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THE ENVIRONMENTAL PERFORMANCE OF MUSEUM DISPLAY CASES

May Cassar and Graham Martin

ABSTRACT
This study describes the investigation of a suitable descriptor of quality for museum display cases. One possibility is to measure the rate of air exchange between the display case and external air. Appropriate building tests were adapted to the scale of display cases. The two techniques applied in the laboratory during the study were an air-pressurization test and a tracer gas concentration decay test. This work has led to the establishment of a standard testing protocol, using the tracer gas concentration decay test, for the measurement of air change rate in display cases purchased by the Victoria & Albert Museum.

1 INTRODUCTION

Full mechanical air-conditioning systems no longer form the backbone of relative humidity control in many museums. Display cases are often used in exhibitions to provide the primary (and sometimes sole) environmental control for objects. There is also a growing awareness that display cases can be constructed specifically to provide this protection. This is demonstrated by work carried out jointly by the Museums & Galleries Commission and the Conservation Department of the Victoria & Albert Museum. These studies centred on the investigation of a suitable descriptor for 'air-tightness'.

In many exhibition installations, the cost of display cases is a significant proportion of fitting-out costs. The use of air change rate measurements as a descriptor can help to keep exhibition budgets under control. If the environmental performance of display cases is reflected in their price, a more detailed assessment can be made of the costs of improvements to displays or of new installations.

There is little to be gained by over-specifying display case quality in situations where all that a case is required to do is provide a physical barrier against accidental damage. Equally, environmentally sensitive objects may require high-performance display cases in situations where the building can provide only minimum protection. It is therefore important to define the quality of display cases according to the use to which they will be put.

A desirable consequence of using measurement of the rate of air exchange between the display case and external air as a descriptor of quality is that with a low rate of change, a high degree of relative humidity stability can be maintained for a reasonable change in temperature. Other advantages of cases with low air change rates are that the quantities of material used as a relative humidity buffer or pollutant chemical adsorbent can be reduced and maintenance schedules can be more easily planned because it is simpler to calculate the exhaustion time of the buffer or adsorbent. In fact, it is essential to know the air change rate of a case in order to calculate the amount of buffering material required.

The build-up of gases that may result from the use of unstable materials in a sealed environment and which can lead to deterioration of objects on display [1-4] is naturally of concern. However, the avoidance of these effects has been covered in detail elsewhere [5, 6] and is beyond the scope of this contribution. Nevertheless, care must be exercised in the selection and testing of construction and display materials when a sealed case is used.

2 BACKGROUND

There are two major schools of thought on display case design for stabilizing the environment [7]. A literature search identified the two viewpoints:

1. provide conditioned air under positive pressure to the case to control ventilation actively;
2. seal the case to extend its thermal and psychrometric half-life.

The relative virtues of each approach are summarized in Table 1. The question remains whether enough work has been undertaken on case design alone, without the use of humidity buffering materials.

Table 1 Comparison of the merits of ventilated and sealed cases.

	Ventilated	*Sealed*
Capital cost	High	Medium
Installation	Difficult/disruptive	Easy
Plant space required	Extensive	None
Maintenance cost	High	Negligible
Breakdown frequency	Variable	None
Write-off period	Five to 10 years	Lifetime
External pollution control	Expensive	Low cost
Internal pollution control	Active	Passive

Work carried out by Michalski [8] and by Toishi and Koyano [9] has concentrated on accommodating atmospheric pressure changes without implosion or explosion of the glazed surfaces. Publications by Brimblecombe and Ramer [10] and by Ramer [11] have considered the aspect of humidity control.

3 STATE OF KNOWLEDGE

A search of the literature identified gaps in information. There is an absence of hard data on the air change rates of existing display cases. Furthermore, no 'standard' method of measurement of air change rate has been published. Clearly, these gaps in knowledge had to be addressed before progress could be made. This led the Museums & Galleries Commission and the Victoria & Albert Museum to collaborate on a project to undertake a series of laboratory tests on several display cases in common use in museums.

The examination of air change rates in buildings has been well studied and documented. This was used as the starting point to identify expertise that could adapt appropriate building test techniques to the scale of display cases. The Building Services Research and Information Association (BSRIA), an independent research and testing organization, was engaged to undertake this work. The results of the tests are summarized in the following section. Subsequently, the Victoria & Albert Museum took this protocol and applied it to new case purchases within the museum. Again, the results are discussed below.

4 TECHNIQUES AND RESULTS

The BSRIA was retained initially to investigate the air-tightness of five museum display cases. The cases were not expected to achieve any air-tightness target, since the tests were primarily intended to help develop a case specification. The only criteria for selection were that the cases had to be typical of those supplied to museums and of a size that allowed them to be easily transported to the laboratory for testing. Some cases included in the investigation were loaned by manufacturers; others were loaned by museum users. Two building test techniques were adapted and applied in the laboratory during the initial investigation. These were an air-pressurization test and a tracer gas concentration decay test.

In considering these techniques, one aim was to develop a simple kit which would allow pressurization tests to be carried out *in situ,* that is, wherever cases might need to be tested. Another aim was to see whether the two tests gave similar results. Both tests can be used with equal effectiveness to test for air-tightness. However, the tracer gas concentration decay test, which is carried out at atmospheric pressure, is a better model than a pressurization test carried out at a nominal pressure of 50Pa and so the idea of a portable kit was not considered appropriate at this stage. At the same time the Victoria & Albert Museum decided that engaging an independent organization to verify that a specification had been met would be more credible to a contractor than an in-house check, when the Museum itself is the customer. Both techniques are described below, although only the results of the tracer gas concentration decay test are discussed in detail.

5 AIR-PRESSURIZATION TEST

Air flow through a building occurs through large openings, such as doors and windows, as well as through narrow cracks, such as fissures and badly-fitting windows. Air flow through large openings is turbulent while flow through narrow cracks is laminar. Air flow through narrow cracks of display cases is also laminar. The flow equation that characterizes the air flow rate through a building component in response to pressure differences across the component can also be used for air change measurements in display cases. The air flow rate and pressure differential across the case are related by the equation:

$$Q = K(\Delta p)^n$$

where Q is the air flow rate supplied to the case (m^3s^{-1})
K is the flow coefficient
Δp is the pressure differential across the case (Pa)
n is the type of flow through the component ($n = 1$ for laminar flow).

This test was used to determine the air flow rate required to generate a 50Pa pressure differential across a display case. Air was supplied to each case via flexible ducting incorporating a flow measuring device, and a bulkhead fitting was used to measure the pressure differential across the display case. The air flow rate supplied to the case was determined by measuring the pressure differential across the laminar flow element used for flow measurement. The pressure differentials across the flow element and display case were measured using micro-manometers (Furness Control).

6 TRACER GAS CONCENTRATION DECAY TEST

This test can be used for quantitative measurements of ventilation rate in all types of enclosure, including buildings and display cases. Air is marked with an easily identifiable gas so that its movements can be traced. In a building, the gas used must be colourless, odourless and inert. Whether this technique is used to test buildings or display cases, the gas must be easily detectable and miscible with the air; ideally there should be no other source of the gas and it should not be absorbed by any of the surfaces with which it comes into contact. Thus air change can be measured under normal conditions of use.

Dinitrogen oxide (N_2O) was chosen as the tracer gas because it is one of the better models of air behaviour. The difference in density between N_2O and air is much less significant than for sulphur hexafluoride (SF_6) which is a tracer gas often used in similar tests on buildings.

The decay in tracer gas concentration in parts per million (ppm) is related to the air change rate in the display case by two equations.

Equation 1: measure of gas concentration

$$C_t = C_0\, e^{-nt}$$

where C_0 is the internal tracer gas concentration at time zero (ppm)
C_t is the tracer gas concentration at time t (ppm)
n is the air change rate per unit time (h^{-1})
t is the time interval between C_0 and C_t (h)
e is the exponential

Equation 2: conversion of gas concentration to air change rate

$$C_t = C_0\, e^{-nt}$$

$$ln\, C_t = ln\, C_0 - nt$$

$$nt = ln\, C_0 - ln\, C_t$$

$$n = (ln\, C_0 - ln\, C_t)/t$$

The ventilation air flow rate, in litres per second, through the display case can then be calculated using the equation:

$$Q_{acr} = (n\, V\, 1000)/3600$$

where Q_{acr} is the air flow rate through the case ($1.sec^{-1}$)
n is the air change rate (h^{-1})
V is the volume of the case (m^3)

The tracer gas, dinitrogen oxide, was introduced through a partially open door and a small fan was used to aid the formation of a homogeneous mixture. During the tracer gas concentration decay tests, the air temperature within the test rig (where the cases were tested) was maintained to within ±1.25°C. Air was sampled from the centre of the case via a tube and bulkhead fitting in the display case. An infrared gas analyzer (Leybold-Heraeus) was used to measure the decay in concentration of the tracer gas. The results of these initial tests are summarized in Table 2.

Table 2 Initial tracer gas concentration decay test data.

Manufacturer	*Date of test*	*Case volume (m^3)*	*Change rate (h^{-1})*	*Change rate (day^{-1})*
A	August 1990	1.12	0.06	1.44
B	August 1990	1.05	0.08	1.92
C	August 1990	2.08	(3)	(72)
D	August 1990	1.19	0.08	1.92
E	August 1990	0.48	0.09	2.16

Cases from manufacturers A to E were used for the initial tests. The case from manufacturer C had air gaps around the glass panels, resulting in the air change rate being considerably greater than for the other four cases: the measured air change rate was three per hour (72 per day). Consequently, further discussion excludes reference to this case. Each of the other cases had similar air-tightness performance which ranged between 1.44 and 2.16 air changes per day. The results are interesting in that no attempt had been made to establish an air-tightness target before the tests. Thus an assessment was obtained of typical air change rates of commonly available cases. These tests showed that all cases, except one, were capable of achieving a higher level of air-tightness.

The initial tests also showed that the tracer gas concentration decay test was better suited than the air-pressurization test to measuring air-tightness of typical museum display cases because the high air leak rate commonly found in museum cases can make it difficult to pressurize them effectively. Subsequent air-tightness tests were carried out using only the tracer gas concentration decay technique.

Table 3 Further tracer gas concentration decay test data.

Manufacturer	*Date of test*	*Case volume* (m^3)	*Change rate* (h^{-1})	*Change rate* (day^{-1})
F	November 1990	3.66	0.04	0.96
F	November 1990	1.30	0.11	2.64
F	April 1991	5.10	0.05	1.20
F	April 1991	18.30	0.01	0.24
G	November 1991	3.58	0.06	1.44
G	November 1991	3.39	0.14	3.36
G	December 1991	3.58	0.02	0.55
G	December 1991	3.39	0.02	0.55
H	September 1992	0.59	0.003	0.08
H	September 1992	8.41	0.012	0.29
F	March 1993	2.78	0.006	0.15
F	March 1993	5.19	0.004	0.10
F	April 1993	1.55	0.009	0.21
F	April 1993	0.10	0.012	0.28

7 FURTHER TESTS

From this initial study, a standard testing protocol for the measurement of the air change rate of display cases was developed by the Victoria & Albert Museum. A target of 0.1 of an air change per day was chosen, based on the results of the first tests by BSRIA and a review of the literature. Another series of air-tightness tests was then carried out, using the tracer gas concentration decay technique. The results are summarized in Table 3.

Cases from manufacturers F, G and H were tested between November 1990 and April 1993. The cases from manufacturers F and G initially failed the air-tightness criterion and the installers had to return to rectify faults and repeat the tests. In cases from manufacturer F, the highest leak rate (2.64 air changes per day) occurred in November 1990 in a case which was among the first to be purchased after the initial investigation. The lowest leak rate (0.1 of an air change per day, which met the Museum's specification) was achieved in March 1993. The 1993 tests for cases from manufacturer F thus show a significant improvement in performance over those which took place in 1990 and 1991. They also show that careful assessment by the client, in providing a measurable standard specification and asking the manufacturer to prove compliance with that specification, enabled improvements to be made and the Museum's requirements to be met.

Two identical cases from manufacturer G were tested in November and December 1991. Between the first and second test, one case achieved a leakage reduction from 1.44 to 0.55 air changes per day, and the other showed a reduction from 3.36 to 0.55 air changes per day. Tests on two cases from manufacturer H recorded the lowest leak rate of all (0.08); the case achieved this level of air-tightness on delivery.

8 CONCLUSION

As a result of these tests, the Victoria & Albert Museum is in the final stages of preparing a case specification for use with tenders for the supply of cases. Since the majority of the permanent displays in the Museum are of mixed media, and cases may be used for different displays in future years, only one specification will be used. This will lead to a common and unified case system in the Museum. The specification provides both the customer and the supplier with a measurable quality assurance criterion.

It should be possible for all museums to apply the same procedures and standard to obtain the greatest cost/benefit ratio for new purchases of cases. There is little if anything to be gained from over-specification. Museums should be able to match the purchase of cases to the available funds without indulging in unrealistic expectations of case performance. They should be able to make a deliberate choice between cases with a high air leak rate for less environmentally sensitive materials and cases with a low air change rate for those objects which require a high level of air-tightness. Manufacturers, on the other hand, should be prepared to set the price of cases according to their environmental performance, and the protocol and specification should encourage them to do this. In time, manufacturers may be prepared to provide a rating system for their own products.

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SUPPLIERS

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Furness Controls Limited, Beeching Road, Bexhill, East Sussex TN39 3LJ, UK.

Rosemount Limited, Horsfield Way, Bredbury Industrial Estate, Stockport, Cheshire SG6 2SU, UK.

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