THE UNIVERSITY of EDINBURGH
Social Responsibility & Sustainability

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Freezers best practice

Executive summary

This paper summarises the findings of research undertaken by the University of Edinburgh's Department for Social Responsibility and Sustainability into best practice in Ultra Low Temperature (ULT) freezer management. It incorporates international best practice as published on the websites of various universities, as well as information gained through judging applications for the Edinburgh Sustainability Awards, and good practices in University of Edinburgh laboratories.

University of Edinburgh lab users should also familiarise themselves with the sustainable cold storage policy and guidance.

This document describes a number of actions and the potential savings, including:

Replace old freezers (up to £400/year saving per freezer)

Defrost freezers regularly (around £200/year saving per freezer)

Save space by clearing out old samples (save up to £1,000 per year for every ULT freezer you can retire)

Run your freezers a little warmer (up to £300/year saving per freezer)

Out with the old, in with new…

The problem:

Older freezers can use as much as £1000 annually in 'plug load' electricity (i.e. not including their impact on room air cooling systems, while new freezers can use less than £600 plug load annually. Investigations at the National Institutes of Health in the United States of America have indicated that for every year of a ULT freezer's life its energy consumption increases by 3%[1].

The solution:

The Roslin Institute has an ongoing replacement of their oldest ULT freezers, with a requirement that new purchases are energy efficient.

This is also an approach being taken by the National Institutes of Health.

[1] Gumapas & Simons, World Review of Science, Technology and Sustainable Development, Vol 10, No.s 1/2/3, 2013

Choked up with ice and dust…

The problem:

Freezers which are not regularly defrosted accumulate frost and ice, reducing internal space (and thus exacerbating the problem of a continual demand for more and more ULT freezers). In addition to reducing the available space for sample storage, poorly defrosted ULT freezers use more energy to operate. Investigations at the National Institutes of Health in the United States of America have indicated that there is a difference in annual operating costs of the equivalent of around £160 between an ice-free freezer and a severely iced up freezer[2].

Freezers draw air through a filter to cool condenser fins, helping the removal of heat from the internal space. If these filters and/or fins are dusty the removal of heat is less effective and the mechanisms for removal need to work harder. Investigations at the National Institutes of Health in the United States of America have indicated that there is a difference in annual operating costs of the equivalent of around £230 between freezer with clean filters and fins and a freezer with severely dusty filters and fins[3].

Freezer defrosting and cleaning filters and fins requires planning and staff time. Reductions in lab technical support staff numbers shifts the onus onto researchers.

The Solution:

Air filters can usually be easily accessed at ground level on the front of the freezer, and can be unscrewed by hand for cleaning with a vacuum cleaner. At the same time the heat exchanger fins will be accessible behind the filter, and should also be cleaned with a vacuum cleaner.

Removal of hard ice build-up is best done by switching off and defrosting the freezer (transferring contents to a spare/ "hotel" freezer). For softer 'frost' build up, this can be removed without defrosting by careful scraping.

Site visits and auditing for the Edinburgh Sustainability Awards indicated that most of the labs involved outsource mechanical maintenance of freezers - it should be checked what actions are included in these maintenance contracts to ensure filters and fins are cleaned.

The awards audits also showed that good defrosting practices were in place at The Roslin Institute, the Biology Teaching Organisation, the School of Chemistry, the Wellcome Trust Clinical Research Facility, SynthSys labs, and the Institute of Genetic and Molecular Medicine. Typically, these labs undertake regular and planned defrosting schedules, and/or audits from senior lab staff.

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[2] Ibid.
[3] Ibid.

Best use of valuable space…

The problem:

ULT freezers are expensive to purchase and have high operational costs due to their plug-load and air conditioning energy consumptions. However, the number of ULT freezers across the University of Edinburgh is over 600 and growing, adding strain to departmental budgets and diverting money away from other uses.

The solution:

Lab users/lab groups should ensure they only use ULT freezers to store items which absolutely must be stored at these temperatures. There are three factors to consider here:

Firstly, do you need to keep all of those samples?

If you are a lab user who stores samples in ULT freezers you can help to reduce significant departmental costs of purchasing and running ULT freezers by regularly checking the samples you are storing and removing those which are now redundant/no longer needed.

Secondly, do your samples need to be stored in ULT freezers?

There is a growing body of evidence which suggests that some sample types can safely be stored in non-ULT freezers (i.e. at -40^{0}C, -20^{0}C, +4^{0}C or even room temperature)[4] [5] resulting in significant energy savings. Stanford University found that up to 25% of their biological samples (DNA/RNA/bacteria) could be stored at room temperature after a successful trial.[6] University of Boulder Colorado and University of California Irvine host an online database of biological samples which can be stored at -70^{0}C or warmer -. Typically, the suitability of a temperature for sample storage depends on the length of the storage time - if you are storing samples for only a short amount of time it may be safe to store them at a higher temperature. Freeze-thaw cycles may be more important than the storage temperature for degrading samples[7] [8] [9] [10].

Thirdly, are you making best use of storage space?

Efficient use of space in ULT freezers can help to reduce the demand for additional units. Ensuring that your samples are neatly stored in appropriate storage solutions (racks/boxes) for the type and size of material will allow more items to be stored in the existing number of freezers. Where possible try to avoid storing bulky items in freezers if you can divide them up into more easily stored small samples/aliquots. Storing your samples in racks/boxes can also make them easier to quickly transfer in the event of a freezer failure.

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[4] Colins et al, (1993), "Storage temperature and differing methods of sample preparation in the measurement of urinary albumin" Diabetologica, vol 36, issue 10, pp 993-997

[5] http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/ulf_freezer_user_guide.pdf (U.S. Dept of Energy "Store Smart" ULT freezer guide)

[6] http://www.goodcampus.org/uploads/DOCS/106-case_10_-_uni_california_final_25_2_11.pdf and http://sustainable.stanford.edu/sites/default/files/documents/Stanford_Room_Temp_Pilot_May09.pdf

[7] http://bitesizebio.com/19700/freeze-thaw-cycles-and-why-we-shouldnt-do-it

[8] M. S. Charde et al. (2014) "Review: The procurement, storage and quality assurance of frozen blood and tissue biospecimens" International Journal of Pharmacological Research Volume 4 Issue 2 (2014)

[9] Brand, J.J., "Cryopreservation of Cyanobacteria" http://www-cyanosite.bio.purdue.edu/protocols/cryo.html

[10] B. L. Mitchell et al., (2005) "Impact of Freeze-thaw Cycles and Storage Time on Plasma Samples Used in Mass Spectrometry Based Biomarker Discovery Projects", Cancer Informatics 1(1): 98–104.

Good practice has been observed around the University of Edinburgh including:

Hugh Robson Building charge for space in the Hotel Freezer.

BTO consolidate their materials into fewer fridges/freezers over the summer holiday and switch off extraneous ones.

Wellcome Trust have good racking to make best use of space, and control samples using a LIMS (providing Biobank storage for researchers).

IGMM consolidated the contents of c.40 small LN2 storage tanks into 2 large ones saving c.£18k annually in LN2 refill costs.

SynthSys allocate specific shelves/space in ULT freezers to lab groups.

QMRI biobanking is done on a ‘cost recovery’ basis.

Chemistry use modular storage containers in fridges and freezers to improve efficiency of space use.

Chancellors' Building are investigating room temperature storage of DNA.

Space to breathe…

The problem:

ULT freezers operate by removing heat from inside the freezer cabinet and expelling it through heat dissipation mechanisms at the back of the freezer. In an enclosed space this quickly results in the air temperature of the room rising to levels which are uncomfortable for the users and also cause the freezer to work harder to maintain the internal temperature. To counteract this, energy intensive air cooling/mechanical ventilation equipment is installed and operated, adding further to the energy consumption of operating freezers.

The solution:

Dedicated spaces with abundant 'natural ventilation' have been constructed at the Roslin Institute to house the majority of their ULT freezers. These spaces have large louvered vents and fans which allow external air to be used either passively (fans switched off, air moves with convection and pressure differentials/wind) or actively (fans switched on to drive air through the space) to remove hot air from the freezers. If external air temperature rises above a certain level the louvers are closed and the room cooled with air conditioning (this is not required very often). This significantly reduces the amount of air conditioning required to keep the air temperature of the freezer space at a level which allows the freezers to operate safely and with low energy consumption.

Too cool…?

The problem:

Up until the end of the 20th Century the lowest temperature achievable by many lab freezers was -70^{0}C. Technology improved and newer freezers were able to achieve temperatures of -86^{0}C. The lower temperature (often -80^{0}C) was then adopted by many lab users/groups as a new standard operating practice. The technological advance which led to freezers achieving lower temperatures came at a price - higher energy consumption in terms of both plug-load and impact on air conditioning loads.

The solution:

There has been little evidence produced which shows that operating ULT freezers at -80^{0}C has any benefit for lab research, and, in fact some sources show that a variety of samples are stable at -70^{0}C[11] [12] [13] [14] [15] [16] [17] [18] [19]. Even if your samples do benefit from being stored at -80^{0}C it is a good idea to run your back-up freezers ("hotel freezers") at -70^{0}C or even -60^{0}C to reduce energy consumption, and then adjust them to -80^{0}C when required. Many freezers around the campus have temperature monitors connected to remote alarms which are activated if the temperature rises above a threshold and alert a nominated member of staff. This reduces the need to store samples at a lower temperature in order to have a 'buffer' to give more time between a freezer failure and the internal freezer temperature exceeding a threshold temperature.

Running a freezer at -70^{0}C instead of -80^{0}C can produce almost 30% plug-load energy savings[20] equating to **up to £300 annually**, as well as further savings on room air conditioning. A number of lab users around the University are running freezers at -70^0 including Roslin, IGMM and BTO.

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[11] http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/ulf_freezer_user_guide.pdf (U.S. Dept of Energy "Store Smart" ULT freezer guide)
[12] Tedeschi, R. & De Paoli, P; (2011) "Collection and Preservation of Frozen Microorganisms"; Methods in Molecular Biology Volume 675, pp 313-326
[13] Marino, D, (2013) "Best practices for storing biological samples in ULT freezers" http://www.biocompare.com/Bench-Tips/137747-Best-Practices-for-Storing-Biological-Samples-in-ULT-Freezers
[14] Colins et al, (1993), "Storage temperature and differing methods of sample preparation in the measurement of urinary albumin" Diabetologica, vol 36, issue 10, pp 993-997
[15] De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910 and Reimer, L. and Carroll, K. (2004) Procedures for the storage of microorganisms In: Manual of Clinical Microbiology (Murray, E., Baron, E., Pfaller, M., Tenover, F. and Yolken, R., Eds.), pp. 67–73. ASM Press, Washington, DC
[16] De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910 and Michel, C. and Garcia, C. (2003) Virulence stability in Flavobacterium psychrophilum after storage and preservation according to different procedures. Vet. Res. 34, 127–132.
[17] De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910 and Harbec, P.S. and Turcotte, P. Preservation of Neisseria gonorrhoeae at 20 C. J. Clin. Microbiol. 34, 1143–1146.
[18] De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910 and Sebire, K., McGavin, K., Land, S., Middleton, T. and Birch, C. (1998) "Stability of human immunodeficiency virus RNA in blood specimens as measured by a commercial PCR-based assay". J. Clin. Microbiol. 36, 493–498. And Winters, M.A., Tan, L.B., Katzenstein, D.A. and Merigan, T.C. (1993) "Biological variation and quality control of plasma human immunodeficiency virus type 1 RNA quantitation by reverse transcriptase polymerase chain reaction". J. Clin. Microbiol. 31, 2960–2966.
[19] Mitchell, B.L. et al, (2005) “Impact of Freeze-thaw Cycles and Storage Time on Plasma Samples Used in Mass Spectrometry Based Biomarker Discovery Projects” Cancer Informatics 98–104
[20] Farley M., et. Al., (2013) "Freezer Energy Consumption Report"

Appendix

Lab contacts who can help you with these projects:

Freezer replacement

Brian McTeir, Roslin Institute, brian.mcteir@roslin.ed.ac.uk

Defrost and maintenance

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Efficient use of space

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Moira Nicol, QMRI, Moira.Nicol@ed.ac.uk

David Brown, School of Chemistry, David.Brown@ed.ac.uk

Heather Anderson, Chancellors' Building, Heather.Anderson@ed.ac.uk

Reducing the requirement for air con in freezer rooms

Brian McTeir, Roslin Institute, brian.mcteir@roslin.ed.ac.uk

Running freezers at higher temperatures (e.g. -70^{o}C)

Brian McTeir, Roslin Institute, brian.mcteir@roslin.ed.ac.uk

Stewart McKay, Institute of Genetic and Molecular Medicine, Stewart.McKay@igmm.ed.ac.uk

Useful links and resources

Impact of age, dust, ice, freezer temperature set point and size on energy consumption of freezers

Gumapas & Simons, World Review of Science, Technology and Sustainable Development, Vol 10, No.s 1/2/3, 2013 http://www.inderscience.com/info/inarticle.php?artid=50786

Impacts of cold storage conditions on sample integrity

De Paoli, P, (2005) "Biobanking in microbiology: From sample collection to epidemiology, diagnosis and research", FEMS Microbiology Reviews 29 897–910

Mitchell, B.L. et al, (2005) “Impact of Freeze-thaw Cycles and Storage Time on Plasma Samples Used in Mass Spectrometry Based Biomarker Discovery Projects” Cancer Informatics 98–104

Colins et al, (1993), "Storage temperature and differing methods of sample preparation in the measurement of urinary albumin" Diabetologica, vol 36, issue 10, pp 993-997

Tedeschi, R. & De Paoli, P; (2011) "Collection and Preservation of Frozen Microorganisms"; Methods in Molecular Biology Volume 675, pp 313-326

Marino, D, (2013) "Best practices for storing biological samples in ULT freezers" http://www.biocompare.com/Bench-Tips/137747-Best-Practices-for-Storing-Biological-Samples-in-ULT-Freezers