THERMAL PAPERS; THEIR STABILITY AND PERMANENCE

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There is very little documentation on the stability and reactivity of thermal papers. The paper explores these issues and shows that thermal papers are very sensitive to environmental changes. It also provides evidence that the application of some common preservation techniques may actually be dangerous to the integrity of documents created on thermal papers.

Specifically, the physical and chemical stability of two thermal papers — Vocafax Thermal Paper *and* Calcomp Thermal Plotter Report Grade Paper *have been investigated. Both papers behaved similarly to the experimental procedures employed and were found to be affected by exposure to heat, light, humidity and friction. Acidic organic solvents also reacted with the thermal coating whereas neutral or alkaline solvents had no effect. The facsimile paper was found to be slightly more physically and chemically robust than the plotter grade paper, although both were easily damaged. Suggestions for the handling, preservation and storage of these papers are included.*

'Thermal direct' or 'direct thermal' refers to the process that uses heat sensitive papers to produce images. These thermal papers consist of a paper base that has been chemically treated with a heat sensitive coating. When first introduced, thermal papers were primarily used in facsimile machines and in the production of labels. Various grades of thermal papers have since been formulated for specialty machinery and end-use applications, e.g. for use in computer assisted design equipment.

This paper examines some of the physical and chemical properties of the coating and paper base of two types of thermal papers: *Vocafax Thermal Paper* for use in electronic whiteboards and fax machines, and *Calcomp Thermal Plotter Report Grade Paper*. Specifically, it examines the stability of thermal papers to various environmental and storage conditions. The coating and paper base were also tested for reactivity during standard preservation and repair treatments.

Image Formation, Composition and Chemistry of Thermal Papers[1]

Thermal Image Formation

The printed image is formed in a Lewis acid-base reaction by the action of a 'developer' on a 'leuco dye'. A leuco dye is an aniline based dye that is colourless or lightly coloured. Once it has reacted with the developer, the resulting image is commonly black, but may be blue depending on the chosen leuco dye. The developer is an organic molecule which is acidic in nature.

The reaction of the leuco dye with the developer occurs in a liquid solvent medium called a 'sensitiser'. Sensitisers are solids which typically melt at elevated temperatures below 100°C. The image develops as the resulting mixture resolidifies. Paraffin waxes are amongst the preferred sensitisers in these reactions.

Figure 1 is a schematic representation of the reaction between the leuco dye and the developer to form the printed image as heat is applied to the sheet. In this diagram, the solid sensitiser has melted to provide a solvent medium for the reaction. Added stabilisers or antioxidants reduce the reversibility and degradation of the colour reaction. The antioxidant favours the action of the developer and so enhances image formation.

Paper Base

Information from manufacturers shows that, in general, the paper base does not contain an alkaline reserve. It may be acidic, 'wood-free' or alkaline but is unlikely to be of permanent or archival quality. More important to the manufacture of thermal papers are the physical and

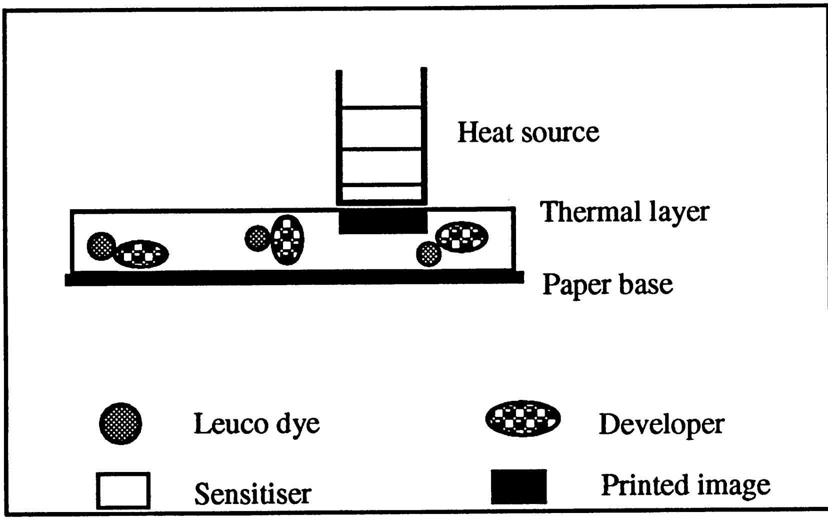

Figure 1. Reaction of a leuco dye with developer in a sensitiser solvent medium.

basic strength properties of the paper base required for the process of applying the thermal coating. These are detailed in the section below on Paper Base — Coating Interactions.

Coatings

A combination of chemical coatings is applied to the paper base to produce a range of thermal papers with varying physical and chemical characteristics. The types of coatings that may be applied are:

- a 'base' coat containing clays and binders, usually applied directly to the sheet of paper;
- an 'active' coating containing the primary image forming ingredients;
- a 'top' coating containing fillers, binders and lubricants which provide protection against environmental forces that may come into contact with the thermal coating;
- a 'back wet' or 'back' coat may be applied for curl control but may also provide antistatic properties.

Usually, it is very rare that all the coatings are applied to any one sheet, but various combinations of the coatings are used to produce a variety of papers for different applications.

The base coat produces a sheet of uniform thickness on which the active coat may be applied. This assures uniform image formation by the thermal printhead. Another function of this layer is to improve the effective heat/energy transfer to the active ingredients. A protective top coat is usually applied to papers that require high resistance properties, such as labels and tags. The back coat may also be applied to seal and bind filler materials to the sheet. This helps to reduce the amount of debris created in the end-use application.

Paper Base — Coating Interactions

Interactions between the paper base and the coating may detract from the overall quality of the printed image. The following paper base properties affect the quality of the finished thermal paper:

- The paper sheet must be strong enough to withstand the coating process, i.e. wet tensile strength must be high.
- Porosity of paper base affects the ability to manufacture at high speeds as well as allowing uniform coating on the surface. Coatings may penetrate sheets that are too porous and deposit on the coating machine causing problems with running of the machinery. Active coatings that sink into the sheet may cause inefficient colour formation.
- Uniform paper smoothness with even coating ensures uniform image formation.
- Uniform caliper of paper ensures consistency of the finished product.
- Whiteness and brightness of the sheet affects the contrast of the copy.
- Good paper opacity is required to eliminate the problems of see-through.

Additives

Several other types of chemicals are critical to the manufacturing function and end performance of thermal media.

The following chemicals are critical to the manufacturing function of thermal media:

- Clays applied to the paper improve calendering effectiveness to produce a smooth sheet.
- Fillers in the sheet absorb excess sensitiser released by the melting.
- Binders adhere the active ingredients, as well as the pigments and other materials to the coating paper base.
- Smoothing or levelling agents added to the coating facilitate the uniform production of a smooth sheet.
- Surfactants ensure that the coating remains dispersed throughout the coating process.
- Defoamers are added to prevent foam formation which may cause defects in the end product.

Chemicals critical to the end performance of thermal media are as follows:

- Clays add whiteness and brightness to the sheet.
- Fillers in the sheet which absorb excess sensitiser, prevent the formation of deposits on the printhead.
- Lubricants are used to allow the sheet to slip by the printhead and release after heating.
- Antistatic agents in the coating dissipate the electrical charge created by the paper feeding through the imaging device.
- Waxes in the coating assist sensitivity but also improve the flow of the image so that a uniform black is obtained.

Experimental

Scope

The experiments outlined below were developed to examine the chemical and physical stability of the two types of thermal papers and conducted at Australian Archives in May 1993. The procedures were designed to determine the stability of these papers in various environmental and storage conditions. Other experiments were developed to test the reactivity of these papers during standard preservation and repair treatments.

Sample Preparation

Samples were not specially conditioned prior to testing and were tested in ambient laboratory temperature and relative humidity. Samples were cut, as required, according to methods specified in the chosen standard for that test.

Paper Base Composition (Non-Fibrous) Components

Each paper sample was tested in duplicate using standard spot tests to identify the possible presence of lignin, alum, rosin, starch and/or carbonate filler.

The solutions were applied by pasteur pipette to the uncoated side of the paper. The paper components were determined using the following:

- phloroglucinol solution followed by a solution of hydrochloric acid and methanol to identify *lignin*;
- aluminon solution to identify *alum*;
- Raspail test (sucrose followed by conc. sulfuric acid) to identify *rosin*;
- iodine/iodide solution to identify *starch*.

Samples were tested for the presence of *carbonate filler* by adding a 1 cm^3 piece of sample to a variety of dilute acids and observing effervescence. The uncoated side was also spot tested with concentrated sulfuric, hydrochloric and glacial acetic acids. This test was included because of observations from the accidental spillage of sulfuric acid onto a sample.

pH

The pH of the two coated papers was determined using both cold extraction and hot extraction methods as described in TAPPI T435os-77 and TAPPI T509os-77. Duplicate samples were measured using an Activon portable pH meter. The pH of each duplicate was measured twice and the average result for each sample is reported.

Exposure to High Humidity

Printed samples of both thermal papers were placed at ambient temperature in a humid environment (90% relative humidity) until a change in print fidelity or overall darkening of the sample occurred.

The humid environment was created in a perspex box which was fitted with an ultrasonic humidifier. Samples were laid on a plastic film tray and a hygrograph was placed in the box to measure the relative humidity.

The samples were monitored twice a day for eleven days.

Exposure to UV Light

Samples of both papers were placed in a darkened, enclosed chamber and exposed to ultraviolet light (254nm) until a change in print fidelity or overall darkening of the sample occurred. The samples were tested at ambient temperature and relative humidity. They were monitored, hourly on the first day, then twice a day for ten more days.

Effects of Friction

Samples were subjected to several common types of friction. After being subjected to each type of friction, the samples were examined for alteration or damage to the coating surface. Each sample was:

- manually folded using finger pressure, not thumbnail pressure;
- scored by quickly running a blunt letter opener across the coated side;
- scored by slowly running a blunt letter opener across the coated side;
- marked with pencil on the coated side followed by attempts to erase these marks with a soft pencil eraser; and
- crumpled and flattened out twice.

Sensitivity to Heat

Samples were treated with a heated spatula to determine the temperature at which the chemical coating is activated. The spatula was warmed to various temperatures before being placed onto fresh portions of each sample. Various time intervals were used to determine the effect of temperature on the samples. Temperatures used ranged from 20°C to 120°C with the spatula temperature being increased at 10°C intervals.

'Desktop disaster' was simulated by subjecting each sample to boiling water. Printed samples were used.

Reactivity with Solvents

The coatings on the samples were tested for solubility and reactivity to solvents which are commonly used in the preservation and repair of records. Solvent was applied by dropper to the coated side of the paper. The following solvents were used:

- toluene;
- acetone;
- 1,1,1 — trichloroethane;
- ammonia solution (pH 8.5);
- petroleum spirits (b.p. 100-120°C).

Samples were immersed in the following solutions:

- ethanol;
- calcium hydroxide solution (pH 8.5);
- 50% aqueous ethanol;
- deionised water.

The following acids were applied by dropper to the coated side of the samples:

- conc. hydrochloric acid;
- glacial acetic acid;
- conc. sulfuric acid.

The solvents were at room temperature and the samples were tested in duplicate.

Washing and Drying

This experiment was a simulation of the effect of flooding on files containing thermal papers.

A 'file' was prepared as follows: a sheet of permanent paper, followed by a sheet of unprinted sample, followed by two sheets of printed sample (print side up), followed by a sheet of unprinted sample, followed by a sheet of permanent paper.

Duplicate 'files' were immersed in deionised water then placed to dry at ambient temperature and relative humidity on a non-sticky surface which was resting on a blotter. The sample was thoroughly immersed so that each sheet was completely wet. The 'files' were examined for evidence of blocking, change in image fidelity or overall darkening of the sample.

Results

Paper Base Composition (Non-Fibrous) Components

The results of the paper base composition tests for Vocafax and Calcomp thermal papers are collated in Table 1.

Spot Test	Vocafax Sample 1	Vocafax Sample 1	Calcomp Sample 2	Calcomp Sample 2
Lignin	negative	negative	negative	negative
Alum	positive	positive	positive	positive
Rosin	positive	positive	positive	positive
Starch	positive	positive	positive	positive
Carbonate Filler	some bubbles	some bubbles	some bubbles	some bubbles

Table 1: Non-fibrous paper base composition of Vocafax Thermal Paper and Calcomp Thermal Paper

In the spot tests with concentrated sulfuric, hydrochloric and glacial acetic acid, it was observed that the samples reacted similarly. Both Vocafax and Calcomp papers turned raspberry red when spot tested with sulfuric acid. The colour was consistent with a positive Raspail test which is the test for the presence of rosin. Hydrochloric acid had no reaction on either sample. Glacial acetic acid turned the Vocafax paper black on contact. The Calcomp paper turned a mid grey.

pH

The pH readings of Vocafax and Calcomp Thermal Papers are reported in Table 2.

	Vocafax Sample 1	Vocafax Sample 1	Calcomp Sample 2	Calcomp Sample 2
Hot Extraction	8.71	8.68	8.68	8.73
Cold Extraction	8.69	8.60	8.98	8.99

Table 2: pH of Vocafax Thermal Paper and Calcomp Thermal Paper Using both Hot and Cold Extraction.

The hot extractions of the Calcomp paper were very cloudy and dark particles were noted. The cold extractions of the Calcomp paper were even cloudier than the solution of the hot extractions. There were no dark particles noted. The hot and cold extractions of the Vocafax paper were only slightly cloudy. All Vocafax samples were of comparable cloudiness. No dark particles were noted in any of the Vocafax samples.

Exposure to High Humidity

On a day-to-day basis there was very little change in the samples. At the end of eleven days, both samples had darkened slightly (turned greyish) but only in places where the sample was in contact with the plastic tray. When the samples had dried the grey patches were not as pronounced. In addition, the printed images were not obscured and were still easy to read after this treatment.

Both samples behaved similarly.

Exposure to UV Light

After about two hours the samples had begun to turn brown. During the eleven days of the experiment the samples gradually darkened and became brittle. At the end of the experiment the samples were light brown in colour, not unlike the colour of an old newspaper. The print quality was still very good although the contrast between print and background had lessened.

Both samples behaved similarly.

Effects of Friction

Manual Folding

The coating on both the Vocafax paper and the Calcomp paper is damaged by manual folding. This is regardless of whether the sheet is folded on the coated or uncoated side. Neither paper seemed to develop marking.

Scoring

Colour developed in both samples regardless of whether they were scored rapidly or slowly. The colour was less developed when the samples were slowly scored.

Erasure

To erase the pencil markings, the coating on the Vocafax sample was mostly removed and even then, faint traces of image were evident. The coating on the Calcomp sample was only partially removed.

Crumpling

The coating of the Vocafax paper is damaged by the crumpling and it becomes harder to read the printed sheet, although this is mainly due to being unable to adequately restraighten the sheet.

The coating of the Calcomp paper is so damaged that small patches of coating are removed.

Sensitivity to Heat

The effect of elevated temperatures on Vocafax and Calcomp thermal papers is recorded in Table 3.

Temp °C	Vocafax	Calcomp
< 60	No change, sample heated for 15s	No change, sample heated for 15s
60	Very slightly darkened after 15s	Light grey after 2s, continued to darken after removal of spatula; definite print after 5s
70	Light to mid-grey after 5s	Deep grey on contact; colour was patchy and uneven
80	Deep grey after 5s; colour development still sluggish and is patchy and uneven	Strong, deep colour; still a little patchy; quick colour development within 5s
90	Strong, deep, uniform colour although paper texture was evident; print could still be vaguely made out.	Strong deep colour on contact; colour formation was uniform although paper texture was evident; a solvent mark, which faded quickly, had formed around the colour development; print was still legible.
100	As for 90°C, but print less easy to read	As for 90°C; print slightly obscured
110	As for 90°C, but print is very faint	As for 90°C, print is vague
120	As for 90°C, but print is totally obscured	As for 90°C, but print is totally obscured

Table 3: The effect of elevated temperatures on Vocafax and Calcomp thermal papers.

Overall, provided colour development has been initiated, both paper samples continue to develop colour for several more seconds after the heat source is removed. This phenomenon is more pronounced in the Calcomp paper.

When printed samples were subjected to boiling water, the two papers reacted slightly differently. The Calcomp paper blackened instantly and the coating was very quickly, and completely, washed from the paper base. The print was obscured from the moment the boiling water was poured onto the paper. No print was left behind after it was treated with approximately 1 cup of boiling water.

The Vocafax paper, on the other hand, went dark grey and it took several cups of boiling water to remove the coating. The print was quite obscured by the initial scalding, however, even after 4–5 cups of boiling water, traces of print were still evident. At this stage the coating had been almost completely washed from the sheet.

Reactivity with Solvents

The effect of various solvents on Vocafax and Calcomp thermal papers is recorded below. Following are the results from spot testing:

- *Toluene* darkened both samples especially the solvent edge;
- *Acetone* darkened both samples especially the solvent edge;
- *1,1,1 Trichloroethane* blackened both samples especially on drying;
- *Petroleum spirits* had no effect on either sample;
- *Acetic acid* blackened both samples on contact;
- *Ammonia solution* caused faint darkening especially the solvent edge;
- *1,2-Dichloroethane* darkened both samples especially the solvent edge.

Following are the results from immersing the samples in various solvents:

- *Ethanol* darkened the paper;
- *Aqueous ethanol* slightly darkened the Vocafax paper which darkened further as it dried; the Calcomp paper darkened and went completely black on drying;
- *Deionised water* had no effect on either sample;
- *Ca(OH)2 solution* had no effect on either sample.

Washing and Drying

The sample had slightly darkened in places and the coating had been washed from some spots. The samples and the permanent paper had stuck together but were easily separated. Similarly, the pages of sample had stuck together but were easily separated. Print had not transferred to the adjacent pages.

The darkened patches of the sample were scored with a thumbnail. Scoring produced an uneven result, i.e. the colour reaction produced from scoring was patchy.

Both samples behaved similarly.

Discussion

Paper Base Composition (Non-Fibrous) Components

These tests indicate that the paper base contains alum, rosin and starch, but has undetectable levels of lignin. The test for carbonate was most likely negative as only a few bubbles were observed, probably due to reaction with carbonate in the coating, not in the paper sheet itself. This is consistent with earlier comments that the paper base does not usually contain an alkaline reserve. Experiments on the Vocafax and Calcomp samples confirm that the paper base is acidic because of the presence of rosin and alum.

Treatment with hydrochloric acid did not affect the paper, although, acetic acid, an organic acid, activated the thermal layer. As mentioned leuco dye molecules are activated by large, acidic organic molecules. It may be that acetic acid reacts as a developer initiating the colour reaction. It is already known that acidic organic solvents, such as those contained in marker and highlighter pens, activate the thermal layer.

Within seconds of treatment with sulfuric acid, a deep raspberry red colour formed, as observed in the Raspail test. The Raspail test involves the application of sucrose solution to the sample followed by concentrated sulfuric acid.

As the raspberry colour did not appear when other concentrated acids were applied, it may be that the samples contain sucrose or a similar substance which reacts with sulfuric acid to form the raspberry coloured species. A more likely explanation for the colour development is that the starch contained in the paper base has been hydrolysed, by chemicals in the coating, into glucose units which react with the sulfuric acid.

pH

The pH of both samples was alkaline and showed little variation in the values obtained using the hot and cold extraction methods. As the paper base has been shown to be acidic due to the presence of rosin and alum, the alkalinity can only be attributable to the coating. As already noted, the various coatings of thermal papers contain clays and fillers which are commonly alkaline.

It is interesting to note that the pH values of the cold extractions of Calcomp paper were higher than the hot extractions. This is contrary to studies which show that generally, the pH values of hot extractions are higher than corresponding cold extraction pH values. Possibly the cause of this phenomenon is that the thermal layer undergoes some type of reaction during the hot extraction which lowers the pH. Reaction of the thermal layer is evident by the formation of black particles in the solution.

Overall, the Calcomp paper was not as robust as the Vocafax paper. This was indicated by the observation that the hot and cold extractions of this sample were, in general, very cloudy, even murky, compared to the Vocafax samples. In the cold extraction the coating of the Calcomp sample did not withstand light maceration with a glass stirring rod. In the hot extraction, less of the coating was removed but it did seem to deteriorate more, indicated by the formation of black particles.

In comparison, the hot and cold extractions of the Vocafax paper were only slightly cloudy. Dark particles were not formed in the hot extraction. This indicates that the coating on the Vocafax paper is better able to withstand physical damage and that it can withstand higher temperatures without coloration of the thermal layer.

Exposure to High Humidity

As noted in the results section, both samples had darkened in places where they were touching the plastic tray. On closer inspection, it was found that the coating had been lost from those areas. This explains why they were not so pronounced once the samples had dried. Other than this observation, the thermal layer seemed unaffected by exposure to high humidity.

Exposure to UV Light

Neither sample responded well to UV light and were very brittle at the end of the eleven day period. Contrast between the print and the background was lessened but the print was still quite legible.

Effects of Friction

Friction by manual folding showed that the coatings of both samples are physically damaged. The thermal layer was not activated by this gentle form of friction. Friction caused by scoring, however, is sufficient to activate the thermal layer of both the samples.

As observed in the experiment with boiling water, the Vocafax paper retains its images much better than the Calcomp paper. Thus the image drawn in pencil on the Vocafax paper is so difficult to remove that the coating is damaged before the marks may be erased. The Calcomp paper, on the other hand, is only partly damaged by this form of friction.

The crumpling experiment confirms the relative delicacy of the Calcomp paper. It causes the print on the Vocafax paper to become difficult to read as it is difficult to adequately straighten the sheet. The Calcomp paper, however, is much weaker and the thermal coating is damaged and removed by crumpling.

Sensitivity to Heat

Experiments using the heated spatula show that, in general, the thermal layer of the Calcomp paper is more easily activated. This is consistent with observations in the pH experiments.

Also, when treated with a cup of boiling water, the coating on the Calcomp paper immediately turns black and is completely removed.

The coating on the Vocafax paper was much more robust and required considerably more application of boiling water before the coating was removed from the sample. The thermal layer also took longer to develop and traces of print were still evident after the treatment.

Reactivity with Solvents

The results of the reactivity with solvents confirmed that the thermal layer is activated by acidic organic solvents. This is consistent with the chemistry of the technology, i.e. the leuco dye is activated/developed by acidic organic solvents.

Aqueous solutions, alkaline solutions and non-acidic organic solvents such as petroleum spirits had no effect. Ammonia solution, although not an acidic organic solvent also affected the thermal layer. This is probably because ammonia is capable of acting as a weak Lewis acid.

Washing and Drying

Inspection of the dried samples did not display any evidence of blocking, although patches of coating had been washed from the samples revealing the less opaque paper base. This explains the presence of darkened patches on the samples which could not be marked by scoring.

Conclusions

Vocafax and Calcomp thermal papers are, overall, alkaline papers. However, the presence of acidic paper base means that these papers are unsuitable for long term storage as the likelihood of the presence of acidic deterioration products is high. Also, the absence of an alkaline reserve means that the paper base does not meet the specifications for permanent or archival requirements.

Similarly, the presence of glucose most likely formed from the deterioration of starch is undesirable. Sugary substances are likely to attract insects and encourage moulds.

In many cases, it has been observed that the thermal coating of both papers is quite unstable. Certainly, the thermal coating is affected by exposure to heat, light, humidity and friction. At times this damage is physical and in other cases the damage causes colour development. This also makes the paper unsuitable for long term storage.

In terms of the thermal layer stability, Vocafax has tested superior to Calcomp. It withstands stronger treatment before activation of the colour reaction. Printed images on Vocafax paper are difficult to fully remove, although the contrast between print and background is easily lost. Both brands of paper are badly affected by organic solvents that are acidic in nature.

Physical treatment of the reactive coating showed that the Vocafax paper was, again, more robust. It was easier to remove the coating from the Calcomp paper, although once certain thresholds were reached, the coating on both papers was removed. In the crumpling test the thermal layer of the Calcomp paper was activated as well as physically damaged.

Caring for Records Created on Thermal Papers

Based on the experimental findings, the following advice is recommended for the storage of records produced on thermal papers:

- Records on thermal papers are too physically and chemically unstable for long term retention and the paper base is unsuitable. Important documents should be photocopied onto plain paper before filing or otherwise storing. Records to be retained for longer than ten years should be copied to permanent paper.
- Under the correct conditions, it is believed that records on thermal paper may last without significant change for as long as five years provided they are undamaged when stored and handled and that they are stored in good conditions (50% relative humidity at 20°C), away from excessive light, humidity and heat (e.g. lamps, heaters and hot liquids). Some thermal coatings appear to contain sugars, probably from the breakdown of starch. It is important that thermal paper records are stored in cool dry conditions to minimise attracting moulds and insects.
- Records on thermal papers should be stored away from other records which may develop damaging fumes, such as acetate film. They should not be stored in PVC folders which likewise emit corrosive fumes.
- According to manufacturers' instructions, records on thermal paper should not be stored with diazo type duplicates which may have residual ammonia fumes that effect the thermal layer.

The following advice is recommended for the preservation of records produced on thermal papers.

- Acidic solvent based marker pens: some highlighter pens and some felt pens will cause darkening of the thermal layer and should not be used.
- Acidic solvent based adhesives and adhesive tapes will likewise damage the thermal layer and stain the paper.
- Aqueous based marker pens and adhesives should be used.

- Excessive handling of records produced on thermal papers should be avoided as heat, moisture and oils from the hands may affect the image.
- Records on thermal papers should be handled with care to avoid scratching the thermal layer.
- Attempts should not be made to clean or remove markings with erasers or acidic organic solvents, including aqueous ethanol which is mildly acidic.
- Records on thermal papers which have been wet should be laid on a non-sticky surface, placed on top of blotters and dried at room temperature. Pages of the document may then be carefully separated. Separation of the pages while wet may cause the thermal coating to be lost. Pressure should not be applied to the drying papers as this causes blocking. Conservation of dried pages which have cockled is preferable to separating blocked pages.
- Individual pages of thermal paper which have been crumpled or folded may be straightened by placing a moistened blotter onto the page and applying light pressure. Likewise, placing the page under light pressure in a humidifying chamber is effective.
- The combined use of heat and moisture to straighten records or to remove adhesive and pressure sensitive tapes is not recommended as the heat will damage the thermal layer.
- Petroleum based or neutral solvents, such as white spirit may be used to remove markings or adhesives.

ENDNOTES

1. The main references used for this section were J. F. Komerska, 'Thermal Imaging Materials', in *Handbook of Imaging Materials*, ed. A. S. Diamond, Dekker, New York, 1991, pp. 487-526, and T. E. Goodwin and D. C. Peterson, 'Direct Thermal Paper Design Parameters', *1992 Pan-Pacific Pulp and Paper Technology Conference*, Japan TAPPI, Tokyo, 1992, pp. 63-72.