Out of the box: measuring microclimates in Australian-made Solander boxes

Andrea Wise, Caitlin Granowski and Belinda Gourley

Abstract The National Gallery of Australia has over 80,000 works of art on paper and photographs, the majority of which are stored in Solander boxes. For some years there have been concerns relating to the stability of the construction materials used for these enclosures, and the quality of the microclimates created within. A preliminary study on a range of Solander boxes was undertaken to determine whether harmful levels of gaseous pollutants were prevalent within the boxes used at the National Gallery of Australia. This paper will outline the initial results and analytical methods employed to detect harmful volatile organic compounds (VOCs), using passive air samplers in conjunction with a nitrous oxide monitor used to measure the air exchange rate.

Background: history and use of the Solander box in Australia

Solander boxes have a long and relatively unchanged history. A botanist at the British Museum, Dr Daniel Solander (1736–1782), developed the well-known flat 'book-like' design to store his collection of botanical specimens, gathered while voyaging with Captain James Cook (Roberts and Etherington 1982; Caldararo 1993). 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 their inherent virtues of rigidity, strength, convenience and the ability to provide protection from impact, light, dust and, to a certain extent, changes in relative humidity (RH) (Caldararo 1993).

A questionnaire survey conducted in 2002 by Belinda Gourley on the storage systems used in Australian and New Zealand cultural institutions found that Solander boxes were the fourth most popular storage option, following the use of plan chests, racks and closed cabinets. At the time, 67% of responding institutions reported using Solander boxes to store works on paper and 22% used them to store the majority (50%–100%) of paper collections. The survey also revealed the large range of material stored in Solander boxes: prints, drawings, watercolours, 19th- and 20th-century black and white and colour photographs, digital prints, books, looseleaf documents, woodblocks and etching plates.

Solander box construction materials

Results of the 2002 survey indicated that the Solander box design favoured by Australian institutions comprises a wooden lid and base constructed with woodworking adhesive such as polyvinyl acetate (PVA) and polyethylene/vinyl acetate (EVA), or nails and staples. The woods used include Hoop pine, Radiata pine, Western Red cedar and various types and grades of plywood. These woods and wood products can be sealed with a range of coatings including neutral pH polyester resins and various polyurethane finishes.

Modern boxes are usually lined internally with acid-free, buffered papers, occasionally incorporating molecular traps, such as MicroChamber paper, and have an exterior covering of book cloth to hinge the lid and base together. Vinyl (PVC) or pyroxylin (cellulose nitrate) impregnated book cloth are both commonly encountered, often with canvas reinforcements along the hinge. Generally the inner paper lining and exterior book cloth are entirely adhered to the wooden box with either EVA or PVA.

Many respondents to the survey expressed concern with regard to these construction materials, mostly in terms of their propensity to produce gaseous pollutants at levels potentially harmful to the objects stored within the boxes. While no respondents could directly attribute the production of pollutant vapours by Solander box materials to the deterioration of works on paper stored within, observations of discoloration and foxing in lining papers and the detection of strong odours upon opening the tightly sealing boxes were reported.

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 have been purchased over three decades from several suppliers and are commonly constructed with a Hoop pine ply frame, covered in synthetic book cloth and lined with acid-free paper using EVA adhesive. In 2003 the Gallery 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. These pollutants were: formaldehyde, which can cause alteration in the characteristics of cellulosic and proteinaceous materials, such as brittleness and denaturing (Gibson and Brokerhof 2001); acetic and formic acids, which hydrolyse cellulose polymers (Dupont and Tétreault 2002; Slavin and Hanlan 1992); reduced sulphur compounds, responsible for colour change in some pigments (Fitzhugh 1986) and silvering out of photographs (di Pietro and Ligterink 1999); and nitrogen oxides, which oxidise to nitric acid causing cellulose degradation through hydrolysis (Mathey *et al.* 1983) and may act as a catalyst for the oxidation of sulphur (Johansson *et al.* 2000). A Medigas PM 3010 nitrous oxide (N_2O) logger was used to determine the air exchange or 'leakiness' of the box.

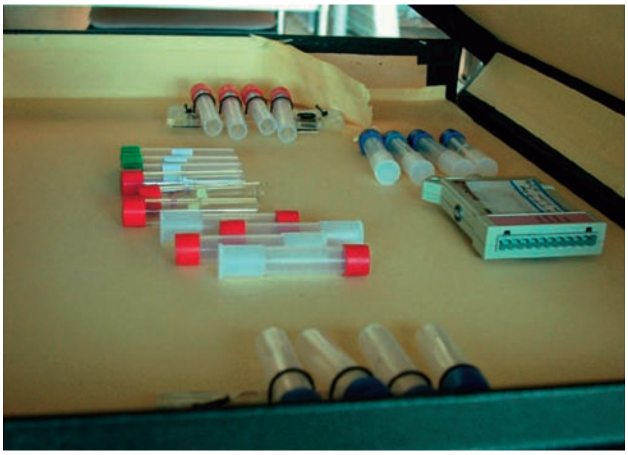

Figure 1 Box A: passive sampling experimental set-up.

Methodology

Test materials

Four Solander boxes, all of similar dimensions (approximately 412mm × 562mm × 58mm), were selected to test for the presence of VOCs (Table 1).

Table 1 Description of boxes tested.

Box	Condition	Contents
Box A	old (<20 years)	empty and yellowing
Box B	working box	empty
Box C	working box	full: containing B&W silver gelatine photographs on original acidic wood-pulp backing boards
Box D	new (July 2003)	empty

Equipment

Passive sampling diffusion tubes used for measuring the specific VOCs were sourced from suppliers in the UK. These tubes are capped at one end and contain a disc of material impregnated with a trapping agent at the closed end where the targeted VOC is collected through diffusion. After exposure, the tubes were returned to the suppliers for analysis. The air exchange equipment was sourced from a supplier in the UK and comprised a Medigas PM 3010 logger with an infrared 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 dataloggers were used to measure temperature and RH 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 RH, at both the deployment site and in box A, were monitored using Smart Reader dataloggers. 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 blanks was uncapped and placed with the datalogger between the boxes (Fig.1). The boxes remained undisturbed for four weeks, at which time the tubes were collected, recapped and returned to their respective 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 Tiny Tag datalogger was placed inside the box, another on the bench next to the box, and the Medigas PM3010 N_2O monitor was positioned inside the box and activated (Fig. 2). Using a plastic feeding tube, each box was opened, charged with N_2O then closed and left for two hours while the monitor took samples. To check for potential absorption of N_2O by the box components, box D was sealed with aluminium-backed Lineco self-adhesive frame sealing 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 with the building was measured.[1] The active monitor was placed on a desk and the remaining gas was expelled into the room which was then 'closed up' and left overnight. The air exchange equipment was returned to the supplier for analysis.

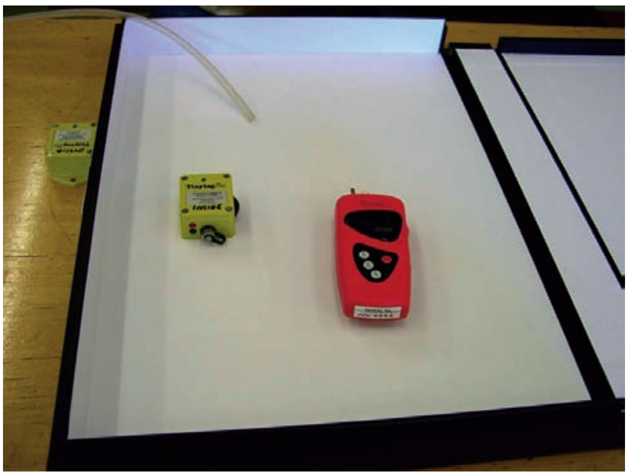

Figure 2 Air exchange experimental set-up showing a Solander box and Medigas PM 3010 nitrous oxide logger.

Table 2 Passive sampling results.

Box	Acetic acid	Formic acid	Formaldehyde	NO_2	H_2S
A	489µgm^{-3} ±12	< 21µgm^{-3}	90µgm^{-3} ±7	3 ppb ±1	228 ppt ±66
B	528µgm^{-3} ±12	< 82µgm^{-3} ±10	524µgm^{-3} ±34	4 ppb ±1	326 ppt ±82
C	638µgm^{-3} ±12	< 21µgm^{-3}	187µgm^{-3} ±12	3 ppb ±1	125 ppt ±28
D	533µgm^{-3} ±12	< 21µgm^{-3}	1589µgm^{-3} ±46	7 ppb ±0	520 ppt ±116
Out	26µgm^{-3} (detection limit)	< 21µgm^{-3} (detection limit)	< 11µgm^{-3} (detection limit)	9 ppb ±1	233 ppt ±50
Blank (Box A)	N/A	N/A	N/A	3 ppb ±2 (2ppb detection limit)	54 ppt ±12 (95 ppt detection limit)

Results and discussion

Passive sampling

A summary of the results to date are given in Table 2. Preliminary findings from this initial investigation have shown 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 black and white photographs backed onto acidic card. Datalogger results from inside the Solander box indicate that over the testing period there was a 10% change in RH (38%–48%) and a 4°C temperature change (18–22°C).

- The median results from the diffusion tubes indicated that all the pollutants investigated decreased in concentration over time. The exception to this was formic acid which was generally beneath detection limits. At the time of writing, the formic acid result for box B is being regarded as an anomaly as there appears to be no obvious reason for the higher levels recorded.
- All boxes produced relatively high amounts of acetic acid, notably box C, which contained vintage black and white photographs.
- The 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

Current testing of Solander box air exchange rates is continuing, as preliminary results have proved inconclusive. Tests will be repeated for a longer time than the two-hour deployment period used initially.

Future directions

This preliminary research has confirmed expectations that, regardless of age, to some degree the Solander box microclimate harbours a variety of VOCs. This has highlighted the need for thorough airing of newly manufactured boxes prior to use. It is hoped that through further testing and 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 pre-use airing times to be made. With our current collaborators, the National Gallery of Australia Paper Conservation Department plans to undertake a more comprehensive study into these boxes in the near future.

Acknowledgements

Sincere thanks and appreciation for an abundance of time and advice are owed to Dr Simon Watts. Many thanks also to Dr Lorraine Gibson, who took time out from maternity leave to advise on this paper. The authors also wish to acknowledge the National Gallery of Australia Conservation team and David Wise of the University of Canberra.

Note

1. The test room is about 240m[3] in volume and has two doors leading to other rooms and five external windows.

Materials, equipment and suppliers

Acid and aldehyde diffusion tubes: Dr Lorraine Gibson, Department of Pure and Applied Chemistry, University of Strathclyde, Thomas Graham Building, 295 Cathedral Street, Glasgow G1 1XL, UK. Tel: +44 (0)141 548 2224, www.strath.ac.uk.

Medigas PM 3010, Tiny Tag dataloggers, NO_2 and H_2S diffusion tubes: Dr Simon Watts (Reader in Biogeochemistry), School of Biological and Molecular Sciences, Oxford Brookes University, Headington, Oxford OX3 0BP, UK. Tel: +44 (0)1865 483613, www.brookes.ac.uk/bms/watts.

Smart Reader Dataloggers: Robson Laboratories PTY Ltd, 31 Pelsart Street, Red Hill, ACT 2603, Australia. Tel: +00 61 2 6239 5656, www.nata.asn.au.

References and further reading

Caldararo, N. (1993) 'The Solander box: its varieties and its role as an archival unit of storage for prints and drawings in a museum, archive or gallery', *Museum Management and Curatorship* 12(4): 387–400.

Di Pietro, G. and Ligterink, F.J. (1999) 'Gas diffusion related degradation patterns', http://iaq.dk/iap/iap1999/1999_08.htm accessed 23/07/04.

Dupont, A-L. and Tétreault, J. (2000) 'Cellulose degradation in an acetic acid environment', *Studies in Conservation* 45(3): 201–10.

Fitzhugh, E.W. (1986) 'Red lead and minium', in *Artists' Pigments: A Handbook of their History and Characteristics*, Vol. 1, R.L. Feller (ed.), 109–39. Cambridge: Cambridge University Press.

Gibson, L.T. and Brokerhof A.W. (2001) 'A passive tube-type sampler for the determination of formaldehyde vapours in museum enclosures', *Studies in Conservation* 46(4): 289–303.

Johansson, A., Kolseth, P. and Lindqvist, O. (2000) 'Uptake of air pollutants by paper', *Restaurator* 21: 117–37.

Mathey, R.G., Faison, T.K., Silberstein, S. *et al.* (1983) *Air Quality Criteria for Storage of Paper-based Archival Records, NBSIR 83-2795.* Washington: National Bureau of Standards.

Roberts, M.T. and Etherington, D. (1982) *Bookbinding and the Conservation of Books: A Dictionary of Descriptive Terminology.* Washington DC: Library of Congress.

Slavin, J. and Hanlan, J. (1992) 'An investigation of some environmental factors affecting migration-induced degradation in paper', *Restaurator* 13: 78–94.

Authors' addresses

Andrea Wise, National Gallery of Australia, GPO Box 1150, Canberra, ACT 2601, Australia (Andrea.Wise@nga.gov.au).

Caitlin Granowski, National Gallery of Australia, GPO Box 1150, Canberra, ACT 2601, Australia (Caitlin.Granowski@nga.gov.au)

Belinda Gourley, National Gallery of Victoria, PO Box 7259, Melbourne, Vic 8004, Australia (belinda.gourley@ngv.vic.gov.au).