Temp.	Peak Temperature	Temperature Rise	60 Sec D/O Recovery (mins)
Compartment 1 Back	-76.9	-79.1	2.2	-78.1	-78.6	-65.6	13	70
Compartment 1 Middle	-75.7	-77.2	1.5	-76.5	-76.8	-64	12.8	111
Compartment 2 Middle	-77.4	-78.6	1.2	-78.1	-77.7	-67	10.7	102
Compartment 3 Middle	-78.8	-78.8	0	-78.5	-78.2	-64.9	13.3	107
Compartment 4 Middle	-77.6	-78.3	0.7	-78	-77.9	-69.5	8.4	77
Compartment 5 Middle	-75.4	-75.8	0.4	-75.6	-75.5	-69.1	6.4	49
Compartment 5 Front	-74.8	-75.3	0.5	-75	-75.2	-64.4	10.8	53

Poor Spacing

Probe Location	Highest	Lowest	Variance	Mean	60 Sec D/O Start Temp.	Peak Temperature	Temperature Rise	60 Sec D/O Recovery (mins)
Compartment 1 Back	-77.2	-79.3	2.1	-78.3	-79.2	-65.9	13.3	70
Compartment 1 Middle	-75.8	-77.2	1.4	-76.5	-77	-63.5	13.5	99
Compartment 2 Middle	-77.6	-78.7	1.1	-78.2	-78.6	-67	11.6	128
Compartment 3 Middle	-78.2	-78.9	0.7	-78.6	-78.9	-66.1	12.8	132
Compartment 4 Middle	-77.6	-78.3	0.7	-78	-77.8	-69.8	8	70
Compartment 5 Middle	-75.4	-76	0.6	-75.6	-75.7	-69.2	6.5	41
Compartment 5 Front	-74.9	-75.2	0.3	-75	-74.9	-63.8	11.1	47

Back To Back With Another ULT Freezer

Probe Location	Highest	Lowest	Variance	Mean	60 Sec D/O Start Temp.	Peak Temperature	Temperature Rise	60 Sec D/O Recovery (mins)
Compartment 1 Back	-76.9	-79.1	2.2	-78	-78.9	-66.2	12.7	65
Compartment 1 Middle	-75.5	-77	1.5	-76.3	-76.8	-64	12.8	97
Compartment 2 Middle	-77.2	-78.4	1.2	-77.9	-77.9	-67.2	10.7	100
Compartment 3 Middle	-77.9	-78.7	0.8	-78.3	-78.6	-65.5	13.1	131
Compartment 4 Middle	-77.4	-78.1	0.7	-77.8	-77.9	-69.5	8.4	67
Compartment 5 Middle	-75.2	-75.7	0.5	-75.4	-74.9	-69.4	5.5	40
Compartment 5 Front	-74.4	-74.8	0.4	-74.6	-74.6	-64.3	10.3	45

Door Seal Obstruction(DSO)

Probe Location	Highest	Lowest	Variance	Mean	60 Sec D/O Start Temp.	Peak Temperature	Temperature Rise	60 Sec D/O Recovery (mins)
Compartment 1 Back	-74.4	-76.7	2.3	-75.7	-74.9	-62.9	12	320
Compartment 1 Middle	-72.1	-74	1.9	-73.2	-72.9	-59.8	13.1	388
Compartment 2 Middle	-75.6	-76.8	1.2	-76.2	-76.2	-64	12.2	118
Compartment 3 Middle	-76.7	-77.5	0.8	-77.1	-76.8	-64.1	12.7	117
Compartment 4 Middle	-77	-77.8	0.8	-77.4	-77.1	-69.8	7.3	69
Compartment 5 Middle	-75.2	-75.7	0.5	-75.4	-75.4	-68.3	7.1	44
Compartment 5 Front	-74.1	-74.7	0.6	-74.4	-74.3	-65	9.3	55

75% Filter Block & DSO

Probe Location	Highest	Lowest	Variance	Mean	60 Sec D/O Start Temp.	Peak Temperature	Temperature Rise	60 Sec D/O Recovery (mins)
Compartment 1 Back	-76.2	-78.4	2.2	-77.3	-76.6	-64.3	12.3	300
Compartment 1 Middle	-75.9	-77.5	1.6	-76.8	-75.1	-62.3	12.8	357
Compartment 2 Middle	-76.1	-77.2	1.1	-76.7	-76.2	-64.9	11.3	105
Compartment 3 Middle	-77	-77.7	0.7	-77.4	-76.7	-64.9	11.8	111
Compartment 4 Middle	-77	-77.8	0.8	-77.4	-76.7	-69.5	7.2	55
Compartment 5 Middle	-75.1	-75.5	0.4	-75.2	-75	-67.9	7.1	46
Compartment 5 Front	-73.9	-74.4	0.5	-74.2	-74.1	-62.8	11.3	52

75% Filter Block, Poor Spacing & DSO

Probe Location	Highest	Lowest	Variance	Mean	60 Sec D/O Start Temp.	Peak Temperature	Temperature Rise	60 Sec D/O Recovery (mins)
Compartment 1 Back	-76.3	-78.6	2.3	-77.6	-78	-67.9	10.1	310
Compartment 1 Middle	-75	-77.1	2.1	-76.3	-76.9	-64.7	12.2	376
Compartment 2 Middle	-76.1	-77.6	1.5	-77	-77.5	-66.1	11.4	114
Compartment 3 Middle	-77	-77.8	0.8	-77.4	-77.6	-65.2	12.4	112
Compartment 4 Middle	-77.5	-77.5	0	-77.1	-76.9	-71.3	5.6	53
Compartment 5 Middle	-74.1	-75	0.9	-74.6	-74.2	-68.7	5.5	39
Compartment 5 Front	-72.9	-73.6	0.7	-73.2	-72.9	-64.6	8.3	48

Poor Spacing & 75% Filter Block

Probe Location	Highest	Lowest	Variance	Mean	60 Sec D/O Start Temp.	Peak Temperature	Temperature Rise	60 Sec D/O Recovery (mins)
Compartment 1 Back	-77.1	-79.5	2.4	-78.5	-78.1	-63.2	14.9	80
Compartment 1 Middle	-75.2	-78	2.8	-77.2	-77.3	-54.6	22.7	112
Compartment 2 Middle	-76.6	-78.8	2.2	-78.3	-78	-67.4	10.6	113
Compartment 3 Middle	-78.5	-78.8	0.3	-78.5	-78.2	-66.6	11.6	140
Compartment 4 Middle	-77.3	-78.6	1.3	-77.7	-77.4	-69.2	8.2	56
Compartment 5 Middle	-74.9	-76.2	1.3	-75.2	-75.1	-68.5	6.6	45
Compartment 5 Front	-74.1	-75.4	1.3	-74.4	-74.3	-62.7	11.6	54

Figure 9: Temperature performance (Celsius) of F570h when bad practice is followed.

Step	F570h Status	Energy Consumption		
		kWh/day	W/L/Day	% Energy Increase
1	Normal	7.995	15.72	
2	50% Filter Block	8.002	15.73	0.09
3	75% Filter Block	8.309	16.34	3.93
4	Poor Spacing	8.196	16.11	2.51
5	Back to Back with another ULT Freezer	8.127	15.98	1.65
6	Door Seal Obstruction	11.062	21.75	38.36
7	75% Filter Block & Door Seal Obstruction	10.21	20.07	27.70
8	75% Filter Block & Poor Spacing & Door Seal Obstruction	12.047	23.69	50.68
9	75% Filter Block & Poor Spacing	8.892	17.48	11.22

Figure 10: Impacts of bad practice on F570h energy performance.

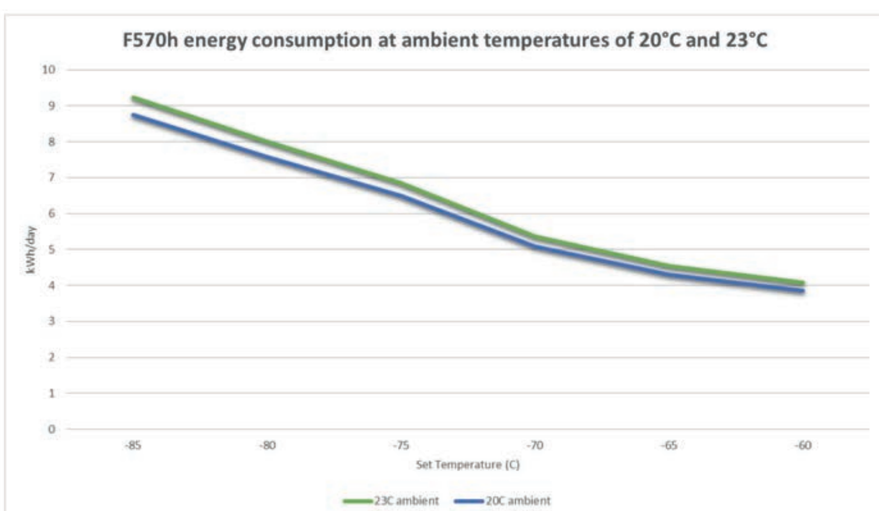

Figure 11: F570h energy consumption at different ambient temperatures. On average, placing the ULT freezer in the 20°C

During the case study the F570h was also tested in a colder freezer room. The temperature in the freezer room was measured as 20°C(+/-1°C). The impact of ambient temperature upon energy consumption is show in *Figure 11*.

Discussion

Individually, blocking the filter and poor spacing did have an effect upon energy consumption, increasing running costs be 3.9% and 2.5% respectively. When considering the impacts of the individual types of bad practice it is clear that obstruction of the door seal has the greatest impact in both the energy and temperature performance of the unit. The energy consumption (step 6 in *Figure 10*) increased by over 38% and door opening recovery times increasing up to fivefold. It could be expected that when bad practices were combined energy consumption would also increase. However, when blocking the filter by 75% and obstructing the seal were combined (step 7, *Figure 10*) this was not the case. One possible explanation may be icing (*Figure 11*). Icing continued to build following the initial obstruction of the seal. This may also highlight why the temperatures in compartments 1 and 2 (*Figure 9*) were the warmest during step 6 (door seal obstruction, only) compared to later steps where the door seal remained obstructed but other bad practices were included.

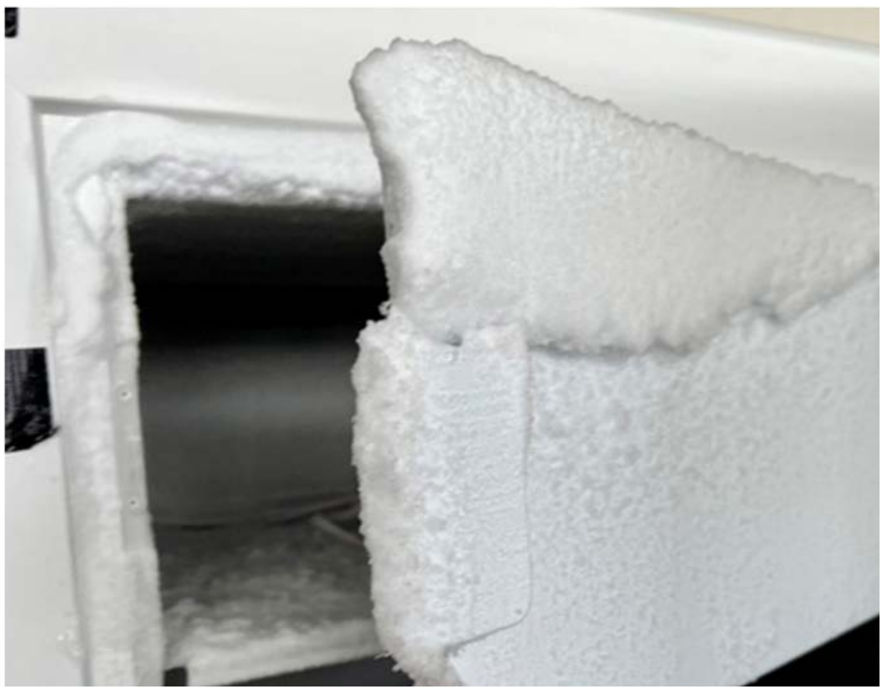

Figure 12: Icing build up progressed throughout the testing steps when the door seal was obstructed and was localised to the inner door and door frame of compartments 1 and 2.

When combining blocking the filter 75%, poor spacing and obstructing the door seal energy consumption increased by over 50%. This increase may be explained due to:

1. The compressor running more frequently to maintain temperature as a result of the door seal obstruction.
2. The impaired ability to both take in air to cool its condenser (filter blocking) and efficiently remove the heated air (poor spacing) from its vicinity

With energy conservation being a vital step towards sustainable lab operations. The testing has shown that raising the set temperature of the ULT freezer and lowering the ambient temperatures do confer much needed energy savings. However, the impacts of bad practice must be conveyed to end users so that their impacts may be avoided (*Figure 13*).

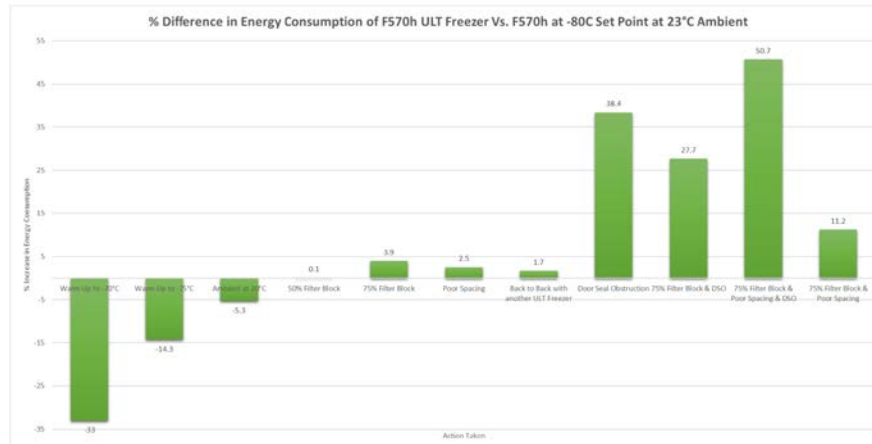

Figure 13. Impacts of actions and bad practice upon ULT freezer energy consumption.

The presence of bad practice in ULT freezer usage may easily eliminate and outweigh the energy savings gained by warming up the freezer set temperature and/or placing the unit is a cooler environment.

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