CARON
Opening Doors for Scientists

WHITE PAPER

THERMAL GEL: A SUPERIOR TEMPERATURE PROTECTION TECHNOLOGY FOR CO_2 INCUBATORS

Bob Dotterer, Engineering Director, and Alan Campbell, VP Marketing

Abstract

Caron's patent-pending GelJacket™ thermal gel provides all the uninterruptable temperature stability advantages of a traditional Water Jacketed incubator, with none of the maintenance issues inherent to that technology. Sealed into the chamber for the life of the unit, and with several times the heat retention capability of water, thermal gel provides a light and effective method of incubator thermal protection.

Introduction

Cells being cultured in-vitro require a stable consistent environment. Temperature, humidity, and CO_2 all need to be kept as close to setpoint as possible, and recover quickly from interruptions caused by the door openings that occur several times a day. Incubators are also vulnerable to power interruptions, which while infrequent in most developed economies, can result in total culture loss when they do occur.

Sealed double-walled incubators were developed during earliest days of cell culture. These units used a gas or electric-heated blanket of insulating water around the chamber to maintain temperature uniformity, recover temperature quickly after a door opening, and conserve heat during a power interruption. Less effective gravity-convection incubators that relied on heated air within gap between the chamber and outer casing, backed up by insulation for temperature maintenance, were also developed. By the early 1900's, the double-wall "water-jacketed" variety had become the standard for the developing field of mammalian in-vitro cell culture, while the lighter, simpler, and cheaper "Air Jacketed" units were relegated to less critical bacteriological culture. Over time, however, "Air Jacket" technical improvements such as forced-air convection and direct-heating of chamber walls, dramatically improved the temperature uniformity and recovery. When combined with their ability to accommodate heat-based decontamination procedures, "Air Jackets" (now commonly known as "Direct Heat") moved back up into the mammalian culture market space alongside Water Jacketed units. Though Water Jackets retain their temperature security advantage for critical culture, their need for regular relocation, to replace evaporated water, their tendency to leak over time, the added risks of extreme temperature and humidity variance due to level float switch failure, and potential for jacket water contamination to spill over into the chamber have all combined to gradually reduce this technology's popularity.

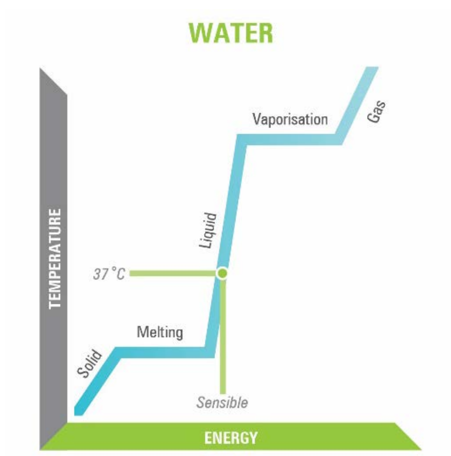
A New Thermal Technology

A third option, however, has recently been developed for incubator temperature maintenance. Phase Change Materials (PCM's) use the transition between material states, at engineered temperature points, to store and release enormous quantities of energy. PCM's take advantage of a basic physical property; that when matter moves from a higher to lower energy state (ie liquid to solid), it gives off latent heat. By adjusting their chemical formula, PCM's can be developed that release that energy at a specific temperature point, and at a constant rate, creating a de-facto heat storage battery.

PCM Gel As Thermal Storage

Energy storage capability for a substance, such as air or water, over a given range is defined as its Sensible heat capacity:

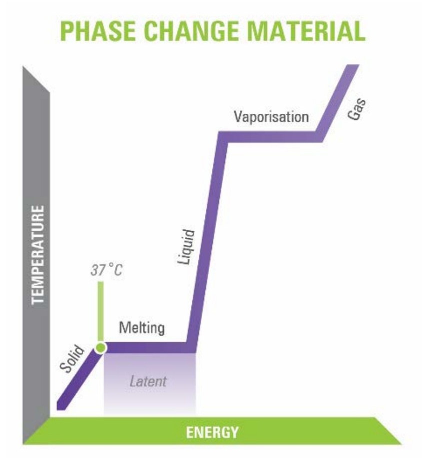
$Q_{sensible} = mc\Delta T$ (Q=heat, m=mass, c=specific heat capacity, and ΔT=change in temperature)



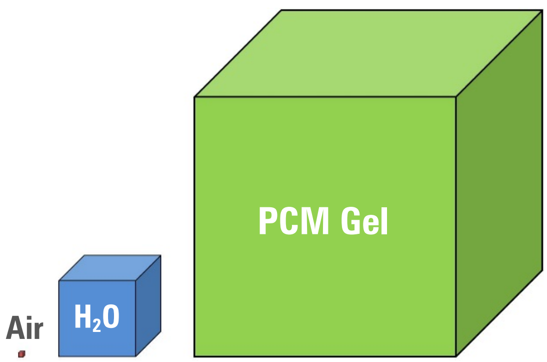
Specific heat capacity depends on material density, with denser materials (such as water) offering greater Sensible capacity than less dense substances (such as air).

Substances, such as PCM's, that change state over a given range, have an additive energy storage capability that is defined as Latent heat capacity, and calculated using a different formula:

$Q_{latent} = mL$ (Q=heat, m=mass, L = specific latent heat)



Specific Latent heat capacity varies depending on the specific elements and phase change (ie.melting, vaporization, fusion) involved. At 37°C, over a 1°C temperature range and due to the latent heat caused by transitioning between a liquid and a solid phase, PCM's actually hold over 40 times the energy, by volume, than water:



	Air	Water	PCM Gel
Density (g/cm3)	0.00115	1	0.82
Latent heat (J/g)	n/a	n/a	205
Specific heat (J/g-K)	1	4.18	2
Volumetric storage capacity	0.0013	4.18	170

Initial PCM Applications

Phase Change materials have become widely used in a variety of applications, ranging from cooling systems for electronics and spacecraft, to therapeutic heating and cooling pads. They are also being evaluated for use as thermal passive storage, for "green" building projects.

PCM Gel & CO_2 Incubators

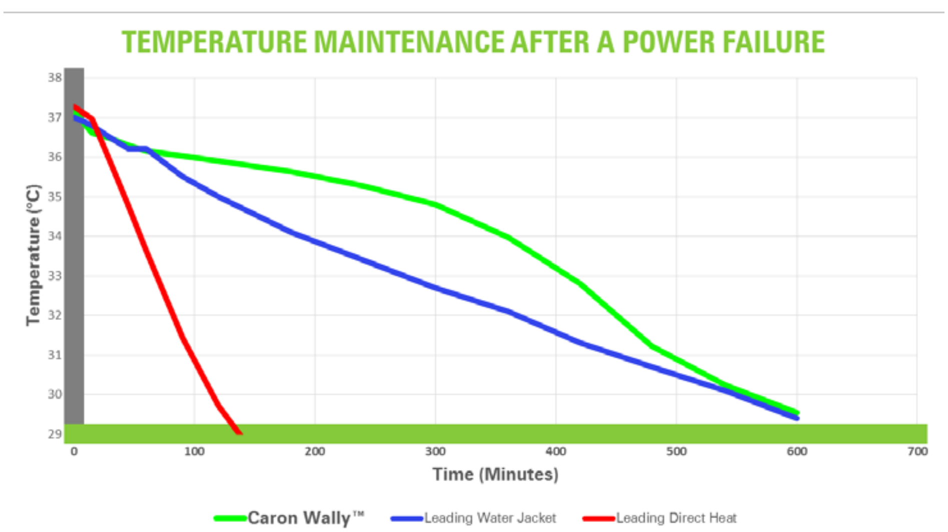
Phase Change Thermal Gel is particularly impactful within the context of CO_2 incubators, radically changing how these units can distribute and store heat. Since its volumetric capacity is much greater than water, far less mass is required to hold temperature than is the case in a Water Jacket. A gel-heated unit would weigh only slightly more than a comparable direct-heat unit. In addition, PCM gel can be sealed into the walls of the unit, cannot become contaminated, and it is stable over time, eliminating the potential for leaks, and the need to periodically “top up” the thermal reservoir.

Phase Change Thermal Gel technology, when used within a CO_2 incubator, combines the benefits of a direct-heat (low weight, low maintenance) and Water Jacket (temperature security) to create a completely new and uniquely valuable incubator category.

Caron Thermal Gel Incubators

Caron has a patent pending for the use of a stable, non-toxic thermal gel within an incubator, and has developed two product lines (Wally™ and Gel Jacket) that employ this technology.

In practice, the thermal stability advantages of PCM are obvious and measurable:



When running at 37°C and presented with a power failure, the Wally CO_2 incubator maintains temperature above 30°C slightly longer (roughly 9 hours) than even the industryleading Water Jacket. A leading Direct Heat unit, under the same circumstances, drops below 30°C in under two hours.

An additional reason for this applied advantage; unlike water, thermal gel can be embedded within the unit door, as well as the 5 chamber walls, creating a thermally stable surface on all six sides of the culture environment.

Caron's novel application of phase change technologies is available both in a space saving lab-friendly format, for general experimental culture, and in a high capacity stackable format, for large volume experimental and scale-up culture.

Conclusion

Existing CO_2 incubator thermal management technologies have remained fundamentally the same since the invention of the laboratory incubator in the late 1800's. Both Air Jacket/Direct Heat and Water Jacket have their own distinct issues, but until recently, there was no alternate approach available. With the commercialization of thermal gel technology, laboratories can select an option that combines all of the benefits of Water and Air Jackets, with none of their legacy technology disadvantages.

Bibliography and References

J. Davis
"The Cell Culture Laboratory." Animal Cell Culture: Essential Methods.
John Wiley & Sons. 14-16. Print, 2011.

A Sharma, V. Tryagi, C. Chen, D. Buddhi.
Review on thermal energy storage with phase change materials and applications
Renewable and Sustainable Energy Reviews, February, Pages 318-345, 2009.

D. Nkwetta, F. Haghighat. Dpt. of Building, Civil & Environmental Engineering.
Thermal energy storage with phase change material – A state-of-the-art review
Sustainable Cities & Society, Volume 10, Pages 87-100, 2014.

S. Sharma, H Kitano, and K Sagara
Phase Change Materials for Low Temperature Solar Thermal Applications
Res. Rep. Fac. Eng. Mie Univ, Vol. 29, pp. 31-64, 2004

H. Mehling, L. Cabeza
Heat and cold storage with PCM: An up to date introduction Into basics and applications
Springer Press, 2008

CARON PRODUCTS & SERVICES, INC. PO Box 715 / Marietta OH 45750 / PHONE 740 373 6809 / 800 648 3042 / FAX 740 374 3760