Solvent reactivation of adhesives in textile conservation: survey and comparison with heat reactivation

Reactivação de adesivos por solventes em conservação de têxteis: questionário e comparação com reactivação por calor

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Abstract
Current practice of solvent reactivation of adhesives in textile conservation was assessed using two methodologies: an international survey of conservators, and practical tests that provided a comparative study between two different reactivation techniques, heat and solvents. Despite some recent technical developments in the application of solvent reactivation for the treatment of textiles, the survey pointed out that conservators are using solvent reactivation techniques less often than more familiar and longer established heat reactivation techniques. The comparative study proved that the two adhesive reactivating techniques (solvents or heat) produce very different results in practice. Moreover, different solvent reactivation techniques (applied via brush or in vapour form) and different solvents used to reactivate the adhesive also produce diverse results. Some of the possible variables to consider when selecting reactivation techniques for adhesives are highlighted.

Keywords
Textile; Support treatment; Adhesive; Solvent reactivation; Heat reactivation; Conservation.

Resumo
Para avaliar a prática actual da utilização de solventes na reactivação de adesivos em conservação e restauro de têxteis foram usadas duas metodologias: um questionário internacional para conservadores-restauradores e testes práticos que providenciaram um estudo comparativo entre diferentes métodos de reactivação – por calor e por solventes. Apesar de alguns desenvolvimentos técnicos recentes na aplicação de solventes na reactivação de adesivos no tratamento de têxteis, os resultados do questionário indicam que os conservadores-restauradores utilizam menos as técnicas de reactivação com solventes do que a reactivação com calor, método mais usual e que foi o primeiro a ser estabelecido. O estudo mostrou que os dois métodos de reactivação produzem resultados muito distintos na aplicação prática. Sobre a reactivação com solventes, verificou-se também que diferentes solventes e diferentes técnicas de aplicação (aplicação com pincel ou sob a forma de vapor) conduzem a resultados diferentes. São destacadas variáveis que devem ser tidas em conta no processo de selecção de técnicas de reactivação de adesivos.

Palavras-chave
Têxtil; Tratamento de consolidação; Adesivo; Reactivação por solventes; Reactivação por calor; Conservação.

Introduction

Improved physical stability of a structurally fragile/ damaged textile can be provided via a support treatment. The support often includes the addition of new 'support' materials to the textile: a backing, an overlay or a combination of both. The support is characteristically a lighter weight, colour matched textile fabric that is secured by conservation stitching or adhered using an appropriate adhesive.

The prevalent type of adhesives currently used in textile conservation are thermoplastic, poly (vinyl acetate) (PVAc) and acrylic adhesives being the most frequently chosen. Thermoplastic materials are defined by their ability to soften on heating and harden on cooling. They soften when they are at temperatures higher than their glass transition temperature (T_g), that is, the temperature below which the polymer is in a glassy state and above which is in an elastic state. When the selected support treatment involves the application of a thermoplastic adhesive to a support fabric, a typical procedure is as follows: the adhesive is first cast onto the fabric, left to dry and when placed on the area needing structural support, the adhesive is reactivated (softened) by the application of heat to adhere to the textile artefact. Reactivation by heat applied for the conservation of textiles is well established and has been invented towards the end of the 1950's [1].

An alternative to this traditional approach is based on the solvent reactivation of adhesives, which, although has been applied since the beginning of the 1990's [2], is less widespread. In this case, the adhesive, cast onto the fabric, is reactivated through the application of an organic solvent, which acts as a plasticizer on the polymer chain of the adhesive, moving it from a glass to an elastic state. As the solvent evaporates the adhesive solidifies, forming a high number of secondary bonds between the molecules of the adhesive and the molecules of the textile fibres.

At the beginning, reactivating an adhesive with solvents was a special procedure in order to use Klucel G adhesive (a hydroxypropyl cellulose adhesive). Since it is not a thermoplastic adhesive its qualities and application procedures differ from PVAc and acrylic adhesives. When applied to an object as a dried film it can only be reactivated by solvents; heat reactivation is not appropriate. Klucel G, however, only produces a weak bond by comparison with thermoplastic adhesives and resultantly has limited application, and is used for the support of very fragile textiles only.

Because the usual introduction of heat and pressure for the reactivation of a thermoplastic adhesive is considered damaging for an extremely fragile textile and is known to cause deleterious effects on fibres [3], the reactivation of adhesives using solvents has been tested in the United Kingdom particularly at the Textile Conservation Centre (TCC) of the University of Southampton at Winchester School of Art [4]. The reactivation by solvents eliminates the need to apply high temperatures and pressure in order to reactivate the adhesive, a problem in cases of multi-layered textiles and textiles with three dimensional features as the risk of damage through pressure is eliminated. In addition, overlays applied by solvent reactivation generally have less sheen than heat reactivated adhesive overlays and can produce a better finished appearance.

At TCC, the reactivation techniques for Klucel G using solvents evolved from the initial simple and direct application of the solvent to the adhesive via a brush [2] to the use of barrier layers through which only the vapour of the solvent passed to reactivate the adhesive (cold poultice technique) [5]. The latter and newer method is more controllable and easier to apply. Further developments involve the use of a vacuum suction table allowing the reactivation with minimal and controlled pressure, without using heat, when appliyng cold poultices [6].

With the advantages of solvent reactivation, and its easier application in mind, conservators at the TCC sought to use the same techniques with thermoplastic adhesives. This would enable a broader range of adhesives and consequently bond strengths to be applied in increasingly sensitive ways to a wider range of textiles. As a result of this developmental work during remedial treatments, scientific research on adhesive support treatments has been completed in the wider discipline. Karsten and Down investigated parameters for solvent and heat reactivation by comparing the peel strength of the adhesive bonds achieved [7]. Other published articles, by Karsten, in particular, explore pertinent issues regarding the application and outcomes from the adhesive support treatments, and the consequences on reversibility and stability of the treatments [8-10]. The use of solvent reactivation for thermoplastic adhesives is continually developing but, despite the advantages that the method appears to offer, its application remains apparently limited and relatively unfamiliar to many textile conservators.

With the aim of developing the existing information available to conservators on the subject of solvent reactivation of adhesives, to ensure its continued development at a practical level, an international survey and comparative practical trials of reactivation techniques were carried out. The survey aimed to reveal the current practice of solvent reactivation techniques by textile conservators and to disclose reservations about its use. For the practical trials, diferent methodologies were compared using resources and procedures accessible to most conservators. By this way textile conservators can replicate the experiments as part of the testing procedures for their own remedial treatments. The properties of the adhesive support treatment tested were based on criteria typically used by conservators at the TCC when testing an adhesive for a support treatment.

Table 1 Area of geographical distribution and response rate by number of sent and replied questionnaires.

Area	Number of sent questionnaires	Number of replies	Response rate
Continental Europe	8	1	12.5%
North America	5	3	60%
United Kingdom and Ireland	20	14	70%

Solvent reactivation of adhesives by textile conservators: a survey of current practice

The questionnaire was sent to a group of 33 textile conservators from ten different countries within Europe and North America in 2001/2002. A response rate of 54.5% was achieved and the collected data reflects a qualitative view of the practice of adhesive reactivation. Table 1 shows the numbers of questionnaires sent and received replies, distinguished by geographical areas. As expected, the majority of replies came from the United Kingdom because solvent reactivation of adhesives in textile conservation was first developed in that country. A reasonable rate of reply was gained from North America which may suggest interest in the subject but far fewer were gained from continental Europe. Possibly this may point to a lower incidence of use of adhesives on continental Europe or less familiarity, hence curiosity, in the subject area.

Responses to the questions asked are presented under individual subheadings.

Adhesive treatments: general frequency of use

The majority of conservators who responded to the survey apply adhesive treatments to textiles with a frequency ranging from six months to two years apart. The rate of adhesive treatments was expected considering that adhesive treatments are generally used for the small proportion of textiles that cannot be effectively stitched [11].

Frequency of use of the two major reactivation methods (heat or solvents) was also established by the

Table 2 Adhesive treatment and reactivation techniques frequency.

Treatment frequency	Response rate		
	50% to 30%	29% to 10%	Less than 10%
Frequency in using adhesives	- once in 6 months - 2 years apart	- once in 3 months	- never
Frequency in reactivating adhesives with heat	- more than 50% of treatments	- less than 50% of treatments - every time	- never
Frequency in reactivating adhesives with solvents	- less than 50% of treatments - never	- more than 50% of treatments	- every time

replies and heat reactivation was confirmed as the prevailing method (Table 2). In most treatments (more than 50 %) heat is used in preference to solvents, which are used far less frequently by comparison. The number of treatments carried out and collective level of experience in reactivating with solvents is thus limited compared with that using heat. Out of eighteen conservators, six affirmed that they had never used any solvent reactivation techniques before with either thermoplastic adhesives or others (three replies came from United Kingdom, two from North America and one from Continental Europe).

However it must be pointed out that from the group of twelve conservators who had experience in using solvents to reactivate, two characterised the results as excellent, eight characterised as good and two as fair. None felt they had obtained poor results with this method. This may suggest that the reasons for the infrequency of solvent reactivation are extrinsic to the outcome of the reactivation which shows an overall success, as revealed by the collected data. Opportunities for learning new adhesive techniques were thought to be limited by the respondents, which may also account for the lack of familiarity. Workshops such as those organized by the Canadian Conservation Institute (CCI) are crucial for supplying updated information on adhesives research and practice [12] but are relatively infrequent. The only other opportunities for trained conservators to obtain new knowledge are through publications. There are published accounts on technical developments for solvent reactivation, though fewer on case studies of treatments [7, 13, 14].

Why solvents are chosen over heat reactivation and the textile objects treated

The need to avoid heat and pressure was the major reason given by respondents for selecting solvents to reactivate an adhesive for support treatments (Table 3). The object dictates this necessity, rather than the conservator, due to its fragile or fragmentary condition in conjunction to the specific structure of the textile. Unsurprisingly embroidered textiles with three-dimensional elements were cited as the type of textile treated most often using the techniques (Table 4).

Table 3 Reasons for solvent reactivating as opposed to heat and number of replies.

Reasons, no.
- to avoid heat and pressure (due to the extreme fragility/fragmentary condition of the textile), **5**
- to avoid heat (because heat might be more damaging to textile and accelerate deterioration or because it can cause shrinkage of materials that are protein-based just as a binding medium in a painting or animal glue under gilded areas), **3**
- to treat three dimensional objects (to minimise the pressure applied), **3**
- to avoid water (due to the sensitiveness of the textile eg the presence of painted surface containing protein-based binding medium or animal glue under gilded areas avoiding the risk of shrinkage, to treat soiled objects), **3**
- to reduce the sheen from adhesive coated support fabric, **2**
- to apply small infills or overlays, **2**
- due to the ease of access and to have more precise control over the area to be treated (threads and overlays can be held in place with pins during the process), **2**
- due to the fragility of a silk textile, **1**
- because the textile is multi-layered, **1**
- bond strength, **1**
- for facing a fabric, **1**
- in order to use Klucel G for its characteristics (eg. translucency), **1**
- when dust pick up is an issue (eg. for object on open display), **1**

Note: between brackets are reasons and examples also presented by conservators.

Table 4 Objects supported with solvent reactivated adhesives and number of replies.

Type of textile objects, no.
- embroidered textiles (including velvets, raised work, appliqué panel, heavy embroidered mirror frame in silk satin, silk picture), **7**
- fragile silk (including banner, lining banner screens, cap lining), **4**
- shoes (including silk ribbon for fastening a 19th c. shoe, silk trim on pair of shoes, silk fabric of pair of boots), **4**
- painted silk (including banner), **3**
- beaded wool band, **1**
- fragmentary fine barkcloth layer, **1**
- Japanese screen decorated with figures made from moulded paper, textile and plant material, **1**

Note: between brackets are specifications within the group of textiles also presented by conservators.

Another significant group of vulnerable and problematic textiles supported through solvent reactivated adhesives by the respondents, are those manufactured from silk. Silk fabrics can have very fine weave structures, which, when deteriorated, can be damaged by stitching. Furthermore, the weighting process of silk during manufacture, whereby specific salts are added to the textile for added weight and stiffness, can accelerate the degradation process. As a result silks can become fragile and prone to shattering. Choosing solvents for adhesive reactivation is clearly thought helpful, when treating such silks, since temperatures needed to heat reactivate adhesives could further promote deterioration through desiccation and thermal oxidation of silk fibres [3].

In addition to these textile types a wide variety of objects have apparently been treated with solvent reactivated adhesives by conservators who are familiar with the technique. These include shoes, painted textiles, a beaded wool band, a Japanese screen and a fragmentary fine barkcloth. Furthermore, the support treatments were used in both small and larger areas of textiles. This diversity is an indication that solvent techniques have potential for a broad range of support problems involving textiles with different materials and structures. Disseminating this data to the wider discipline is important because, despite this innovative practice by a small number of conservators, other conservators reported that they only apply the techniques in far more limited ways for example, to specific areas (small areas and/or overlays), or only with Klucel G.

Which adhesives and solvents are used and how is the adhesive film prepared?

From the list of adhesives suggested in the survey, Klucel G was the adhesive most commonly used by the respondents. For its reactivation they reported using the solvent Industrial Methylated Spirits (IMS), a combination of 95% ethanol and 5% methanol (Table 5). Again, this data was unsurprising considering that Klucel G was the first adhesive to be known as a solvent reactivated adhesive in textile conservation [2]. Other conservators, however, used thermoplastic adhesives particularly Lascaux (acrylic adhesives) with acetone and IMS. Vinamul 3252, a PVAc adhesive, was less used. IMS was the solvent used with all three adhesives and acetone was used with just Klucel G and Lascaux adhesives. Two main reasons can explain why these two solvents were more used from all the solvents available. They present comparatively low health and safety risks for the conservator, and, because its rapid evaporation rate, they minimise the risk of staining and lateral movement of the adhesive during long reactivation periods. They are also readily available.

As originally thought, the desire for a variety of adhesive bond strengths reactivated by solvents explained why a wider range of adhesives were sought for this process. Importantly the reactivation of Vinamul 3252 in particular indicated that progress in parallel with the TCC is occurring in other conservation units. Such developments are encouraging because it indicates not only a wider interest in the subject area but that greater collective experience is gained for the wider good.

The majority of conservators used the same preparation procedure for adhesive films for both solvent and heat reactivation. Significantly, one used their chosen thermoplastic adhesive diluted in a mixture of deionised water and solvent for a solvent reactivation procedure. The mixture of solvent with water to dilute the adhesive was developed at the TCC [13] because observations suggested that the consequent adhesive film produces stronger bonds with lower adhesive concentration and, when reactivated with solvent vapour, the bond can be stronger than when heat reactivated.

Table 5 Adhesives and solvents used and number of replies.

Commercial name (type of adhesive), no.	Solvents, no.
Klucel G (modified cellulose adhesive), **12**	IMS, **12** Acetone, **4**
Combination of Lascaux 360 HV with Lascaux 498 HV (acrylic adhesives), **6**	IMS, **3** Acetone, **3**
Vinamul 3252 (PVAc adhesive), **3**	IMS, **3**

Table 6 Solvent reactivation methods, materials used and number of replies.

Method of solvent reactivation, no.	Specified materials used, no.	
Direct application of solvent, 6	Mean of application of the liquid	Brush, **3**
		Swab, **1**
Exposure to vapour, 9	Using a barrier between the wetted layer and area to reactivate.	Barrier: Gore-Tex®, **3** Wetted layer: - Filter paper, **2** - Blotting paper, **1**
	No barrier, slightly damp layer placed adjacent to area to reactivate.	Damp layer: Blotting paper, **2**

Solvent reactivation techniques and materials

From the replies it became apparent that the application of the relatively new technique of reactivation, using solvent vapour through a cold poultice, has surpassed the earliest application of solvent directly onto the support fabric in liquid form (Table 6).

A cold poultice is formed by placing different layers over the area to be supported: a dry barrier layer is placed between a layer that is dampened with solvent and the area to be reactivated. The dry barrier layer is frequently Gore-Tex®, a semi permeable membrane of Teflon® laminated to non-woven polyester sheet that allows the vapour to penetrate but prevents the liquid from wetting the textile. One experienced conservator when expressing the task of controlling the reactivation time when using Gore-Tex® alone, sensed it occurred "too quickly", and prefers to "use/play with several layers of tissue paper, with different 'wetnesses' depending on the required result. One or more layers of dry tissue paper were used to control the speed of reactivation. I always used an impermeable layer on the top, so that vapour was forced down through the poultice to the support." A number of factors will inevitably influence the final adhesive bond achieved: the number and type of dry layers, whether a cover is used during reactivation to reduce the rate of solvent evaporation (for example a polyethylene chamber) and the quantity of solvent on the wet layer.

When using a cold poultice eleven conservators specified that the reactivation process is often combined with the application of a small amount of pressure. The quantity of pressure applied was regulated during reactivation typically by placing glass weights on top. Similar to heat activation the respondents found the greater the pressure the stronger the bond strength achieved. Five conservators reported using stitching techniques after reactivation to supplement the adhesive bond. Other auxiliary reactivation agents described were temperature (two replies) and suction (two replies).

Reservations and limitations

A key fact collected by the survey was that solvent reactivation is not used as widely as heat reactivation and concerns of reversibility or removability were noted, which partly accounts for this (Table 7). Another major concern was the quantity of adhesive that is transferred to the textile artefact during solvent reactivation. These worries are closely connected with general ethical concerns expressed by conservators regarding the application of all adhesives, because in the past they have not always been used successfully. These factors were addressed in the tests that follow.

Another significant practical limitation expressed by the respondents was the possible effects of solvents on the textile during reactivation. When using these techniques the conservator must indeed know the effect of the solvents on all components on the textile. Swelling, desiccation or dissolution can occur on some materials because the chosen solvents, acetone and IMS, can have effects on some man-made materials and also some natural materials found associated with textiles.

Table 7 Reservations for application of solvent reactivation techniques and number of replies.

Reservations / reasons, no.
- Lack of objects requiring the adhesive support reactivated with solvents, **11 (3)** - Concerns regarding reversibility of the resulting adhesive,, **8 (2)** - Concerns regarding possible effects of solvents on textile during reactivation (cleaning effects, solubility of textile components), **7 (3)** - Ethical issues concerning use of adhesive treatments to support textiles, **5 (2)** - Insufficient research/published literature on the subject, **4 (2)** - Lack of opportunities for training/education in their use, **4 (1)** - Health and safety concerns, personal, **3 (2)** - Amount of adhesive transferred to object, **3** - Health and safety concerns, environmental, **2 (2)** - Durability of the treatment in open display (uncontrolled environment), **2** - Concerns regarding the strength of the adhesive bond, **1 (1)** - Concerns regarding possible long term effects to the textile due to exposure to solvents (eg drying effects), **1**

Note: between brackets is the number of replies from conservators that never used solvent reactivated techniques.

For example, acetone can swell cellulose triacetate fibres and dissolve cellulose acetate, whilst alcohols can extract bound water of structural proteins of wool fibres [3]. In some cases it is not possible to know the effects of the solvents on the materials and it can be difficult to collect a representative sample from the textile for testing. These limitations can preclude solvent reactivation.

Health and safety risks, which have always to be considered when using solvents, were also a concern for conservators. Because their risks are low, the solvents used for solvent reactivation are usually limited to acetone and IMS. Other solvents, such as toluene and xylene, can be more effective in softening adhesives to form a good bond, however, due to their toxicity, they are infrequently chosen.

A technique for the future?

Respondents to the survey were unanimous in believing that solvent reactivation was an appropriate technique for the future, but many also recognised that further developments and research was needed. Long term stability of adhesives in an uncontrolled environment was a specific area of interest for some conservators. A conservator stated that they "would be interested to see some comparative theses of the performance/durability of heat activated and solvent activated adhesives on open display or otherwise poorly controlled environments". Another conservator said "To date we have not been convinced that solvent activated adhesives produce a strong enough bond for the display environments we work with (open display in historic house environment) however we would certainly consider their use given different circumstances - a glazed frame textile for museum display."

The relationship between the required bond strength and the adhesive distribution/ transference into the textile artefact and its support was a further area discussed. As a conservator expressed it "from my limited experience of using this technique (solvent reactivation) with Lascaux, I found that it was difficult to control/adjust the degree of reactivation even if you use Gore-Tex®. In some uneven surfaces, I had to repeat the reactivation, or do it for a longer time, to achieve a sufficient bonding. But I was not sure whether the adhesive was appropriately reactivated or dissolved and spread between the object surface and the silk crepeline, or if it went into the object." Arguably this becomes an area that is easier to evaluate with practice; practical experience in such techniques will undoubtedly give more controlled and better informed results. What the comments from the respondents indicate is that there are many variables involved in the application of solvent reactivation and, despite a level of use within the discipline on a variety of objects, there is still a considerable lack of confidence in their use. A study of some of the variables involved in the use of solvent reactivation with thermoplastic adhesives was thus devised in order to help reduce some of the uncertainty and clarify the properties of reactivation techniques of thermoplastic adhesives in practice.

Comparison between different adhesive reactivation techniques - practical tests

The samples and their preparation

A set of fifteen samples were created for the tests. A plain woven habutai silk was used to represent an arte-fact since this was noted by survey respondents as a category of textile that repeatedly demanded an adhesive support. Adhesive coated silk crepeline (semi-transparent open weave) fabric was used to support it. The adhesive chosen for testing was a mixture of 1 part Lascaux 360HV with 2 parts Lascaux 498HV (acrylic adhesives) since this was the most popular thermoplastic adhesive used for solvent reactivation by textile conservators. The adhesive was prepared in 3 different concentrations (10%, 15% and 20% w/v: weight of adhesive to volume of deionised water). Time limitations prevented further thermoplastic adhesives from being included.

To each millilitre (ml) of the three different adhesive dilutions, were added 4 microlitres (μl) of 30% w/v of a fluorescent dye, Rhodamine B, in deionised water. The dye was added for the removability assessment. Under ultraviolet radiation, Rhodamine B fluoresces orange thus any adhesive residues are seen. All the procedures for the preparation of the samples were carried out regarding Heath and Safety regulations in the United Kingdom, namely the Control of Substances Hazardous to Health, under monitored environmental conditions.

The casting bed used for the silk crepeline was polyethylene sheeting. This casting bed is frequently used at the TCC and in other conservation units in the UK, as it is cheap, readily available and the adhesive coated support fabric can be easily removed. A single coat of each adhesive dilution was brushed in even parallel applications with a brush 35 mm wide, in one direction onto silk crepeline. The fabric was fixed at the top edge by masking tape in order to avoid weave disturbance by brushing. 140 ml of adhesive dilution was applied per square metre of silk crepeline and was left to air dry.

Samples of each of the adhesive concentrations was reactivated using three different techniques, heat reactivation with a heated spatula and two techniques of solvent reactivation (solvent applied via a brush and via a cold poultice) and for each, two solvents were used, IMS and acetone. The properties of the supported samples tested were peel strength, flexibility, surface sheen, colour change of the adhesive on reactivation (darkening) and removability (determined as the amount of adhesive on the textile after mechanically removing the adhesive support fabric). The last test also acted as an indication of how much adhesive has transferred into the artefact after reactivation.

Reactivation techniques

Heat

The reactivation by heat was performed on a flat table surface with a conservation spatula tacking iron using a temperature control station (supplied by Preservation Equipment Ltd). After setting the temperature at 80°C, the spatula tacking tip, measuring 32 mm by 17 mm, was applied once to the surface in parallel strokes. The adhesive side of the coated silk crepeline was placed on top of the silk habutai and silicon release paper was used between the heated spatula and the silk crepeline to avoid it adhering to the spatula.

Solvent applied in liquid form via brush

The solvent was applied with a small brush in parallel strokes in one direction on the silk crepeline while placed on top of the silk habutai. The sample was reactivated on a flat surface on top of Melinex® polyester sheet. Two different solvents, acetone and IMS, were used for each set of samples. The samples were left to air dry.

Solvent vapour applied via cold poultice

As for the technique described before, two sets of samples were reactivated using the same solvents previously mentioned. The silk crepeline was aligned with the weave structure of the silk habutai, and all layers placed on Melinex® polyester sheet. The cold poultice was made using the following sequence: first a layer Gore-Tex®, then on top filter paper wetted with solvent with the aid of a brush and finally a glass weight to offer light pressure to encourage a bond to form, in accordance with practice noted through the survey. Samples were left to reactivate for 5 minutes.

Testing procedures

Peel strength

The peel strength tests were performed with an instrument using weights to pull the support fabric from the silk habutai, thus breaking the adhesive bond. This instrument was specially devised at the TCC to assess the bond strength of differently reactivated adhesive supports [14] (Fig. 1). The samples were cut into strips measuring 7 cm by 3 cm. The instrument held the silk habutai horizontally flat, 30 cm above the surface of the table, while the support fabric (silk crepeline) was peeled away vertically by adding weights. Prior to adding the weights, 3 cm from the edge of the silk crepeline was separated from the silk habutai. After each weight was added ten seconds were allowed to elapse, if no peel was noted further weights were added. The final weight was noted when the support fabric started to peel immediately. Three repetitions of each sample were made; from the three repetitions an arithmetic mean was calculated.

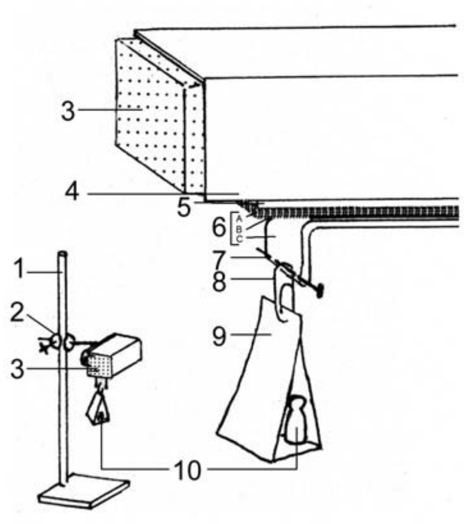

Fig. 1 Instrument used to assess the peel strength of adhesive bonds of textile samples adhered to support fabrics. 1-Stand; 2-Clamp; 3-Bolck of EthafoamTM; 4-Stitched cover of silk habutai; 5-Double side adhesive tape; 6-Sample (A-Textile Silk habutai; B-Adhesive Lascaux 360/498 HV; C-Support fabric Silk crepeline); 7-Entomological pin needled from side to side at the edge of the support fabric; 8-Paper clip; 9-Strip of paper folded to form a balance pan; 10-Weights.

Flexibility, surface sheen, darkening

A panel of five conservators was asked to assess the flexibility, the surface sheen and the darkening of the reactivated samples through observation and handling. Whilst it is acknowledged this is a subjective method it is also the only means typically available to the majority of conservators when using adhesives in remedial treatment and reflects practice in the field. The same group of fifteen different samples of 10 cm by 10 cm were assessed using a scale from 1 to 3 and using half decimal values when necessary, for example 0.5.

Removability and transference of the adhesive into the textile

Removal of the adhesive support from the sample by mechanical means demonstrated how much adhesive was left on the textile after this procedure and gave an indication of how much adhesive had transferred into the textile sample during reactivation.

The silk crepeline was removed from the silk habutai without the application of heat or solvents. The samples were placed on a flat surface with the silk habutai facing down and the support fabric facing up. The support fabric was then separated carefully from the textile with a pair of tweezers. Removal was timed so that each sample received similar conditions. The results were assessed visually under ultraviolet radiation (UV) which, as for the last test is acknowledged as subjective testing, but again reflects practice in the field.

Results and Discussion

Peel strength

An unsurprising general trend evident in the test samples suggested that with increasing amounts of adhesive on the sample, the weights required to peel off the support fabric are heavier (Fig. 2). The bond strength is therefore greater with increased quantities of adhesive on the support fabric. The samples illustrated that this fact is independent from the method of reactivation.

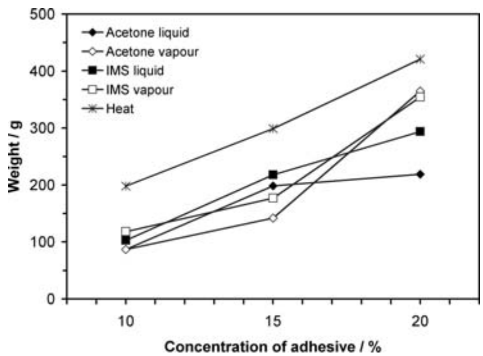

Fig. 2 Results from the peel strength test.

Furthermore, the samples that were heat reactivated needed heavier weights to break the adhesive bond than the solvent reactivated samples. In 42% of measurements, the heat reactivated samples required the double quantity of weight to peel off the support fabric compared with solvent reactivated samples, demonstrating that, in these samples, heat reactivation gave a much stronger bond. This fact does not correlate with one of the reasons conservators initially pointed out for the use of solvent reactivation for adhesives which states that the bond can be stronger than the ones obtained by heat reactivation. Obviously a longer reactivation time may encourage a stronger bond to be formed and this may support the observations made empirically by conservators in practice. Recent work at the TCC, subsequent to the project, has used 10-15 minute reactivation times for solvent vapour to encourage a strong bond to be formed, but again this is only empirical testing. Time constraints of the project prevented further testing to be undertaken at the time, however, but this remains an area ripe for further investigation. Certainly empirical testing of conservators and the test results obtained during the project suggest that the time used for solvent reactivation is a major and influential variable on the final bond strength obtained.

The peel tests further revealed that there was not a direct relationship between a specific solvent reactivation technique and the strength of the adhesive bond in the samples tested. All samples reactivated with solvents (liquid or vapour) had similar bond strengths at the lower concentration. At the slightly higher adhesive concentration of 15%, the samples reactivated with solvent liquid had a slighter stronger bond than the samples reactivated with solvent vapour. Furthermore, at 20% adhesive concentration the samples reactivated with vapour had distinctly stronger bonds than the samples reactivated with solvent liquid. A possible reason for this is when the solvent liquid interacts with high concentrations of adhesive the softening and swelling of the adhesive polymer mass is too effective surpassing this phase of interaction, occurring then the partial dissolution of the adhesive, consequently minimising the number of secondary bonds for a stronger adhesive bond to be established. Weaker cohesive forces on the adhesive layer, as observed on the removability assessment, can be linked with this result. Applying liquid solvent by brush is a very direct action and is not a very sensitive technique. Solvent vapour, on the other hand, is a more controllable technique that softens the adhesive more slowly thereby allowing it to adhere to the textile more effectively whilst keeping it in place on the support.

In terms of the solvent used, the samples that were reactivated with IMS had predominantly stronger bonds than the samples reactivated with acetone. The most likely reason for this is the higher evaporation rate of acetone compared with IMS, which might slightly reduce the adhesion time available for the adhesive.

Flexibility

The observations obtained from conservators suggested that the flexibility and suppleness of finished adhesive treatments seems to vary with the concentration of adhesive, the reactivation technique and the solvent used to reactivate.

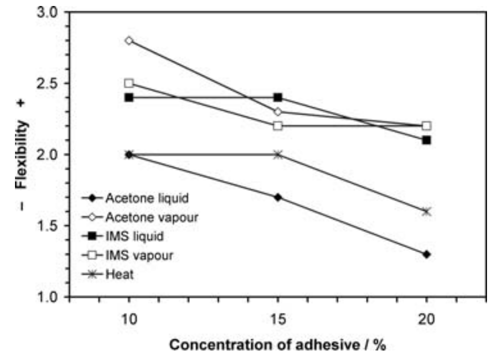

Fig. 3 Results from the flexibility assessment.

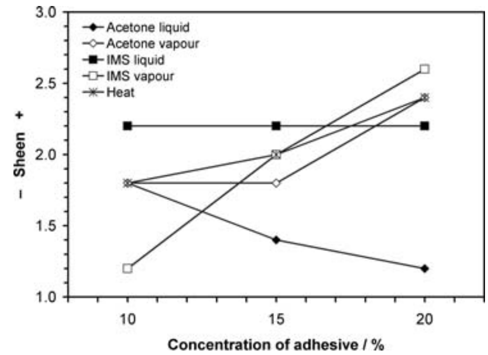

Fig. 4 Results from the surface sheen assessment.

The tendency observed from the samples was that the greater the concentration of adhesive, less flexible the finished sample (Fig. 3). The result is logical because, the greater the quantity of adhesive the greater the area of contact points between the textile and the support fabric and the thicker the layer of adhesive, which will in turn, result in less flexibility.

In terms of reactivation techniques, the samples reactivated with acetone vapour and IMS (vapour and liquid) were evaluated as the most flexible samples. Samples reactivated with heat were assessed as being moderately flexible falling in the middle of the assessment range and were less flexible than vapour reactivated samples. The samples that had the least flexibility were those reactivated with liquid acetone. The assessment results indicated that the quantity of solvent influences the flexibility of the samples. Analysing both solvent reactivation techniques (reactivation with solvent vapour via poultice and reactivation with liquid solvent via brush) the general trend was that the reactivation with vapour produced more flexible samples than the reactivation with liquid solvents, especially when reactivating with acetone. Given that more solvent is typically used for application of liquid solvent via brush than by the use of solvent vapour, if a more flexible film is required solvent reactivation is a pertinent choice.

Comparing the performance of the two solvents used to reactivate the adhesive, IMS produced samples that had small differences in flexibility and acetone produced the samples with extremes of flexibility. Acetone liquid produced the least flexible sample of the group presenting values below the medium value, while acetone vapour produced the most flexible samples, mainly in samples with a lower concentration of adhesive.

Surface Sheen

The results from the surface sheen assessment for each reactivation technique were distinct. The samples with the least surface sheen were those reactivated with liquid acetone. Samples reactivated with IMS vapour at 10% also had a low sheen but in contrast the sample with 20% adhesive concentration, reactivated with IMS vapour, had the highest sheen of all samples. The result would suggest that when using high concentrations and a matt surface finish is needed, solvent vapour is a less effective choice. In contrast, samples reactivated with IMS liquid had a consistent level of surface sheen on the three different concentrations with values slightly above the middle value. Samples reactivated with heat and acetone vapour also had results close to the middle value and were very similar to each other, with both having a greater resultant sheen at a 20% concentration of adhesive (Fig. 4).

From the five different reactivations, three resulted in samples, which the resultant surface sheen was higher with the increase of adhesive concentration: reactivation with solvent vapour (IMS and acetone) and reactivation with heat. The two exceptions were observed on samples reactivated with IMS liquid (the sheen was evaluated with the same level for the three concentrations, slightly above the medium value for surface sheen) and the samples reactivated with acetone liquid (with the increase of concentration of adhesive the surface sheen of the samples decreased). The test results demonstrate that the sheen that remains after an adhesive is reactivated can be very varied. If a matt surface finish is required choices must be carefully made as most of the test samples did retain a degree of shine. Moreover, according to the test results, selecting a reactivation method that has no sheen also means selecting the method that produced the least flexible sample, which may or may not be appropriate for the textile in question. No reactivation method will be perfect in every way. Instead the qualities required from the adhesive have to be balanced and a reasonable compromise found between, for example, bond strength, flexibility, sheen and other qualities. Moreover, every textile treated will have different needs so an understanding of the possibilities and variables of different reactivation methods is essential for decision making.

Darkening

The results obtained through assessing the colour change (darkening) of the samples before and after reactivation were very distinct (Fig. 5). The samples that were reactivated with vapour (IMS and acetone) showed the least change in colour, darkening, after reactivation, by comparison with other samples. The samples that were reactivated with heat and the samples reactivated with IMS liquid had middling values. Samples reactivated with acetone liquid showed a marked level of darkening and were given the highest values available by the panel of testers, close to the maximum 3.

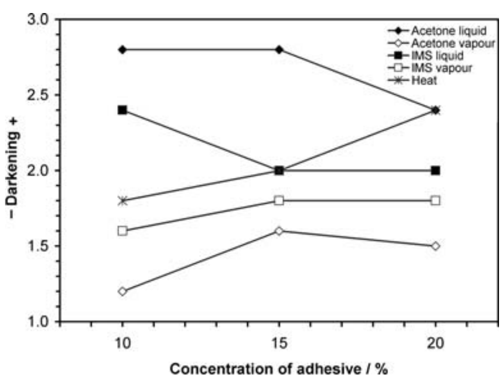

Fig. 5 Results from the darkening assessment.

The relationship between the concentrations of adhesive and the darkening is not linear: in four cases out of ten increases of concentration, the darkening increased. In three cases with the increase of concentration of adhesive the darkening remained relatively constant and in other three cases the darkening decreased. The results suggest therefore that any darkening of adhesive after reactivation is not necessarily due to the amount of adhesive but more likely due to the reactivation technique applied. Choice of reactivation technique will therefore readily influence the final colour and appearance of the adhesive in terms of both surface sheen and colour change through darkening.

Removability

After removal of the support fabric the textile sample with more adhesive left on their surfaces were those reactivated with acetone liquid and vapour, especially at the highest concentration of 20%. The textiles that had the least amount of adhesive were from the samples reactivated with IMS (liquid and vapour) and those reactivated with heat (Table 8). Under UV light, it was also observed that on the textiles reactivated with heat, the amount of adhesive was unevenly distributed on the surface by contrast with the textiles that were reactivated with solvent, which had the adhesive distributed uniformly on the silk habutai surface. The results may suggest therefore that a more even adhesive bond is created by solvent reactivation.

It was expected that the silk habutai from heat reactivated samples would have the most adhesive residues after the removal of the support fabric, as it was the strongest bond. However the test results did not support this. In the samples reactivated with acetone the cohesive forces in the adhesive layer were probably weaker than the adhesive forces between the silk habutai and support fabric. When the support fabric, silk crepeline, was removed the adhesive was readily left behind on the silk habutai. The results may suggest therefore that a strong bond and a higher concentration of adhesive do not necessarily mean that the adhesive treatment is less removable than a treatment with a weaker bond.

Table 8 Results from the assessment of the tack on the silk habutai surface after the mechanical removal of the silk crepeline.

Technique of reactivation	Concentration of adhesive			
	10%	15%	20%	Mean
Acetone liquide	3	4	4	3.7
Acetone vapor	2	4	4	3.3
IMS liquid	1	2	2	1.7
IMS vapour	1	2	3	2.0
Heat	1	2	2	1.7

Key:
1 - slight tacky surface (the surface hardly adhered to the fingertip),
2 - medium tack on the surface (the surface adhered to the fingertip and separated immediately),
3 - higher tack than medium on the surface (the surface adhered to the fingertip and separated before one second),
4 - maximum tack on the surface (the surface adhered to the fingertip and separated after one second).

Conclusion

Although solvent reactivation techniques are less often used compared with heat reactivation, the appropriate results obtained by different textile conservators, in different conservation units, as revealed by the survey, are encouraging for the continued future use of the techniques. Furthermore, a lack of familiarity and opportunity for professional development were cited by many survey respondents as a major reason for not using solvent reactivation techniques. Many felt they did not have enough data about the techniques to use them with any confidence. The project reported here has endeavoured to redress this and to introduce a wider number of textile conservators to the possibilities of solvent reactivation of adhesives.

The test results to compare different techniques of solvent reactivation with the more established heat reactivation technique demonstrated that many variables are at work when adhesive treatments are used on historic textiles. Varying reactivation techniques and adhesive concentrations will produce very different end results. In addition, the tests show that one particular technique may produce one very good quality but perhaps also one that is less desirable, for example, a high flexibility can be achieved but maybe at the expense of poor bond strength. Similarly low surface sheen may mean accepting a lack of flexibility. Because every textile treated is unique and has its own particular needs, an understanding of the possible variables of reactivation techniques is pertinent. No one method of reactivation or concentration of adhesive can be cited as being appropriate or beneficial for textile conservation because it will not be apt for every textile. Moreover, each method of reactivation has its own advantages and disadvantages.

What has been achieved in this paper is a demonstration of the effect of some of the variables involved in reactivation techniques. In this way more informed choices can be made when different reactivation techniques are considered. Textile conservators are encouraged to try solvent reactivation techniques for themselves to learn how the qualities they produce may be effectively employed in their work. For example, the instrument used to assess the peel strength can be an aid in a conservation unit as it can easily be built and used with a systematic methodology providing comparative results. Only by trying the techniques will textile conservators really learn how solvent reactivation behaves. Solvent reactivation of adhesives can offer benefits over established heat reactivation because heat is not required and very little pressure is needed. Thus these techniques have the potential for use where heat reactivation is not currently favoured. Furthermore, solvent reactivation can be used to create similar or, depending on the criteria desired, perhaps better results than heat reactivation. Certainly if a textile conservator is familiar with a broader range of techniques their choices are also wider and the search for an appropriate adhesive treatment becomes a more realistic goal.

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