Out of the box

Measuring micro-climates in Australian-made Solander boxes

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Dr Daniel Solander
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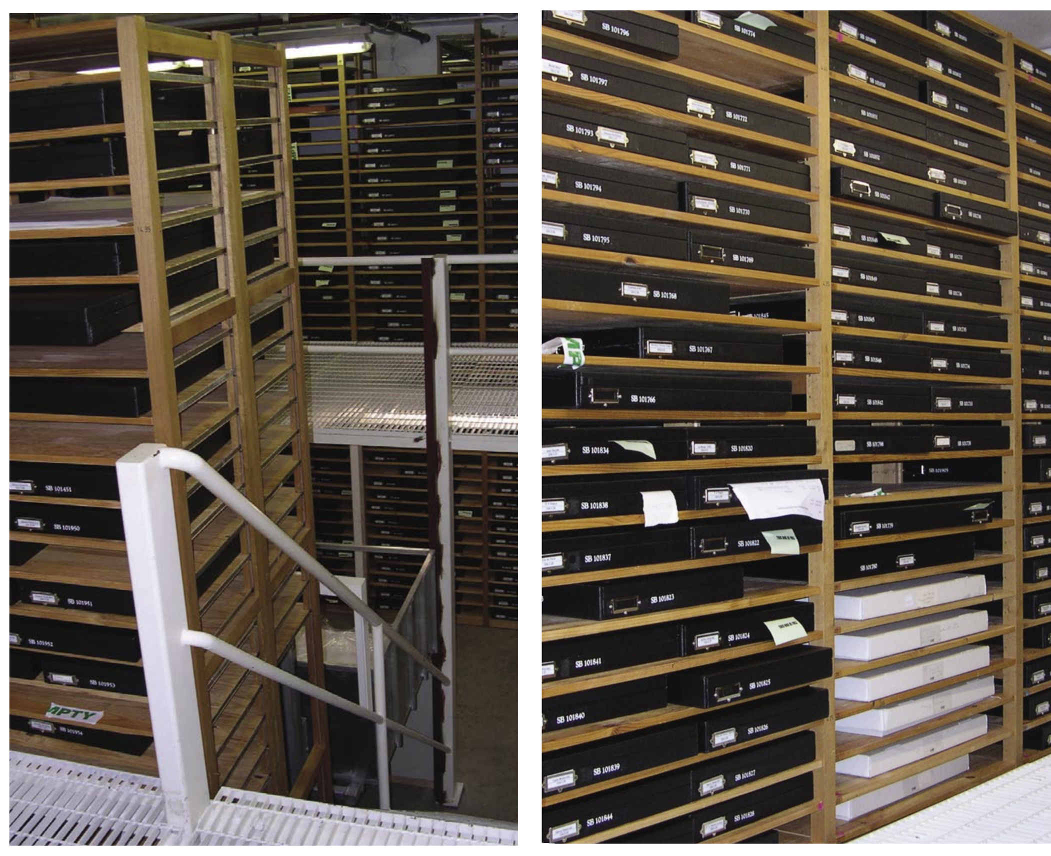
Introduction

The Solander box clam-shell design was developed by a botanist at the British Museum, Dr Daniel Solander (1736–1782), to store botanical specimens. Storage of works of art on paper in Solander-style boxes became common practice by the mid-1840s and continues to this day due to the inherent qualities of rigidity, strength, convenience, and the ability to provide protection from impact, light and dust, and to act as a buffer for changes in relative humidity.

A survey conducted in 2002 on the storage systems used in Australian and New Zealand cultural institutions found that Solander boxes were the fourth most popular storage option for works of art. It also revealed the large range of material stored in Solander boxes: prints, drawings, watercolours, 19th-century photographs and later black-and-white silver gelatin and colour photographs, digital prints, books, loose-leaf documents, woodblocks, and etching plates.

Many survey respondents expressed concern over box construction materials. Whilst none could directly attribute off-gassing by Solander box materials to the deterioration of works on paper stored within, observations of discolouration and foxing in lining papers, and the detection of strong odours upon opening the tightly sealing boxes were reported.



Two rooms of four Solander box storage areas

Manufacturing in Australia

Results from the survey show Solander box materials favoured by Australian institutions include:

- wooden lid and base adhered or nailed/stapled together
- internal acid-free lining of buffered paper, occasionally incorporating molecular traps
- exterior covering of vinyl (PVC) or pyroxylin (cellulose nitrate impregnated) book cloth
- wood-working adhesive such as polyvinyl acetate (PVA) and polyethylene vinyl acetate (EVA).

Woods commonly used for manufacture are Hoop or Radiata pine, Western Red Cedar and various types/grades of plywood, all of which can be sealed with a range of products, including neutral pH polyester resins and various polyurethane finishes.

The National Gallery of Australia stores the majority of its collection of more than 80 000 works of art on paper and photographs in Solander boxes. These boxes are comprised of Hoopwood pine (a hardwood with no oils or resins), Youlan hardwood ply (three-ply laminated with acid-free adhesive), book cloth, Rexine (cellulose nitrate impregnated cloth), acid-free recycled box board, 135 gsm Glowpaque acid-free paper, and acid-free adhesive. The frame is nailed together and the cloth, board and paper are all adhered to the shell, or carcass.

Stages in the construction of a National Gallery of Australia Solander box

Testing methodology

In 2003 the National Gallery of Australia conducted preliminary investigations into the Solander box microclimate. Passive sampling diffusion tubes were employed to detect the presence of pollutants known to catalyse deterioration of works of art on paper: see Table 1. A Medigas PM3010 nitrous oxide (N_2O) logger was used to determine the air exchange, or 'leakiness', of the box with the ambient environment.

Pollutant	Adverse Effect
formaldehyde	*brittleness and denaturing of cellulosic and proteinaceous materials*
acetic and formic acids	*hydrolyse cellulose polymers*
hydrogen sulphide (H_2S)	*pigment colour change; silvering out of photographs*
nitrogen dioxide (NO_2)	*Hydrolysis from oxide to nitric acid, catalysing cellulose deterioration and the oxidation of sulphur*

Table 1 *Pollutants tested and their potential adverse effects*

TEST MATERIALS

Four Solander boxes, all of a similar dimension (approximately 412 × 562 × 58 mm), were selected to test for the presence of volatile organic compounds (VOCs).

EQUIPMENT

UK-supplied passive sampling diffusion tubes were used for measuring the specific VOCs. These tubes have a disc of material, impregnated with a trapping agent, at the closed end collecting the targeted VOC through diffusion. After exposure the tubes were capped and returned to the suppliers for analysis. The air exchange equipment was also sourced from a UK supplier, and comprised an N_2O monitor (Medigas PM 3010) with an infra-red cell, which was used to measure the rate of N_2O dissipation from the closed Solander box. The monitor records gas measurements by drawing an air sample through an internal pump once every two minutes. Tiny Tag and Smart Reader data-loggers were used to measure temperature and relative humidity internally and externally at the test sites.

EXPERIMENTAL

Passive sampling

Four boxes were placed in a stable environment for the duration of the experimental work. Temperature and relative humidity, at both the deployment site and in Box A, were monitored using Smart Reader data-loggers. The diffusion tubes were deployed by removing the cap immediately prior to placement in the designated deployment area. A set of capped control tubes was placed inside Box A and a set of controls was uncapped and placed with the data-logger between the boxes. The boxes remained undisturbed for four weeks, at which time the tubes were collected, recapped and returned to the suppliers.

Air exchange

As all the boxes were a similar size, only Boxes A and D were used to measure the rate of air exchange between the Solander box and the ambient atmosphere. For each deployment period a data-logger was placed inside the box, another on the bench next to the box, and the N_2O monitor was positioned inside the box and activated. Each box was charged with N_2O, closed and left for two hours. To check the absorption of N_2O by the box components, Box D was sealed with aluminium-backed framing tape, and the experiment was repeated. As an indication of whether the test site affected the air exchange of the Solander box, the air exchange of the room was also measured. This was done by expelling the remaining gas into the room, which was then 'closed up' and left overnight. The equipment was then returned to the supplier for analysis.

Results

Passive sampling

Preliminary findings show that the newest box, Box D, produced high levels of all VOCs tested. The notable deviation from this pattern is Box C, producing the highest reading for acetic acid. This is not unexpected, as the box is full of vintage black-and-white photographs backed onto acidic card. Data-logger results from inside the Solander box indicate that over the testing period there was a 10% change in RH (38–48%) and a four-degree temperature change (18–22° C).

- The median results from the diffusion tubes indicated that all pollutants investigated decreased in concentration over time. The exception to this was formic acid, which was generally beneath detection limits.
- All boxes produced relatively high amounts of acetic acid, most notably in Box C.
- Levels of formaldehyde detected varied greatly; the low reading for Box C suggests VOC absorption by the contents. As expected Box D, with the freshest wood content, exhibited high levels of formaldehyde.
- The levels of nitrogen dioxide imply a VOC source external to the boxes, which appear to act as a buffer. The low reading in Box C suggests VOC absorption by the contents.
- The level of hydrogen sulphide in Box D is high, indicating an internal source. The low level in Box C suggests VOC absorption/adsorption by its contents.

Air exchange

Inconclusive results using N_2O for case exchange rate (CER) determination suggested that the gas was dissolving into one or more of the box materials. For this reason Boxes A and D were sent to Brookes University, Oxford, for comparative testing with N_2O and carbon dioxide (CO_2).

The results from subsequent testing are shown in Table 2 and confirm a good seal on the newest box, Box D, yielding a CER of 1.4 per day.

Future directions

This preliminary research has confirmed expectations that the Solander box microclimate harbours VOCs. It has also highlighted the requirement to allow Solander boxes to air well before use, as such a low CER will aid containment and build up of VOCs in newly manufactured boxes. It is hoped that through further analysis, a fair evaluation of construction materials used for National Gallery of Australia Solander boxes can be produced allowing recommendations for alternative materials, methods and airing times to be made. With our current partners, the National Gallery of Australia's Paper Conservation Department plans to undertake a more comprehensive study into these boxes in the near future.

Box	Gas	time /min	time /day (d)	CER /d-1	R*
A	N_2O	1369.27	1.0	1.1	0.47154
	CO_2	645.6688	0.4	2.2	
D	N_2O	3216.31	2.2	0.4	0.3229
	CO_2	1038.542	0.7	1.4	

*R = ratio of N_2O to CO_2

Table 2 *Results from air exchange measurements*

Test equipment suppliers
Passive sampling: Dr Lorraine Gibson (lorraine.gibson@strath.ac.uk) and Dr Simon Watts (sfwatts@brookes.ac.uk)
Air exchange: Dr Simon Watts

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