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# 'Giving them back their voice'—the development of an in situ conservation treatment for bound twentieth-century moisture-damaged paper

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# 'Giving them back their voice'—the development of an in situ conservation treatment for bound twentieth-century moisture-damaged paper

**Abstract**
This article describes the paper analysis and design and application of an in situ conservation treatment for the moisture damaged paper of a twentieth-century World War Two nominal roll. This work was enabled by the award of a Wellcome Trust Research Bursary to book and paper conservator Emma Nichols. The nominal roll had suffered extensive moisture damage, resulting in the weakening of its paper leaves and bleeding of inks. The historical importance of the roll's binding meant conservation of the leaves needed to be carried out in situ. The roll's paper was analysed with near infrared spectroscopy, optical microscopy, and fibre furnish in collaboration with researchers at University College London's Institute for Sustainable Heritage. Ultraviolet photography and a Dino-Lite microscope were used at Cambridge University Library. The analysis revealed moisture damage extended beyond what was visible, and when used in conjunction with the extensive testing of conservation adhesives with an aerosol generator and the design of a Perspex frame for use with a suction wedge, it informed the design and execution of a successful in situ conservation treatment. The paper leaves of the roll were strengthened by the aerosol application of isinglass and 2gsm Berlin Tissue.

**Keywords**
Wellcome Trust; moisture damage; nominal roll; World War Two; paper analysis; adhesive vapour

## Introduction

This article will discuss the paper analysis and conservation treatment of a World War Two (WWII) moisture-damaged volume titled *Changi Internment Camp Nominal Roll of Internees* from June 1942.

The nominal roll is one item from the Voices of Civilian Internment archive owned by the Royal Commonwealth Society (RCS), housed at Cambridge University Library (CUL). The roll is one of two volumes, created by civilians interned by the Japanese in Singapore during WWII as a means of recording their personal information.

A stab-sewn hardback binding with paper leaves, the roll had suffered extensive moisture damage, leaving the paper very weak and at high risk of irreversible damage from handling. Some areas of the binding, leaves and text had already been lost, and some of the inks had bled. The roll was due to be conserved and digitised as part of a Wellcome Trust–funded project at CUL for the entire Voices of Civilian Internment archive. However, it was able to receive much needed individual attention and time beyond what had been originally allocated thanks to the award of a separate research bursary to CUL book and paper conservator Emma Nichols.

This article will describe the history of the Voices of Civilian Internment archive to which the roll belongs, the pre-conservation condition of the roll, the application for the research bursary, the analysis carried out on the paper of the roll, and the research and testing conducted to design and execute a bespoke in situ conservation treatment for the roll.

## History of the Voices of Civilian Internment: WWII Singapore archive[1]

When WWII began, British civilians living and working overseas were requested by the UK government to remain in their posts. The rubber and tin industries of Malaysia were vitally important in the construction of military hardware such as vehicles and planes, so those working and overseeing these industries were crucial to the war effort.

There had been plans to evacuate women and children living in Singapore to Australia but the speed of the Japanese invasion caught many by surprise. Three days after the official surrender of Singapore in February 1942, all British civilians of European descent were required to report for internment. Soon after, they were marched to Changi Gaol, a grim concrete building in the eastern part of the city which would serve as their internment camp until they were moved to Sime Road in 1944.

Although built to house 600 inmates, roughly 2,500 civilians were confined at Changi. Internees were separated by gender, with boys over 12 being considered adults and so separated from their mothers. Although mainly comprising British citizens, the final roll call of internees from August 1945 listed people from more than twenty countries.

**1** Cardwell, John, "Voices of Civilian Internment: WWII Singapore," *Cambridge University Library Special Collections Blog* (Cambridge: Cambridge University Library, 2017). https://cudl.lib.cam.ac.uk/collections/civilianinternment/1

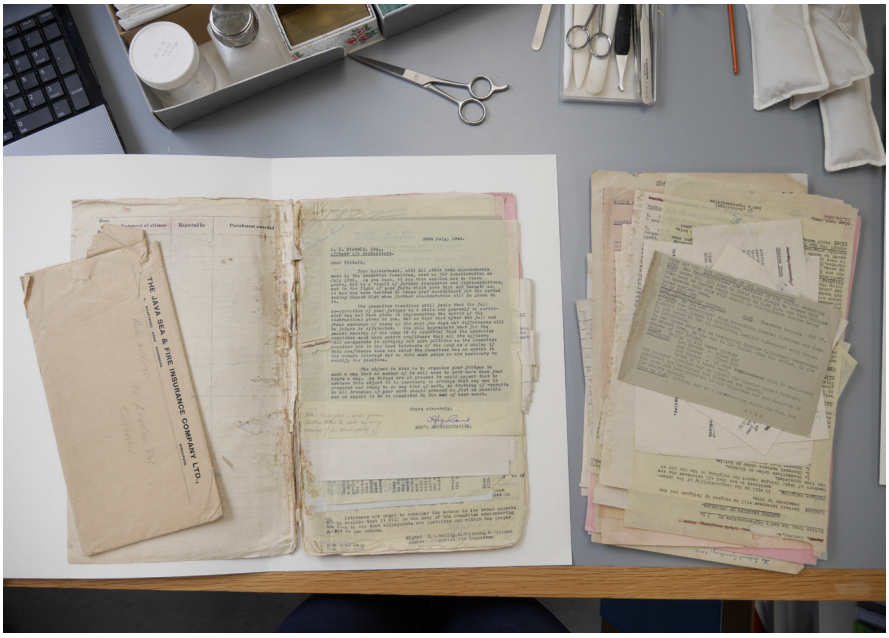


**Fig. 1** Papers from the Voices of Civilian Internment Archive before conservation. RCMS.103.12.15.3. Photograph by Emma Nichols, Conservation Department, Cambridge University Library. RCMS 103/12/22.

The internees lived in terrible conditions under extreme stress, on meagre rations of rice and beans. In the three years they were interned the average man lost 29% of his body weight and a snail farm was set up as a desperate attempt to ingest some protein. Red Cross parcels containing essential supplies and medicine were blocked from entering the internment camp, and the lack of nutrition and hygiene meant diseases were endemic.

Although food and medicine were strictly controlled, the internees were largely allowed to organise themselves and had access to typewriters, pens and scrap paper. This enabled them to keep their own records, document their situation and even produce newsletters which were circulated around the camp to share news and raise morale.

The survival of this material after the war is largely due to Hugh Bryson, an internee and member of the Malayan Civil Service. After the war he collected the original documents and files of the Camp Commandant and Quartermaster, the nominal rolls, and the diaries and correspondence of the internees, and he also encouraged people to write their memoirs. It is this combination of the material produced inside the internment camp, and that created in the years afterwards, that form the Voices of Civilian Internment archive.

The archive meticulously documents the internees' captivity: their accommodation, work for the Japanese, their recreation, diet and health, and repatriation at the end of the war. Survivors of internment rarely spoke of their traumatic ordeal, meaning that the content of the archive is of international importance and interest to the families of internees, academics, scholars of malnutrition and tropical diseases, and the general public.

**Condition of the archive**

The archive was awarded a Research Resources Award from the Wellcome Trust in 2015 to enable it to be conserved and digitised, with the images shared freely with a global audience on the Cambridge Digital Library site.

Composed of poor quality twentieth-century materials and held together with pressure sensitive tape, low-grade animal hide adhesives, and staples, much of the archive had been stored in the humid and squalid conditions of the internment camp and as such had deteriorated to a stage where it was unable to be safely handled. One of the nominal rolls was identified as being particularly vulnerable by the pre-conservation visual condition assessment.

**Nominal roll**

Contrary to the name, the nominal rolls are not physically rolls, but bindings made by the internees, composed of paper textblocks bound into laminated wood pulp pasteboard covers with a stab sewing. The information in the rolls is typewritten, with pencil and ink anno-

**Fig. 2** (left) The nominal roll. (right) Detail of the moisture damaged paper and inks of the nominal roll. Photographs by Emma Nichols, Conservation Department, Cambridge University Library. RCMS 103/12/22.

tations, and lists for each interned civilian their name, date of entry into the camp, marital status, occupation, age, nationality and camp address. The roll is arranged in three parts: men, women and children. Those who passed away during internment had a thin red line drawn through their record. Because they contain such personal information, the nominal rolls are often the first resource used by those trying to trace relatives or friends.

One of the two nominal rolls in the archive, dated May 1943, was able to be digitised and handled safely; the other, earlier one, from June 1942, had suffered extensive moisture damage resulting in the loss of paper and text, the bleeding of inks and delamination of the boards. The remaining paper was very weak and at high risk of further damage and loss (see Fig. 2). As the sewing of the binding was un-damaged and an important part of the roll's history, it was decided that any conservation would need to be undertaken in situ, that is without disbinding. The inks were tested with both water and ethanol, and the handwritten inks were discovered to be fugitive.

Many archival repositories hold large collections of twentieth-century material, a significant proportion of which has been water damaged to some degree and embarking on large digitisation programmes to make this material more accessible to researchers is becoming more common.[2]

Traditional practice for conserving similarly moisture- and mould-damaged paper usually requires the separation and individual treatment of leaves,[3] with more recent practices treating bound items using alcohols or brush applications of adhesive.[4] Due to the decision that the roll must remain bound throughout any treatment, the delicate fibrous nature of the paper, and the fugitivity of the inks in both water and ethanol, neither of these treatments were considered suitable for the roll.

When the Wellcome Trust suggested that the project would be eligible for further funding by means of a research bursary, it was felt that the roll proved the perfect candidate as it would benefit from more in-depth analysis and conservation.

**Application for a Wellcome Trust Research Bursary**

The first step of applying for the bursary was to create a viable project plan. The primary aim was the longevity of the roll, and stabilising it for digitisation and future consultation.

Due to limited access to analytical equipment at CUL, collaboration with another institution was essential when it came to analysing the paper of the roll. Working with researchers from the Institute for Sustainable Heritage at University College London (UCL), an experimental plan to investigate the paper properties of the roll with near-infrared and optical microscopy was created.

**2** Laura O'Brien Miller and Melissa Tedone, "Archives Conservation Discussion Group 2011: Digitization and Its Effect on Conservation Treatment Decisions: How Has Wide-Spread Digitizing of Collections Changed Our Approach to Treatment?" *The Book and Paper Group Annual* 30 (Book and Paper Group, American Institute for Conservation, 2011).

**3** Anna-Klara Hahn, "Letterbook: Egypt Letters 1862–1865," *Conservation Report P&O Heritage* (P&O Heritage Collection, 2017).

**4** Aurélie Martin, Véronique Rouchon, Thierry Aubry, Nelly Cauliez, Marthes Desroches and Marlene Margez, "Local Strengthening of Mould-Damaged Manuscripts: A Case Study on Logbooks of Early French Expeditions in Louisiana (1684–1722)," *Journal of Paper Conservation* (IADA, 2011); Kyla Ubbink and Roberta Partridge, "Preserving Letterpress Copybooks," *Journal of the Canadian Association for Conservation* 28 (2003): 38–45.

With the collaboration at UCL in place and the support of CUL colleagues in the Conservation, Digitisation and Manuscripts Departments, the project 'Development of an In Situ Treatment Method for Twentieth Century Moisture Damaged Paper' was developed.

The project consisted of three main strands:

- The analysis and characterisation of the composition and condition of the roll's paper using various spectroscopic methods, including near-infrared (NIR), ultraviolet (UV), and optical microscopy. New UV equipment would be bought by the bursary for the CUL digitisation team; used initially for the analysis of the roll but retained and used for the analysis and preservation of CUL's wider collections in the long term
- The design and execution of a bespoke in situ conservation treatment for the roll, informed by the results of the analysis and the specific requirements of the roll, and the creation of bespoke housing. This work would be conducted by the project conservator, whose contract would be extended by the bursary
- The digitisation of the roll at CUL and engagement by all departments involved with WWII Far East Prisoner of War (FEPOW) groups and the families of those interned

The application was successful and it was revealed to not only be the first time the Wellcome Trust had awarded a Research Bursary to a conservator, but to have been the largest amount of money awarded in that round of applications.

**Analysis of the nominal roll's paper**

*1. Optical microscopy and fibre furnish*

The first step of the project was the analysis of the roll's paper. At UCL a Keyence–VHX 5000 Digital Microscope (Milton Keynes, UK) with a magnification range from 0.1x–5000x was used to magnify the roll's paper fibres in situ (see Fig. 3). It was established that the fibres varied in length, width and cellular structure, indicating that several different fibres types had been used in the making of the paper.

It was not possible to identify fibres in situ and loose fibres were extracted for fibre furnish. The results showed that the paper was composed of a mixture of bast and woody fibres. As bast fibres were commonly used in East Asian papermaking but not in European, this indicated the paper could have been made in or near Singapore.[5] It could be speculated that, due to limited resources during the war, the paper may have been made from recycled Western and Eastern paper mixed together.

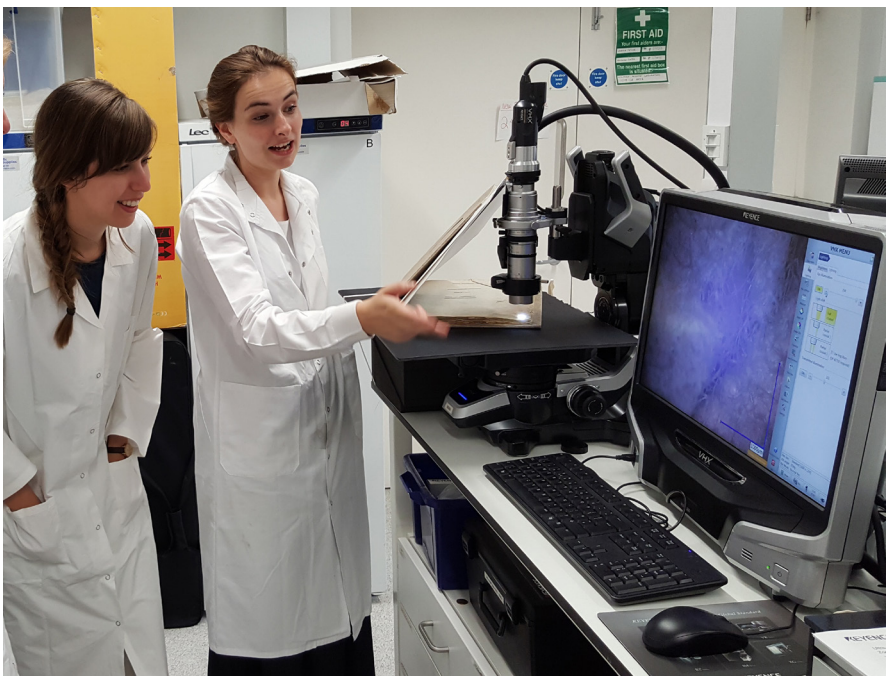


**Fig. 3** Emma Nichols and Natalie Brown analysing paper fibres of the nominal roll using a Keyence Digital Microscope at the Institute for Sustainable Heritage at UCL. Courtesy of Emma Nichols.

**5** Dard Hunter, *Papermaking: The History and Technique of an Ancient Craft* (New York: Dover Publications, 1947); Timothy Barrett, *Japanese Papermaking: Traditions, Tools and Techniques* (New York and Tokyo: Weatherhill, 1983); Thomas Collings and Derek Milner, "Identification of Oriental Paper-making Fibres," The Paper Conservator 3(1) (1978), 51–79; Sukey Hughes, *Washi: World of Japanese Paper* (New York: Kondansha International, 1978); Masazumi Seki, "Database of Traditional Papermaking Centres in East Asian Regions," *Research on Paper and Papermaking* 85 61–81 (Senri Ethnological Studies, 2013).

*2. SurveNIR*

In addition to microscopy, SurveNIR (a system based on NIR in combination with chemometric data evaluation) was used to characterise the paper, allowing rapid and non-destructive measurements of the chemical and physical properties important for preservation.[6] SurveNIR was able to identify the paper type and approximate the pH, degree of polymerisation (DP), lignin, protein and rosin content, as well as other properties.[7]

Although a range of pH values across the roll's paper were measured, the damaged areas of the textblock were particularly acidic (pH≤4). The paper had a low lignin content, which, given the presumption that (due to its age) the paper in the archive would have high lignin content, was unexpected—but did correlate with the paper composition being a mixture of Western and Eastern fibres.[8] The rosin and protein content of the textblock were both low, with higher levels being found in the end leaves. East Asian papermaking did not historically use rosin or gelatine sizing, but rosin has been found in more modern Eastern papers with the influence of Western papermaking practices due to globalisation.[9]

The DP measurements, the average number of repeat units in a polymer—in this case cellulose[10]—indicated the extent of water damage. Though the bottom right corner of the nominal roll's paper had obvious clues to paper weakness, such as fibrous paper and bleeding inks, the upper parts of the leaf displayed no visible signs of damage.

The DP measured in several different areas on the leaf varied dramatically. The areas at the top of the leaf measured ≥1000 whereas in the visibly damaged bottom corner, the measurements reduced to ≤500. A recent work[11] demonstrated that an appreciable accumulation of missing pieces due to brittleness occurred in 95–98% of Western paper objects with DP<300, indicating that 300 DP units is the usability threshold for these paper objects.[12]

What was of particular interest was how dramatically the results varied over a very short distance, and how far up the leaf the lower DP measurements extended. In the middle of the fore-edge of the leaf the measurements decreased by over 500 in the distance of three millimetres. This was quite surprising, given that the area in question had no obvious visual clues to damage. It was possible to theorise that the DP measurements indicated the extent of moisture ingress and damage across the leaf and the results of UV imaging were eagerly anticipated to see if they corroborated the DP readings.

*3. UV imaging*

At CUL the Digital Content Unit team and Conservator began using the new UV imaging equipment to capture images of the leaves of the nominal roll. When the UV lamps were switched on it was clear that there was an area of each leaf that did not fluoresce. This area

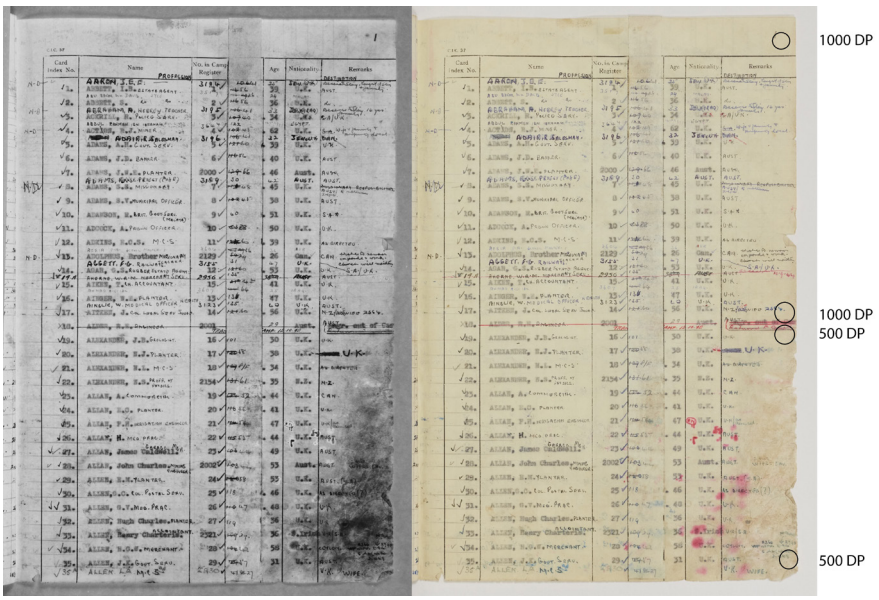


**Fig. 4** (left) UV photograph of page one of nominal roll, (right) visible light photograph of the same page with circles demonstrating where approximate DP measurements were made. Reproduced by kind permission of the syndics of Cambridge University Library, Conservation Department, Cambridge University Library.

**6** Dirk Lichtblau Matija Strlič, Tanja Trafela, Jana Kolar and Manfred Anders, "Determination of mechanical properties of historical paper based on NIR spectroscopy and chemometrics—a new instrument," *Journal of Applied Physics* A 92 (1) (Melville: American Institute of Physics, 2008); Matija Strlič, Jana Kolar and Dirk Lichtblau, "The SurveNIR project—a dedicated near infrared instrument for paper characterization," *Museum Microclimates* 81–84 (Copenhagen: National Museum of Denmark, 2007).

**7** In the SurveNIR system the chemometric models used to predict the physical and chemical properties of paper are based on a reference collection of 1400 European papers. The analysed nominal roll paper is potentially made from mixed fibres not included in this reference database and therefore the measurements can only be used as approximations and not as absolute values.

**8** Gisela Marques, Jorge Rencoret, Ana Gutiérrez and Jóse del Río, "Evaluation of the Chemical Composition of Different Non-Woody Plant Fibers Used for Pulp and Paper Manufacturing," T*he Open Agriculture Journal*, 4 93–101 (Sharjah, UAE: Bentham Open, 2010); M. Inaba, G. Chen, T. Uyeda, K. Katsumata and A Okawa, "The Effect of Cooking Agents on the Permanence of Washi (Part 2)," *Restaurator* 23 (3) 133–144 (De Grutyer, International Journal for the Preservation of Library and Archival Material, 2002); Natalie Brown, Dirk Lichtblau, Tom Fearn and Matija Strlič, "Characterisation of 19th and 20th Century Chinese Paper," *Heritage Science* 5(47) (Springer Open, 2017); James Han, "Properties of nonwood fibers," *Proceedings of the Korean Society of Wood Science and Technology Annual Meeting* 3–12 (Seoul: The Korean Society of Wood Science and Technology, 1998); P.L. Bégin, S. Deschâtelets, D.W. Grattan, N. Gurnagul, J. Iraci, E. Kaminska, D. Woods and X. Zou, "The impact of lignin on paper permanence: A comprehensive study of the ageing behaviour of handsheets and commercial paper samples," *Restaurator* 19 (3) 135–154 (De Grutyer, International Journal for the Preservation of Library and Archival Material, 1998).

**9** Elaine Koretsky, *Killing green: an account of hand papermaking in China* (Ann Arbor, Michigan: The Legacy Press, 2009).

**10** Matija Strlič, Jana Kolar and Boris Pihlar, "Methodology and analytical techniques in paper stability studies," *Ageing and stabilisation of paper* 27–47 (Ljubljana: National and University Library, 2005).

**11** Matija Strlič, Carlota Grossi, Catherine Dillon, Nancy Bell, Kallipi Fouseki, Peter Brimblecombe, Eva Menart, Kostas Ntanos, William Lindsay, David Thickett, Fenella France and Gerrit De Bruin, "Damage function for historic paper. Part II: Wear and tear," *Heritage Science* 3 (36) 1–11 (Springer Open, 2015).

**12** It is challenging to offer a figure for a 'normal' DP for the paper found in the roll, given its possibly mixed Western and Eastern fibre composition and the lack of characterisation studies on East Asian papers. DP is also fibre-dependent, with Kozo fibres commonly found in Japanese papers measuring as high as 4000. Co-author Natalie Brown undertook

a study of nineteenth- and twentieth-century Chinese papers of unknown fibre content, returning average DP values of 1860; however, the DP values ranged from 500 to 4500, reminiscent of pre-1850 European paper (values between 810 and 3800). East Asian paper fibres also degrade differently to Western paper, which further complicates comparison. (For more information about deterioration of East Asian fibres, see this paper from the 2015 Book & Paper Group conference.)

started from the bottom corner of the leaf, where there was visible moisture damage, and spread up the leaf to where the DP was 500 or less. As the paper pre-dates 1950 this lack of fluorescence was unlikely to be due to optical brighteners being washed from the paper.[13] However, without further testing, it was not possible to identify whether this was due to dirt being absorbed or to biodeterioration.[14] Either way, it could be confidently acknowledged that there had been disturbance to the paper, and that this disturbance covered a larger area than what was visible. Using a 550 nm camera filter with UV lamps images were produced that clearly demonstrated the extent of the damage.

When comparing the UV images with the DP measurements it was found that they corresponded closely with one another (see Fig. 4). This meant that the Conservator would be able to use the UV images as a rough guide to the parameters of moisture ingress and damage on each leaf, therefore informing how far any conservation treatment should potentially extend.

*4. Dino-Lite microscope*

In addition to the analysis at UCL and the UV imaging, inspection of the damaged areas of the paper was carried out with a Dino-Lite Digital Microscope. At a magnification of 250x, the Dino-Lite emphasised the fibrous nature of the damaged areas of the paper (see Fig. 5).

**Designing a conservation treatment**

*1. Treatment requirements*

With the results of the analysis in hand, the next stage of the project was to devise a conservation treatment for the vulnerable paper leaves of the roll. Due to the necessity for the roll to be handled and digitised, the key requirement of a treatment would be to impart strength and support to the paper, thereby minimising the risk of further loss of material. It was felt this would be best achieved by the application of an adhesive and supportive conservation grade tissue. However, there were a number of challenges that needed to be considered in order for this to be carried out safely and successfully.

The first was the requirement that any treatment to the leaves would need to be carried out in situ. The second challenge was the fugitivity of the handwritten inks in both water and ethanol, meaning as little moisture as possible should be used in treating the paper. Thirdly, as the paper was soft, fibrous, and had significant damage to the cellulose chains, the risk of forming tidelines from moisture and disturbing the fibres was considerable. Lastly, the expanse of area needing treatment had to be taken into account. The DP measurements and UV imaging had shown that some leaves needed an area as large as 180 x 130 mm treated.

*2. Aerosol generator*

Research of conservation literature had found limited options for this combination of requirements. It was felt a brush application of adhesive should be avoided, as the soft, fibrous paper could easily be disturbed, and the moisture sensitivity meant there was a high risk of creating tidelines which could lead to a line of weakness.[15] It was felt that using remoistenable tissue would prove complex given the size of the area needing treatment and the fact that the roll would be treated whilst still bound. It was theorised that applying adhesive as a vapour by using an aerosol generator, or ultrasonic mister, could be a solution. This method would

**13** Paul Messier, Valerie Baas, Diane Tafilowski, Lauren Varga, "Optical Brightening Agents in Photographic Paper," *Journal of the American Institute for Conservation* 44 (1) 1–12 (American Institute for Conservation of Historic and Artistic Works, Routledge, 2005).

**14** Danielle Measday, "A summary of ultra-violet fluorescent materials relevant to conservation," *The Australian Institute for the Conservation of Cultural Material* (Canberra: Taylor and Francis, 2017).

**15** A. Dupont, "Degradation of Cellulose at the Wet/Dry Interface. I. The Effect of Some Conservation Treatments on Brown Lines," *Restaurator* 17 (1), 1–21 (De Gruyter, 1996).

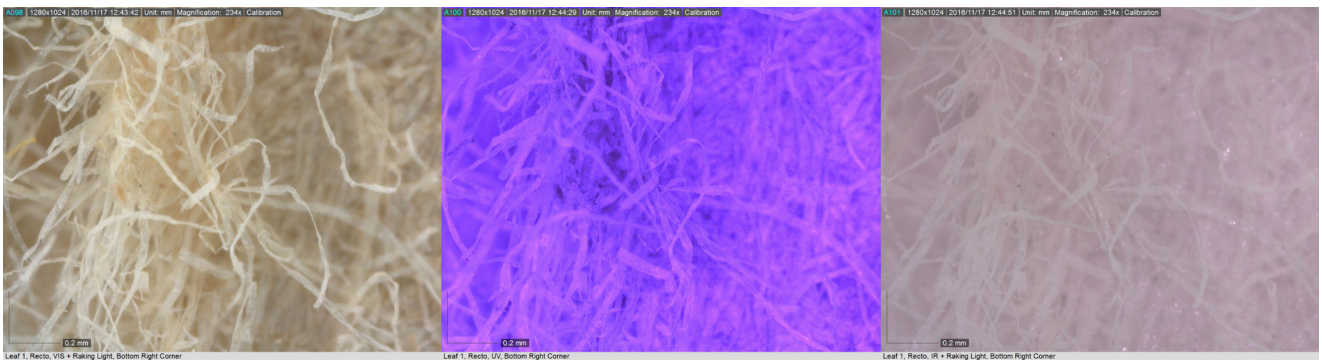

**Fig. 5** Damaged paper fibres of the nominal roll viewed at 250x magnification with the Dino-Lite® microscope (L-R) visible light, ultra-violet light, infrared light. Photographs by Emma Nichols, Conservation Department, Cambridge University Library. RCMS 103/12/22.

allow greater control of the amount of moisture applied to the paper and minimise the risk of over-saturation or disturbance to the fibres.

After research of ultrasonic misters on the market, a Recolo 100 aerosol generator was purchased. Capable of atomising aerosol particles from 0.5 to 6μm, the generator also has a heated hose fitting that contains a spiral heating element, allowing the aerosol contents to be heated to 43°C: good for use with protein adhesives. The atomisation chamber capacity is 625 ml; however, smaller quantities of 5–15ml can be atomised out of a cone cup. There is also a control to vary the strength of the fan.

*3. Selecting an adhesive*

Having decided on aerosol application, the next stage was to find an adhesive with the following properties:

- flexibility
- a low viscosity, essential to become airborne in the aerosol generator
- a neutral to high pH, to counteract the acidity of the paper
- enough strength to adhere tissue

Through consulting literature[16] and contacting other conservators, a list was compiled of adhesives. Those with weaker adhesion properties, such as *funori*, were disregarded and instead those with a lower viscosity such as Klucel E and G (two types of hydroxypropyl cellulose—non-ionic cellulose ethers), gelatine, isinglass, wheat starch paste and methylcellulose were investigated. Techniques that used adhesives in alcohol solutions were also disregarded due to the increased risk to health and safety, and the undesirable increased speed at which the paper and inks would be saturated.[17]

To discover the highest percentage at which each of the selected adhesives would vapourise, solutions were mixed with deionised water and run through the aerosol generator. Eight different adhesives were tested, and by increasing the concentrations of solutions by small increments, the maximum percentage at which vapour was successfully achieved was discovered (see Table 1). Methylcellulose A4M, type A 230 bloom pork gelatine and wheat starch paste did not create a vapour and so were disregarded.

**Table 1.** Tests of adhesive solutions with the Recolo 100 aerosol generator.

| Adhesive | Maximum percent in water at which aerosol vapour was successfully achieved (w/w) |
|---|---|
| Type B 84 Bloom pork and beef gelatine | 1.00 |
| Isinglass | 2.00 |
| Klucel E | 0.80 |
| Klucel G | 0.50 |
| Methycellulose A4C | 0.25 |

pH measurements were taken of each of the viable solutions before testing their ability to adhere tissue with minimal disturbance to the substrate. This was conducted by examining the success of each vapour in adhering Berlin Tissue (2gsm 30% *Ibaragi kozo* and 70% *Suruga mitsumata*) to Dutch Fe-Migration test paper (filter paper stamped with iron gall ink and impregnated with bathophenanthroline [indicator for ferrous iron] in ethanol)[18] whilst visually monitoring for colour change demonstrating a disturbance to the ink.

Each adhesive was also applied to small moisture damaged paper samples that displayed similar characteristics to the paper of the roll. Each sample was observed subjectively by eye and touch to assess the success of adhesion, flexibility, shrinkage upon drying, discolouration or visual changes, and if there was any residual tackiness once dry. All tests were conducted on the suction table to minimise the risk to health of the conservator from breathing in the adhesive vapour and to help the adhesive better penetrate the paper.

At the end of testing, methylcellulose and Klucel G were discounted as at the requisite low concentrations they were ineffective at adhering tissue. Having narrowed down the choice to three—gelatine type B, Klucel E and isinglass—the in situ conditions in which the treatment would be applied were replicated.

**16** Vishtal, Alexey, Alexey Khakalo, Orlando Rojas and Elias Retulainen, "Improving the extensibility of paper : Sequential spray addition of gelatine and agar," *Nordic Pulp and Paper Research Journal* 30 (3) 452–460 (The international research journal on sustainable utilization of forest bioresources, De Gruyter, 2015); Manuela Reikow-Räuchle, "Aerosols and Their Use in Conservation," Talas website (2014) https://www.talasonline.com/images/PDF/ProductInformation/Recolo1000.pdf; Eva Hummert, Ute Henniges and Antje Potthast, "Stabilisation Treatments with Aerosols: Evaluating the Penetration Behaviour of Gelatine and Methylcellulose," *Restaurator* 34 (2) 134–171 (De Gruyter, 2013); Eva Hummert, Ute Henniges and Antje Potthast, "Fluorescence Labelling of Gelatin and Methylcellulose: Monitoring Their Penetration Behavior into Paper Cellulose," *Cellulose* 20 (2) 919–931 (Springer, 2013).

**17** Masazumi Seki, Naoko Sonoda, Tsuneyuki Morita and Takayuki Okayama, "A New Technique for Strengthening Book Papers Using Cellulose Derivative," *Restaurator* 26 (4) 239–249 (De Gruyter, 2005).

**18** Eliza Jacobi, Birgit Reissland, Claire Phan Tan Luu, Bas van Velzen, Frank Ligerink, "Rendering the Invisible Visible—Preventing Solvent-Induced Migration During Local Repairs on Iron Gall Ink," *Journal of Paper Conservation* 12 (2) (IADA, 2011).

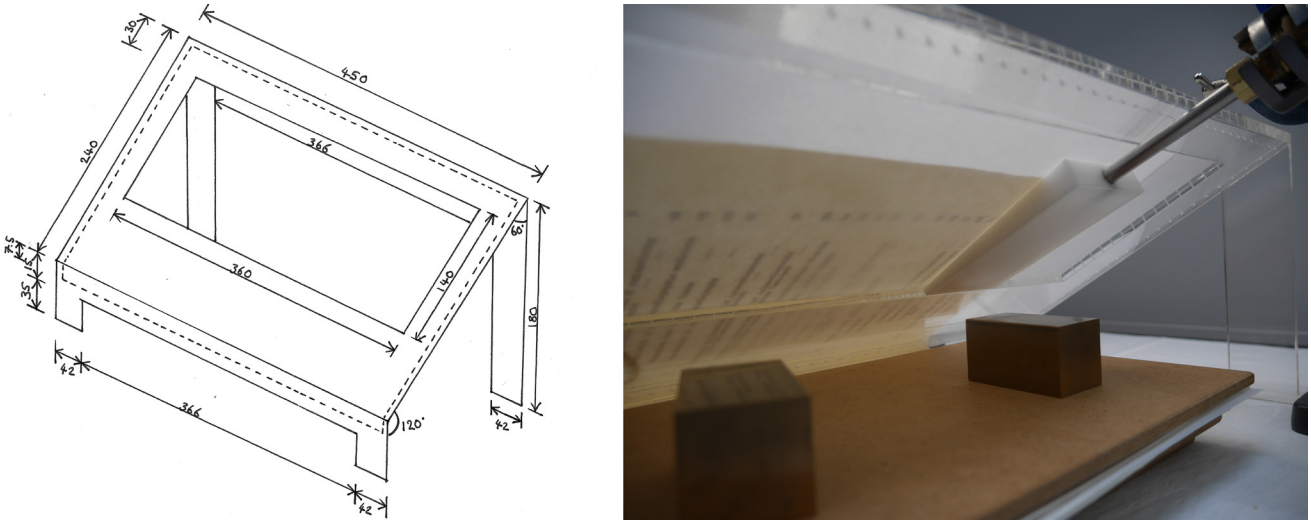


**Fig. 6** (left) Line drawing design for Perspex frame, (right) Perspex frame with suction wedge in position. Line drawing and photograph by Emma Nichols, Conservation Department, Cambridge University Library.

*4. Suction wedge and frame*

Although the suction table had been used during the initial testing, this would not be possible when working on the nominal roll as it was a bound volume.

Tests were conducted using the fume cupboard as an alternative method of extraction but with no success as the downward pressure of the suction was essential in helping to draw the adhesive vapour into the paper. The decision was made to test the suction table wedge attachment. Attached to the suction table by a hose, the suction wedge is a small 120 x 60 mm wedge-shaped head with a 100 x 50 mm working suction area. In order to test whether the wedge could be used as a method of extraction, a solution needed to be found that would somehow securely and safely position it behind each individual leaf during treatment.

A Perspex frame (see Fig. 6) was designed, which would stand over the open nominal roll and allow for a leaf at a time to be laid across it. Saatifil (breathable polyester mesh) was sewn over a window in the frame to support the leaf and to prevent it sagging through the window when the suction was turned on. The suction wedge was held in position behind the window of the frame by being clamped to a laboratory stand. As the wedge was smaller than the leaf, during application of adhesive the wedge would be moved around in the window to sit where necessary.

In order to test whether this set-up would work, a surrogate version of the nominal roll was created by accelerating the ageing of one of the books from CUL's disaster salvage training kit. This was accomplished by pouring hot water onto the salvage training book and wrapping it in cling film until it developed enough mould that the sizing was damaged and the paper soft and fragile.

Upon completion of testing on the sacrificial book, it was discovered that the isinglass and gelatine adhered the tissue more successfully to the paper than the Klucel E. The Klucel E required more applications to adhere the tissue, meaning the paper and inks were exposed to moisture for longer.

Between the isinglass and gelatine type B, it was decided that isinglass would be used for treating the nominal roll. It enabled the higher concentration in vapour form, was strong yet flexible, and had a neutral pH in comparison to the gelatine's more acidic one.

**Conservation treatment**

The textblock was dry cleaned, and the delaminating corners and edges of the boards consolidated. The paper leaves of the textblock were then treated one leaf at a time. A leaf was laid across the frame on top of a sheet of Bondina (non-woven polyester), the folds turned down, and damaged areas realigned.

Berlin Tissue was shaped with a needle on Melinex (polyester film) placed over a scale UV photograph of the leaf to guide to the extent of the area to be treated.

The suction wedge was turned on and a fine layer of adhesive vapour applied to the leaf. The tissue was carefully laid in position and rubbed down with a bone folder through silicon

**Fig. 7** (clockwise from left) Applying isinglass adhesive and tissue to a leaf of the nominal roll on the Perspex frame with the suction wedge held behind with a laboratory stand, detail of adhesive vapour, detail of silicon paper and bone folder, detail of Berlin Tissue. Courtesy of Emma Nichols, Conservation Department, Cambridge University Library. RCMS 103/12/22.

paper. The silicon paper was removed, more adhesive vapour applied on top of and through the tissue, and then returned and rubbed down again (see Fig. 7).

The suction wedge was then turned off and removed, a sheet of Bondina slid behind the leaf to support it, and the frame removed. The leaf was then laid flat between Bondina, blotter, boards and a weight. The frame and wedge were then returned to their positions over the drying leaves and the next leaf to be worked on was laid on the frame. Around five leaves were worked on individually in one session before being left to dry undisturbed.

Depending on the fragility of the leaves, which were in a poorer condition at the beginning of the roll, there was a tiered system of treatment. Aerosol adhesive was applied to the weakened area, followed by tissue, with the same procedure on the other side of the leaf if it was still considered weak once the first side had dried.

The decision was made to not infill areas of loss in order to avoid bulking and adding weight to the fragile leaves. Instead, the repair tissue was continued to what would have been the edge of the leaf. The majority of leaves had not lost much material, however, those that had were weaker in general and so had tissue applied to both sides.

Upon completing the textblock repairs, a flax paper cover and four-flap folder were made for the roll. A box was made with a sheet of ArtSorb paper, made with moisture-sensitive silica, mounted in the lid to counter any fluctuations in humidity once the roll was back in the store room stacks.

Despite the complex requirements of the nominal roll, the conservation treatment was a success. There was no further disturbance to the paper or inks and although the leaves were still fairly delicate, they were no longer as vulnerable, could be handled more easily and were digitised successfully (see Fig. 8).

**Outreach**

In order to share the progress of the project and promote the archive, posts were regularly published on the CUL Special Collections blog throughout the project. The archive also featured as part of the Cambridge University Science Festival, where papers on the history, conservation and digitisation of the archive were presented, supplemented by tours of the Conservation and Digitisation Departments. Some documents from the archive were also displayed in an exhibition at CUL.

Upon completion of the project, there were several events to celebrate the launch of the archive on Cambridge University Digital Library. Previous internees, Members of the Malayan Volunteers Group, COFEPOW (Children of Far East Prisoners of War), and families and friends of those who had been interned visited CUL. Hearing their stories and seeing

**Fig. 8** (Top row) Examples of nominal roll paper leaves before conservation. (Bottom row) Examples of nominal roll paper leaves after conservation. Photographs by Emma Nichols, Conservation Department, Cambridge University Library. RCMS 103/12/22.

their faces as they saw the archive first hand and found the names of their families, and of themselves, in the nominal roll was unforgettable. It was humbling to see how much the conservation, digitisation, and long-term stable storage of the archive and the nominal roll meant to them.

**Reflections on the project**

It is hoped that the use of UV imaging, DP measurements provided by SurveNIR, and the in situ conservation treatment devised will be of use to other conservators with vulnerable twentieth-century bound paper and fugitive media.

Insights provided by the optical microscopy, NIR, and UV imaging meant that the Conservator could confidently define the areas of paper in need of support and thus direct repairs accordingly. Thanks to this, repairs could be extended beyond the parameters of damage onto stronger, healthier paper, thus avoiding creating areas of weakness.

The aerosol generator proved to be a reliable, controlled way of applying adhesive with minimal moisture. Being able to carry out the treatment without disturbance to the binding and to work effectively on one leaf at a time was paramount to its success. The ability to use suction during treatment, thanks to the suction wedge and Perspex frame, meant that the adhesive vapour could be applied with control and direction. This resulted in minimal risk to health and maximum results in penetrating the paper. The combination of adhesive and tissue was effective at imparting strength and support to the weak areas of each leaf. The conservation of the nominal roll and Voices of Civilian Internment archive, and their global access through digitisation, means the voices of the internees and their ordeal are not lost in history but instead retained for generations to come, serving as a humbling reminder of human resilience.

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**Biographies**
Emma Nichols has been working as a Book and Paper Conservator at Cambridge University Library (CUL) since July 2013. She became interested in conservation through a paintings conservation module during her Fine Art and History of Art degree at Aberystwyth University, and through her father who has been an Archive Conservator for over forty years. She gained her MA in the Conservation of Books and Archival Materials from Camberwell College of Arts in 2013. During her studies she received scholarships from the Anna Plowden Trust, the Clothworkers' Company and Queen Elizabeth Scholarship Trust (QEST). Emma has worked closely with the BioArCh team at the University of York on their analysis of parchment manuscripts since 2013 and was named as a co-author on their paper in the Proceedings of the National Academy of Science. She has featured in New Scientist magazine extolling the benefits of the research to conservators, and in National Geographic magazine promoting the many decades of experience in conserving Genizah material by the conservation team at CUL. She sits on the Archives and Records Association (ARA) Conservation Training Committee, and is a member of Icon, ARA, Society of Bookbinders, East Anglian Conservators Forum and Midlands Conservators Group. In May 2016 she was the first conservator to be awarded a Research Bursary by the Wellcome Trust. Emma is passionate about supporting other conservators and recently presented a webinar for Icon BPG discussing the increase of fixed-term positions across the conservation profession.

Natalie Brown is currently a Senior Conservation Manager at The National Archives. She is also completing her PhD within the SEAHA (Science and Engineering in Arts Heritage & Archaeology) centre for doctoral training at UCL Institute for Sustainable Heritage, University College London. Her thesis focuses on the assessment of near-infrared spectroscopy as a collection survey method for library collections. Prior to this, Natalie has completed a BA in History of Art from University of Nottingham (2008–2011), an MA from Camberwell College of Arts, specialising in Art on Paper (2011–2013) and an MRes in Science and Engineering in Arts Heritage & Archaeology from UCL (2014–2015) where she researched the characterisation and degradation of nineteenth- and twentieth-century Chinese paper. Within this study Natalie lead on the spectroscopic analysis and digital microscopy at the UCL Institute of Sustainable Heritage.

**Materials & suppliers**
Art-Sorb® paper—Preservation Equipment Ltd (PEL)
'Berlin' Tissue—2gsm 30% Ibaragi Kozo and 70% Suruga Mitsumata, handmade in Germany by Gangolf Ulbricht, supplied by JVO Papers
Keyence Digital Microscope
Fibre Furnish—ISO 9184-3:1990
SurveNIR
Camera—Panasonic Lumix
Lens—Universe Kogaku
Filters—Edmund Optics
Dino-Lite® microscope—VWR
Suction table and suction wedge—Alan Buchanan
Aerosol generator—Recolo 100, Talas
Perspex® frame—Engineering & Design Plastics Ltd
Saatifil®—Preservation Equipment Ltd (PEL)
Dutch Fe-Migration test paper—Practice-in-Conservation
pH 0-14 Universal Indicator strips—PEL
Isinglass—Kremer Pigmente
Klucel® G – Conservation by Design
Klucel® E—Kremer
Gelatine Type A 230 Bloom Pork—Dr Oetker
Gelatine Type B 80 Bloom Pork/Beef—GMW
Methylcellulose A4C—VWR
Methylcellulose A4M—VWR
Wheat starch paste—VWR

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