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Monitoring Liquid Nitrogen Storage Dewars by Weight

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Introduction and Background

Scientific liquid nitrogen dewars are employed to store cell lines and other biologic material. These vacuum-insulated tanks are filled with liquid nitrogen which keeps the samples cold and cryopreserved. In many cases the cell lines or other biologic material inside are valuable and even irreplaceable and so it is extremely important that the units remain cold which means that it is extremely important that liquid nitrogen always be in the tank.

There are two main kinds of events that can cause dewars to run out of liquid nitrogen 1) not replenishing the nitrogen supply periodically and 2) internal damage to the dewar that causes evaporation faster than anticipated. A third type, spills, can occur but in the case of spills the staff that inadvertently caused the spill is usually on-hand to correct the problem.

The dewars used for scientific applications come in a variety of sizes but are most commonly between 15 and 50 liters. They are extremely efficient at insulating the liquid nitrogen from the surrounding atmosphere however the -196C liquid nitrogen will slowly evaporate. A properly functioning dewar in this size range will lose all of its nitrogen after 20 to 120 days depending on the brand and model and the condition of the tank. The dewars therefore need refilling with liquid nitrogen periodically to replace the evaporated volume. The lab checks nitrogen level by various means including by dip sticks that are inserted into the tank. Some laboratories manually check nitrogen level every few days.

If refilling needs to be done every 2 weeks then the nitrogen must be added 26 times per year for each tank. Labs can often have dozens of tanks. For a lab with one dozen dewars this is 312 dewar fillings per year. If any fillings are missed and the tank runs out of nitrogen then there is the potential that valuable cells will be lost. Each filling is also a possible mishandling of sample or liquid nitrogen.

Scientific dewars can maintain temperature with only a small volume of liquid nitrogen, but once that volume is gone, the temperature rises to room temperature within hours (see the plot of a nitrogen-depletion event below for a highly insulated tank).

The Current State of Data Acquisition

There are several monitoring systems made by different vendors with different data collection and notification parameters. We intend to examine how and what types of data are collected rather than how monitoring systems operate once that data has been acquired.

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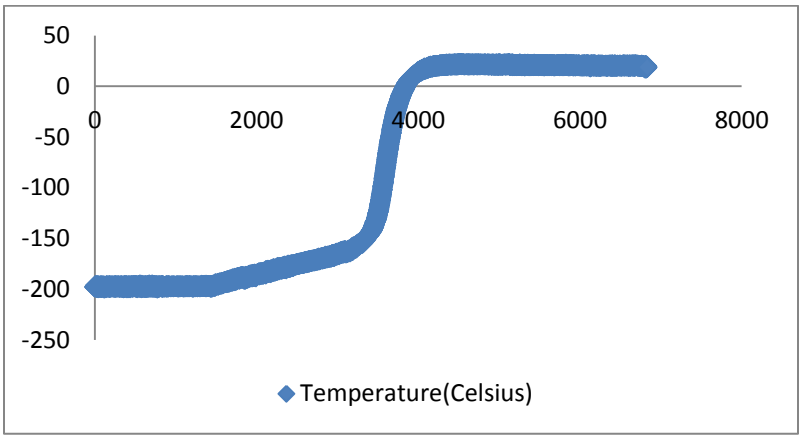
Dewars are usually monitored with temperature probes inserted into the tank through the opening on top – either through the gap between the top plug and the neck or through a hole drilled in the plug and lid. Networked Robotics uses PT-100 platinum RTDs for this purpose which are designed for use at very low temperatures.

One of the issues with the use of temperature sensors is the vertical position of the sensor within the dewar. Position anywhere in the liquid phase will result in a reading of -196C at sea level. Position in the vapor phase near the top of the tank will result in a gradient of readings with lower temperatures the closer the sensor is to the liquid nitrogen.

The liquid nitrogen level drops with evaporation so a sensor can be in liquid phase one moment and in the vapor phase an hour later. The graph below shows the temperature of a Networked Robotics PT100-RTD-probe in a high-efficiency Taylor Wharton XT20 20 liter dewar as it runs out of liquid nitrogen. The curve represents a 26-pound-empty tank without a sample load. The x-axis is shown in minutes. There are three phases in the curve. Initially the dewar is stable at -196. Eventually the nitrogen evaporates to a level lower than the sensor and in phase 2 the sensor is now measuring vapor-phase temperature. The temperature reported is gradually warmer as the liquid nitrogen retreats lower and farther away from the sensor. When the liquid nitrogen runs out completely a more rapid change in temperature occurs. In this highly insulated dewar version the temperature rises from -150 to 0 in eight hours. Less efficient dewars will warm faster.



The Temperature of a 20 Liter Dewar as Liquid Nitrogen Evaporates

The liquid nitrogen level inside the tank can be monitored with level-sensing electronics that are also inserted into the opening of the dewar. Internally the level-sensing electronics are wires that must reach from the top to near the bottom of the tank. Networked Robotics provides network interfaces to the level-sensing instruments sold by other companies.

In our experience laboratories often implement temperature monitoring in cryogenic dewars but more rarely monitor the liquid nitrogen level. We think that this is because the addition of an extra set of wires inside the tank is physically complicating. These wires for both temperature and level are hard to secure inside the tank. They may migrate and change the reading. They may interfere with sample movement in and out of the dewar. When the dewar needs to be refilled the lab may need to move the dewar to the fill-site which can be unduly complicated if there is too much attached equipment.

The Monitoring of Dewars by Weight

Networked Robotics has implemented the capability to continuously monitor the weight of scientific dewars via our Tempurity™ System via a network interface to commonly available platform, bench, and floor scales and balances. Currently we support dozens of different models in two major product lines from scale manufacturers Adam Equipment® and Ohaus®.

How it Works

The dewar is placed on the platform scale and remains there. The scales have a digital display where personnel in the storage area can see the weights at a glance. The weight is transmitted constantly to the Tempurity System. As liquid nitrogen evaporates the weight decreases. The weight is collected on any computer on the network and is available in a trend plot to any authorized person on the network. If that weight hits a critical level, the Tempurity System sends e-mail, text, and phone as it does with other kinds of monitoring that we do for CO2 incubators, freezers, gas sensors, voltage, pressure, RPM, and other types of data sources.

There are wheeled scale model numbers with from both manufacturers with racks for stability. When the dewar needs to be refilled there is no disconnection of a nitrogen level sensor needed, the scale is simply taken away, filled, and brought back to its permanent position.

Networked Robotics hardware has four data collection ports that can be used with any of our diverse data collection methods in any combination. For example temperature, the weight of the dewar, oxygen concentration in the air to detect spills, and a direct data connection to a nearby incubator can all be monitored by a single Networked Robotics network device.

Other Advantages of Monitoring Dewars by Weight

Having the weight of the balance gives you a few other advantages besides the liquid nitrogen level. It gives you an indication of when samples are added and removed. These weight changes are slight compared to the weight of the tank, but are still detectable on higher-end scales.

Weight also gives you an indication of the health of the tank, because the recorded weight data indirectly shows the evaporation rate. Tanks that evaporate more quickly than others can be replaced before they worsen and cause a risk to cells.

The fill process is optimized. When you know how much nitrogen is in the tank you only need to fill it when it needs to be filled, thus saving staff time.

The amount of time in man-hours spent by a lab on checking the level of nitrogen in their tanks may be less as levels are visible both in the lab and from any computer.

Any time the lid is off, nitrogen will be lost, and when a dip stick is placed in liquid nitrogen it causes some of it to boil. So the weight-based method prevents nitrogen from evaporating because opening the tank periodically to check nitrogen levels is no longer necessary.

Liquid nitrogen costs money and so preventing evaporation saves money.

Potential Downsides in the Monitoring of Dewars by Weight

One of the potential downsides of monitoring dewars by weight is that the tanks are one or two inches off the floor and so they are a little less stable than when they rest completely on the floor

or are on a tipping stand or roller base. These tanks are less stable as they empty so a fuller dewar will have less tip-risk than an empty dewar. Several models of scales from our two supported manufacturers have vertical racks or poles to which the balance can be attached which we believe if attached properly virtually eliminates the risk of a spill.

The larger scales used to monitor larger dewars may take up a little more floor space than the tank itself. This could be relevant in the small storage rooms used to store dewars where room space is at a premium.

While these scales support battery operation we don't recommend their exclusive use in this mode but rather as a backup to line power and for use during refilling. Therefore the scales need to be plugged in, and if the lab has a dozen dewars there will be a dozen more connections to wall power sockets in the lab.

We were initially worried about unintentional retares. If the scale retares without warning would you have to lift the tank off the scale to manually tare again? Lifting a liquid-nitrogen-filled 65 pound dewar is strenuous and has to be done carefully to avoid injury. We have found though that as long as the scale is chosen carefully this is not an issue. Some scales have an algorithm for retare based on the weight at the time that the scale recovers from a power failure. As long as the scale's weight is within the right fraction of full-scale weight unintentional retares are not an issue.

Further Discussion

In general empty dewars from 20 liters to 50 liters weigh about 1/3 of the full weight of the dewar. Thus 2/3 of the weight of a full tank is liquid nitrogen. We believe that in most labs the samples and their aluminum racks are light relative to the 30-50 pounds of liquid nitrogen inside the unit. So there's plenty of room to set weight limits for alarm notification of e-mail, text, and phone regardless of sample movement.

Conclusion

We believe that easily obtained access to the most important risk factor in biologic cryogenic storage, liquid nitrogen level, will facilitate the safety of the critical, unique cells often stored in scientific dewars and may have other advantages such as sample tracking, lower liquid nitrogen cost, and enhanced laboratory workflow.