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mercury in m^3 of air (Croners, 1998). Naphthalene, mercuric chloride, arsenic trioxide and barium fluorosilicate levels may quickly exceed the HSE regulations even at low temperatures as very small levels in air are regarded as highly hazardous.

Monitoring the herbarium temperature is imperative and increasing ventilation after a period of warmer conditions is advisable.

Reference:

Croners (1998) Chemical Hazards *in* Kellard, B. *Substances Hazardous to Health.* Kingston upon Thames, Surrey, Croner Publications Ltd pp3/A-3/868.

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Note from Ed:
Though the 'Ten Agents...' series is primarily concerned with museum collections and not the people working on/with them, it was decided to include this last piece as it relates to comments by KA. Vicky hopes to publish a more detailed and comprehensive report of her work later in the year (see page 4 of main newsletter).

Incorrect Temperature as a Risk - how significant is it?

Incorrect temperature levels may pose any of the three types of risks to collections depending on the frequency of occurrence and severity of the risk (Waller, 1994, 1995). It is easy to consider and estimate the magnitude of a type 1, rare and catastrophic, incorrect temperature risk if one considers, for example, the fate of an ice core collection exposed to >°C for several days. Similarly, the type 2, sporadic and severe, occurrences of thermal shock causing fracturing of well crystallised mineral specimens, or partial melting of wax models or casts in a collection, are relatively simple to appraise. Incorrect temperature-type 3 (T-3) is another matter. Within the T 3 generic risk are considered the mild and gradual consequences of storage at a temperature level somewhat higher or lower than ideal.

What makes this risk difficult to incorporate in risk analysis is the fact that storage at a non-optimal temperature is seldom considered and calculated as a direct risk causing damage. Rather, it tends to be either complicit with another agent in causing damage, or simply contributes to the susceptibility of specimens to damage caused by another agent. As an example of complicity, consider how the susceptibility of a collection to insect pest damage might change depending on whether the collection is stored at 10°C or 30°C. As an example of incorrect temperatures contributing to susceptibility to damage by another agent of deterioration, consider the embrittlement, and eventual physical failure, of lignin rich, acidic herbarium sheets. The degradation, leading to eventual failure, of these sheets would proceed at a greatly reduced rate at 0°C as opposed to 25°C.

The interplay of temperature with other agents of deterioration might, at first, give the impression that the effect of modest changes in collection storage temperatures cannot be considered in a risk assessment context. Recently, however, an issue arose at the Canadian Museum of Nature that required exactly that consideration. The recently completed Natural Heritage Building was designed and built to provide a state of the art facility for housing our national natural science collections. Environmental conditions called for relative humidity levels that varied according to the principal materials in a collection but a constant temperature of 18°C was set for all collections. The selection of this temperature involved striking a balance between minimising pest activity and thermal degradation of collections, on the one hand, and energy and human requirements on the other. Encouraging separation of collection management from other activities better accommodated in laboratory or office spaces was seen a an additional benefit of lower temperatures.

After approximately one year in our new building, however, it was evident that maintaining 18°C made collection management work in the insect collection very difficult. The nature of the work done requires frequent, random access to all parts of the collection and detailed, meticulous handling and placement of minute fragile specimens. The difficulty in completing this work at a temperature as cool as 18°C was resulting in a reduction of collection management productivity. Consequently, we were required to evaluate the risk associated with raising the temperature in certain dry-biological collection areas to 21°C. Other considerations, beyond the scope of this discussion led to the selection of 21°C as the target rather than, say, 20°C or 22°C. The question we sought to answer was not: what is the exact (to several decimal places) dependence of total risk on temperature levels?; but, rather: will a 3°C increase in temperature cause a substantial (100%), significant (10%), slight (1%(0.1%), or negligible(0.1%) increase in total risk?

Review of the existing (1992) risk assessments, showed that there were no significant T-3 risks assessed for any of the dry biological collections. Of the remaining generic risks, the magnitudes of risk for physical force types 2 and 3 (PF-2 and PF-3) and for pests were considered most dependent on storage temperature over time. The risks PF-2 and PF-3) and for pests were considered most dependent on storage temperature over time. The risks PF-2 and PF-3 were responsible for approximately one-half of the total risk to three representative dry-biological collections (vascular plants, ornithology and invertebrate zoology). This will be considered first.

Within the generic risks, PF-2 and PF-3, are included a variety of specific risks leading to physical damage. Examples include physical damage from routine handling, overly crowded storage, handling and transportation accidents, and so on. It was estimated that approximately one half of the PF-2 and PF-3 risk would occur as readily for new material as for aged, embrittled material. Consequently, thermal degradation resulting in eventual physical damage was estimated to be responsible for about one quarter of the total risk to these collections (one half of PF-2 and PF-3 risk which itself is one half of total risk).

Stefan Michalski has recently reviewed the literature on the relative humidity and temperature dependence of a number of reactions causing deterioration in organic materials in museum collections (Michalski, pers. comm. 1998). He has found that all the experimental data, as well as the fundamental equations of chemical kinetics, support the general rule that reactions causing extensive organic degradation over periods of decades to centuries have activation energies in the range of 100kJ/mol K. This can also be stated as the rule of thumb of "half the rate for each 5°C drop". (Reactions that go to completion in minutes to days average half this activation energy, and follow the old chem-lab rule of "double the rate for each 10°C rise.) The effect of this on relative decay rates and remaining lifetimes are shown in Table 1.

Consequently, we expect a 50% increase in reaction rate to result from a 3°C increase in temperature. Applying this to the ¼ of total risk due to thermal degradation resulting in eventual physical damage gives an estimated 13% increase in total risk.

The risk due to pests in these three representative dry-biological collections accounted for approximately 3% of the total risk 1. This risk was associated primarily with insect pests. It was relatively low due to reasonable control of temperature and relative humidity and effective policies and procedures related to pest management. We believe that further improvements in environmental control and in policies and procedures related to pest management in our new building would result in some reduction in this risk, even at a temperature of 21°C. The fraction of total risk due to pests, for these collections in the NHB, is thought to be less than 3%. Consequently, the increment in total risk, due to the change in risk due to pests, resulting from a change in temperature from 18°C to 21°C, is thought to be much less than 3%. It is probably on the order of 1%.

The expected increment in total risk resulting from a change of temperature of + 3°C is an increase of about 14%. This number implies greater precision than is warranted considering the assumptions and roughness of estimates. Nevertheless, the true increment in risk is probably within or near the range of 10% to 20% increase. Consequently, we have answered the question set out. A 3°C increase in temperature will cause a significant (10 to 20%) increase in total risk.

The question then became will the proposed temperature change result in an increase in the utilisation of the collection that offsets the increase in total risk? The answers to that question were yes, for the insect collection, and no, not at this time, for the remaining collections.

In summary, it is possible to consider the effect of a change in mean temperature on the risk to collections. This is true even if no specific temperature - type 3 risks are identified. It is, however, necessary to know the total risk to collections and the proportion of the total that is comprised of risks affected by temperature. Moderate (1-5°C) changes in mean temperature for the storage of dry-biological collections at the CMN are predicted to result in significant (10%), as opposed to substantial (100%), slight (1% (0.1%), or negligible (0.1%) increments in total risk. The final decision of what constitutes an acceptable risk to collections depends on considerations related to collection management and utilisation. This suggests the idea that expressing risk per unit of utilisation may be more meaningful than simply expressing risk per collection. After all, in the words of the immortal IP Sofacto, "Collections not used are useless collections". (Sofacto, 1991).

Temp. Change	Relative Decay Rate	Relative Remaining Lifetime
-5	0.50	2.0
-4	0.57	1.75
-3	0.66	1.52
-2	0.76	1.32
-1	0.87	1.15
0	1	1
1	1.15	0.87
2	1.32	0.76
3	1.52	0.66
4	1.75	0.57
5	2.0	0.50

Table 1. Relative decay rate and relative remaining lifetime for degradation of organic materials assuming an activation energy of 100kJ/mol K and all other factors being constant. Table reproduced courtesy of Stefan Michalski, Canadian Conservation Institute.

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I am very grateful to Stefan Michalski for providing information on the temperature dependence of chemical degradation rates and for allowing that information to be reproduced here. I thank Stefan Michalski, Canadian Conservation Institute, Jean-Marc Gagnon and Judith Price, Canadian Museum of Nature, for helpful comments on this paper.

Total risk after correcting the risk due to fire for the situation in the new LHIB building. The risk due to fire had been very high for certain of these collections.

References

Sofacto, I.P. 1991. Untitled poem. Remains To Be Seen. 4(2):4.
Waller, R., 1994. Conservation risk assessment: A strategy for managing resources for preventive conservation. Pre-prints of the Contributions to the Ottawa Congress, 12-16 September 1994, Preventive Conservation: Practice, Theory and Research, A. Roy and P. Smith (Eds.), IIC, London, p. 12-16.

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Hanwell Radio Telemetry

The Hanwell radio system has now been in use for eight years and has developed considerably during that time to accommodate ever more sophisticated requirements from customers. When the system is correctly installed and maintained, a very high degree of reliability is now routinely achieved in the collection of data.

The system is based around a data logger (The 'Architect') which in its latest version offers a range of features which ensure data integrity. These features include flash memory and on-board battery back up. The large memory capacity allows the unit to run for long periods of time independent of a Host PC.

The Temperature/Humidity sensors themselves are now in their MkIII version offering high accuracy Vaisala sensors as standard and optional LCD screens. These new units are also slimmer and lighter than their predecessors.

A wide range of sensors can be added to the standard system including Lux, Lux/UV, PT100 surface temperature sensors, smoke and flood detectors, people counters, power consumption meters and wood-moisture sensors.

One major development in the last year has been the acceptance of the system for environmental control as well as monitoring. A range of schemes have been implemented which include conservation heating for National Trust properties and the control of Humidifier/Dehumidifier combinations via Hanwell radio Humidistats.

Liz Halliday
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