Vented film can research

Introduction

Film cans are generally manufactured from a stable plastic or metal, usually steel or aluminium. The can lid is often a tight fit but does not seal the can completely allowing a small degree of equilibrium between the external environment and the internal microclimate. Film cans have a buffering effect on the rate of change of the internal microclimate in relation to the storage conditions. Temperature is buffered less than relative humidity[1].

One of the major issues in film preservation is the autocatalytic decomposition reaction of cellulose ester polymers used as the film base. In this reaction the acids, created as a by-product, will accelerate the reaction rate at any given temperature[2]. The most commonly used and effective method of controlling the rate of the decomposition reaction, and thus the amount of acid in the film, is by low temperature and low relative humidity storage. However this can be very expensive for archives in poorer countries, not only in establishing suitable vaults and plant, but also in the ongoing running costs.

Other approaches to lower acid levels in decomposing films

Several methods have been proposed to reduce or remove the decomposition by-products:

• Kodak/FPC Molecular Sieve-Acid Scavenger uses zeolites as a passive sorbent to capture acids in the film can microenvironment

• Neutralisation treatments using alkali baths to neutralise free acids in the film system (emulsion and base)

• "Dry Treatment" developed by the Vietnam Film Institute (VFI)[3]. Film is loosely unwound and placed in a high air exchange environment for 24 hours, during this time the decomposition acids diffuse from the film.

All these methods require a relatively high level of resource to carry out. Apart from the resource implications there are other drawbacks that limit the potential success of their application.

The kinetic energy of the vapours is very low and there is little energy to move the acid vapours into the sorbent, this requires a flow (positive pressure)[4]. This significantly reduces the sorbtion potential of molecular sieves inside a film can where there is no air movement.

The neutralisation bath involves a very high degree of risk to the film materials. The acid by-product of the decomposition reaction increases the solubility of the emulsion gelatin to such an extent that it becomes feasible for the emulsion to dissolve in the bath during treatment.

The Dry Treatment in its current form as practised in the VFI, or even with a higher degree of mechanisation, has a degree of risk of physical damage and the time-out-of-storage considerations.

General Theory of Diffusion

The diffusion of gases, in this case acetic acid vapour, is driven by the kinetic energy of the gases. Fick's First Law of Gas Diffusion describes diffusion as a response to a concentration gradient expressed as the change in concentration due to change in location.

$$J = -D\frac{dC}{dx}$$

Where:

J the gas flow (g cm^{-2}s^{-1}), this is perpendicular to the planes of equal concentration and points towards the regions of lower concentration.

D the diffusion coefficient for that gas in air

For maximum efficiency in removing the decomposition acids by diffusion from the film the surrounding environment must have a zero concentration. As the concentrations inside the film and the outside environment approach equilibrium the emission rate reduces until at equilibrium the rate becomes zero[5].

The linear relationship between emission rate (ER) and concentration can be expressed:

$$ER = k(C_{eq} - C_{chamber})$$

Where:

k the pollutant transfer coefficient

C_{eq} the equilibrium concentration (μg/m^3) when ventilation = zero

$C_{chamber}$ the concentration in the chamber (e.g. film can) at time = zero

In a film can with little or no air flow a steady state concentration will be reached when the concentration inside the film is equivalent to the concentration inside the film can.

A steady state concentration can be reached where the total mass of the gas leaving the material will equal the total mass of the gas leaving the film can.

This is shown in the Hoetjer Equation:

$$C_{st} = \frac{C_{eq}}{\left[1 + \left(\frac{N}{Lk}\right)\right]}$$

Where:

C_{st} the steady state concentration

N the ratio of air flow over the chamber volume

L the loading or ratio of the object surface area over the chamber volume

Any air movement through the film can will maintain a lower the steady state concentration. However, if the flow of air inside the film can is sufficient to maintain the concentration at zero then the rate of diffusion, in this instance from the film, will be maximised.

From experimental data, physical dimensions of film cans and typical films some basic assumptions can be drawn for further refinement.

Film Can (Chamber) Dimensions

As defined in the Hoetjer Equation the ratio of the chamber (film can) volume to the total surface area of the object (the film) is required. For general calculations the "average" length of a 35mm film in the ScreenSound Australia collection is assumed to be 700 feet.

		Radius (mm)	Height (mm)	Volume (m³)	Surface Area (m²)
1000'	35mm film can	135	38	^{V1} 2.18×10^{-3}	
700'	35mm film[1]	112	35	^{V2} 1.38×10^{-3}	8.58×10^{-2}
	75mm film core	37.5	35	0.15×10^{-3}	0.44×10^{-2}
	Volume $_{(V1 - V2)}$ [2]			0.80×10^{-3}	
700'	Diffusive film surface [3]				8.10×10^{-2}

Notes:

[1] This is an approximation. The wind tension of the film pack will alter the actual figure. A film with a Preservation wind, which is a low tension wind, will have a larger radius and thus a larger surface area than a tightly wound film.

[2] The "airspace" surrounding the film inside the can. This volume is used to calculate the concentration of acetic acid diffused from the film and also the number of air changes per hour.

[3] The film core is part of the overall radius of the film. The surface area of the film core is subtracted from the total surface area to give a surface area of the total diffusive area of the film.

Experiment 1

Aim

To investigate any effect of positively ventilating a film can on the free acid level of a decomposing film.

Method

Films will be analysed for free acid content by the method described in Appendix 1.

Each film is split to provide two samples of equal length and equivalent acid content. The films are preservation wound on a 75mm core and one film from each pair is stored in a non-vented can and the other film in a vented can. The surface area of each film will be calculated individually.

The experiment is conducted in pairs of cans, in each pair:
- test can one (1) is non-vented and used as a control
- test can two (2) is vented by 10mm diameter holes cut into the sides of the can with aligned holes cut in the sides of the lid (Diagram 2)

Each can has a neoprene grommet let into the side of the can. The detector tube makes a tight seal against the grommet ensuring that no air can enter around the grommet during sampling. The grommet is covered by a polyester tape except when readings are being taken.
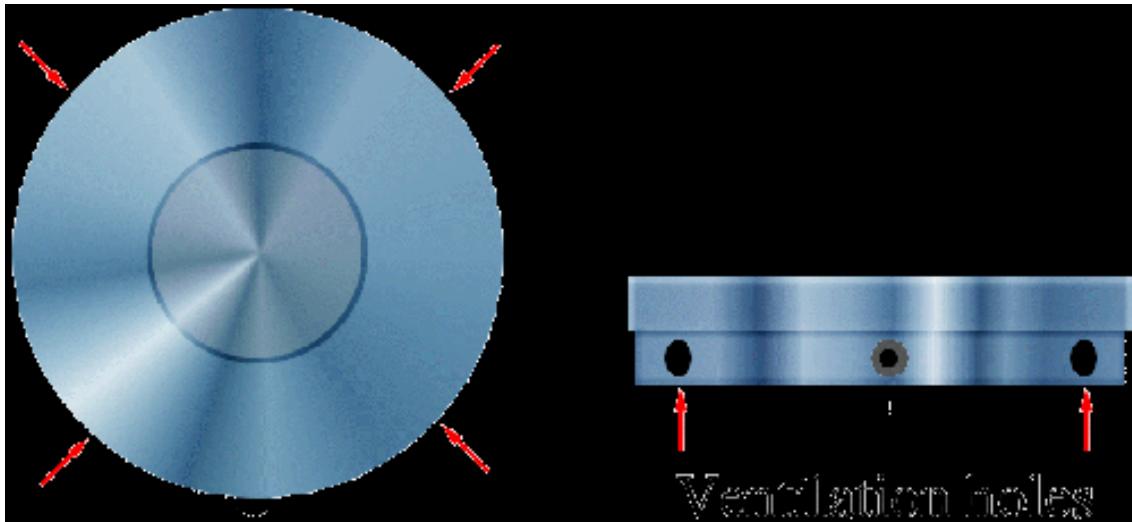
(insert- filmcan2.gif)

Diagram 2: test can two (2)

Each can has 2000 grams placed on the lid to simulate storage condition in a stack. All acetic acid concentration measurements are taken through the grommet placed in the side of each can.

The acid concentration inside the cans is measured by Kitegawa detector tubes: 216S - Acetic Acid 1 - 50 ppm.

The cans are arranged in pairs under identical environmental condition:
- "Still" air, no detectable air movement

- Air moving slightly (about 0.3 m/sec)

The films are stored at 20°C and 50% RH for 12 months.

At regular intervals acetic acid concentration readings are taken from inside each can and recorded. After 12 months each film will be analysed for the free acid content. Comparisons between the free acid level at the start and vented and non vented cans will be made.

Results
Acetic acid concentration inside the film cans:

Non vented cans	100 ppm
Vented cans	4 ppm

Free acid level:

The head sample readings on vented can showed approximately a 35% lower acid content than the non-vented. However as the samples were taken further in the reel the difference in acid content decreased until the centre of the reel where there was only an imperceptible difference between vented and non-vented cans.

Conclusions

The lower steady state concentration surrounding the film predictably gave a lower free acid concentration in the outer layers of the film.

However it would appear that the limited ability for air to move over the top and under the film within the can, creates high local concentrations of acetic acid which reduces the diffusion of acid from the centre area of the film reel.

The decrease in free acid at the head of the non-vented reels is surprising.

Possible explanations are:

1. a degree of diffusion either around the can lid or through the plastic walls
2. adsorption/absorbtion of acid by the plastic, in this case high impact polystyrene
3. reaction with some other component of the plastic e.g. the pigment

Experiment 2

Aim

To investigate the airflow through a film can with different ventilation apertures. This will be used to calculate air changes per hour within the cans. Different lengths of film will be housed inside the test cans to observe the effect that this has on airflow inside the can.

Method

Film cans are modified with various ventilation apertures, both in style and location. The cans will be placed in a measured airflow and the air movement observed by using vapour air flow indicators (Kitegawa Air Flow Indicator apparatus).

The test will be run using various aperture/film length combinations.

A standard airspeed of 0.3 m/sec (approximately 1 km/h or 0.675 miles per hour) is used. This was chosen as an attainable speed in a variety of vaults.

Results

Four apertures oblique to the airflow.

The arrangement used for Experiment 1.

Areas of low air movement occurred above and below the apertures. A high rate of movement occurred along the "sides" of the film.

In Experiment 1 the air sampling location was inadvertently placed in an area of low air movement.

Four apertures aligned in the airflow.

This pattern created a low air movement area below the centreline of the can.

There was a small degree of air movement at the trailing end of the can. This was observed as a "pulsing" in and out of the can.

Two apertures coaxial to the airflow.

This arrangement produced an even airflow through the can. There were no observable eddy currents that impeded air flow.

Conclusions

The round film cans used in the experiment behaved in accordance with Bernoulli's Principle. The "leading edge" of the can slows the air flow and increases the pressure and the "trailing edge", with higher airspeed, creates a proportionally lower pressure area. The air flows through the can to equalise the pressure differential.

The simple arrangement of two holes aligned in the airflow is the most efficient location for creating an airflow through a film can.

Sources

1.   Jean-Louis Bigourdan, James Reilly, Final Report to the Office of Preservation, National Endowment for the Humanities.
"Environment and Enclosures in Film Preservation" p71-79

2.   James Reilly, Image Permanence Institute.
"IPI Storage Guide for Acetate Film" p13

3.   Dr Ngo Hieu Chi, SEAPAVAA-UNESCO Advanced Training Seminar on the Treatment of Vinegar Syndrome and Mould Affected Films, Report.
"Dry Treatment at the VFI" Annexe S

4.   Dr Mike Morris, Proceedings of 1998 IAP Meeting.
"Passive Sorbents for Organic Acid Removal"

5.   Frank Ligternik, Proceedings of 1999 IAP Meeting.
"Application of the Hoetjer Equation in Climate Control Studies"

6.   P.Z. Adelstein, J.M. Reilly, D. Nishimoura and C.J. Erbland, SMPTE Journal , May 1995. "Stability of Cellulose Ester Base Photographic Film: Part III - Measurement of Film Degradation"

Appendix 1: Test Procedure for Water-Leach Free Acidity Test

1. A film sample weighing approximately 1g is weighed to the nearest 0.01g

2. The film sample, including the emulsion layer and all coatings, is cut into small (approximately 25mm^2) pieces and placed in 100ml of de-ionised water.

3. The sample is allowed to soak in the water for at least 24 hours at 38°C, with moderate stirring.

4. The solution is filtered to remove film particles (important to remove gelatin as it amphoteric).

5. The solution is titrated with 0.1N sodium hydroxide with metacresol purple*

6. A blank titration is made using the same de-ionised water source.

7. The free acidity (fa) is calculated as equivalent millilitres of 0.1N sodium hydroxide.

$$fa = \frac{(S-B)N_t}{0.1W}$$

Where:
S mL of titrant used for the sample
B mL of titrant used for blank
N_t normality of the titrant
W weight of sample in grams

* m-Cresolsulphonephthalein, 0.1g dissolved in 13.1mL 0.2N NaOH and diluted to 250mL.

Appendix 2: Observations and optimising the design for ventilated filmcans.

It is most probable that it is the inability of air to flow adequately across the major diffusive surfaces of the film reel that has a major reduction in the effectiveness of positively ventilating film cans.

To design a filmcan that allows greater air flow over and under a film reel requires several changes in traditional design.

- The height of the filmcan needs to be increased slightly to allow more air space above the film.
- Ridges to adequately support the film and permit airflow under the film moulded in the floor of the can. These should be moulded so that they direct the air through the can, whether this is in parallel with the axis of air flow or at a slight angle to the air flow axis needs to be determined
- Ventilation slots cut as low in the walls of the can as possible, slots appear to be preferable to round holes as they disperse the air more evenly around the film. By cutting slots low in the can wall the air moves more freely across the bottom of the can and carries away the heavier decomposition by-products that tend to pool in the bottom of the filmcan.

- Moulded ridges on the floor of the filmcan (section X - Y) allow air to pass beneath the film. This should flush away the decomposition by-products that tend to be heavier than air.

- Slots cut in the walls of the can create more of a laminar air flow through the can