A CLOSER LOOK AT PRESSURE-SENSITIVE ADHESIVE TAPES: UPDATE ON CONSERVATION STRATEGIES

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Introduction

Study of the history of pressure-sensitive tape manufacturing and industry standards can be of great value in addressing the preservation and conservation problems associated with these materials. This paper reviews the history of pressure-sensitive tapes and discusses the stability of tape components and their effect on paper. To date, the works of Feller and Encke[1], Smith et al[2], and Burgess and Charette[3] represent some of the more comprehensive investigations into the deterioration of pressure-sensitive tapes. This information, combined with a close examination of tape industry literature, is useful in projecting the degradative behavior of tape and developing guidelines for conservation prioritization with respect to large collections. Updated treatment techniques for removing tapes, their adhesive residues, and associated staining are described.

Structure of pressure-sensitive tape

Pressure-sensitive adhesive tapes consist of two main elements: the backing and the adhesive. Tape backings, or carriers, can be made of plastic film, fabric, paper, metal foil, and other materials that provide a flexible support for the adhesive mass. The two general classes of pressure-sensitive adhesives are those made from rubber and those made from synthetic polymers such as acrylics. The primary ingredients of a pressure-sensitive adhesive are the elastomer, the tackifier, and the plasticizer. Additives such as antioxidants and fillers can be incorporated also[4].

Elastomers: comprise the basis of a pressure-sensitive adhesive. Elastomeric materials are solid elastic polymers. Most are insufficiently tacky by themselves to enable pressure-sensitive adhesion.

Tackifiers: enable an elastomer to bond with other materials by brief contact under light pressure, a property called "quick-stick".

Plasticizers: are liquids or soft solids at room temperature, that are added to the elastomer in order to make it softer and more conformable to the surface to which the pressure-sensitive adhesive is applied.

Antioxidants: are additives which stabilize pressure-sensitive adhesives against heat and light degradation, as well as against oxidation.

Fillers: are added to increase adhesive viscosity and specific gravity, to add color, and to reduce cost.

History of pressure-sensitive tape

Medical tapes were the first pressure-sensitive products, beginning with the United States patent awarded to Shecut and Day in 1845. The fundamental components of most modern rubber-based pressure-sensitive formulations appear in the Shecut and Day formula. The adhesive consisted of India rubber (the elastomer), pine gum (the tackifying resin), spirits of turpentine (the solvent dispersant), and litharge (the filler). Turpentine extracts of cayenne pepper and other minor medicinal ingredients were also present in this seminal formula.

In Europe, a German patent was issued in 1882 to druggist P. Beiersdorf for a medicinal plaster containing medical components mixed in an adhesive based on *gutta-percha* (a form of natural rubber). The Johnson and Johnson Company, of the United States, began large scale manufacture of surgical tapes in 1886[5]. Beiersdorf A.G. continued to manufacture pressure-sensitive tape and is now the largest tape producer in Europe, operating under the name Tesa[6]. It is second in worldwide production to the Minnesota Mining and Manufacturing Company (3M), of the United States.

The first non-medical applications of pressure-sensitive tapes were in the 1920s. 3M initially developed masking tape for use in the automotive paint industry in 1928, and patented cellophane tape, the first "Scotch" Brand product, in 1931. The elastomer for all of these early tapes was natural rubber.

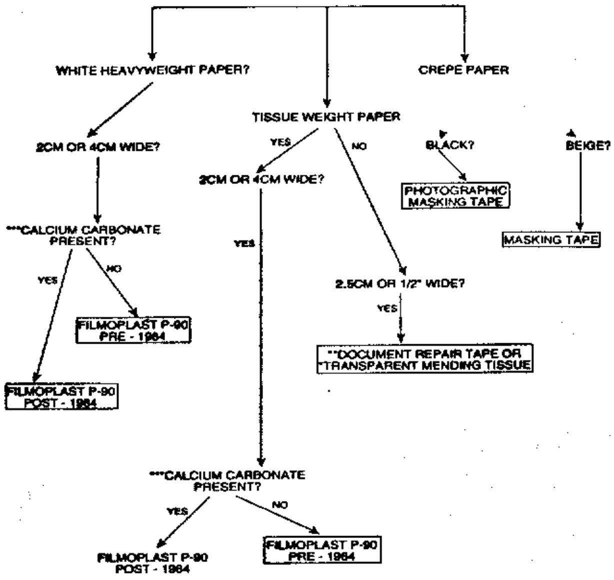
Natural rubber adhesives dominated the pressure-sensitive adhesives market until a shortage of natural rubber during World War II prompted the search for substitutes. Polyisoprene and styrene-butadiene synthetic rubbers were among the first polymers to temporarily replace natural rubber during war time. By the time rubber was again in plentiful supply, the synthetic rubbers had gained a foothold and continued to be used to a limited degree in place of natural rubber[7].

Tackifiers can comprise as much as 50-75% of rubber-based mixtures, and contribute proportionately to an adhesive's characteristics[8]. Early tackifying resins were highly unstable wood rosin and were commonly used in natural rubber-based adhesives through the mid-1930s. By 1940, the less acidic esterified rosin was introduced because of its greater resistance to aging. Succeeding esterified rosins, terpene and petroleum-based resins were incorporated into rubber adhesives during the late 1950s and the 1960s.

The introduction of mineral oil and lanolin plasticizers was a further improvement in rubber adhesive compounding. Phthalate and phosphate plasticizers became available in the 1920s and 1930s [9], although the use of mineral oil and lanolin persisted due to their low cost.

An alternative to rubber as the principal component of pressure-sensitive adhesives was sought early in this century. Synthetic viscoelastic polymers, such as polyacrylates, were employed in the German pressure-sensitive adhesive industry prior to and during World War[10]. In 1959, 3M obtained the first United States patent for pressure-sensitive acrylic adhesives [11]. The introduction of two acrylic tapes, #810 Scotch Magic (frosted) and #800 (glossy), followed in 1961 [12]. Both used cellulose acetate film, patented in 1953 as a tape backing.

The 1970s saw the debut of pressure-sensitive tapes marketed as "archival". These have thin paper backings which frequently contain alkaline salts. Quite often the synthetic polymer adhesives are compounded with vinyl acetates or plasticized with phthalates. In spite of the advent of acrylic tapes they have not supplanted cellophane rubber-based tapes. Because acrylic adhesives are costly, manufacturers still offer rubber-based mending or office tapes as "economy" products. Most masking tapes still

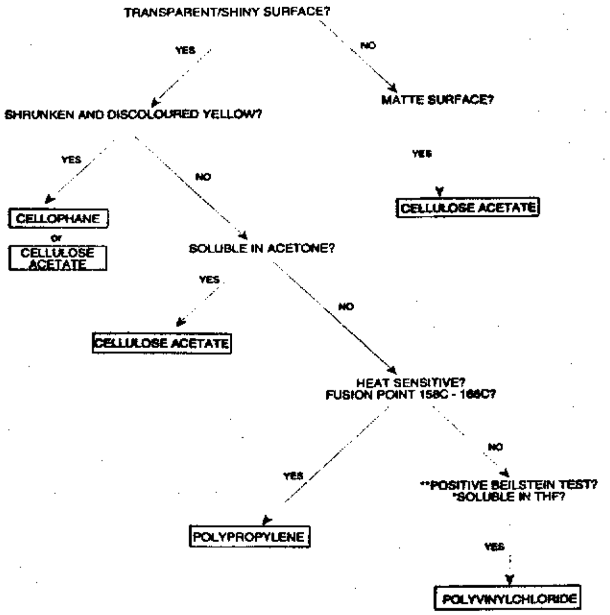


*IODINE/POTASSIUM IODIDE SOLUTION TURNS DARK RED POSSIBLY FROM PRESENCE OF STARCH FILLER IN BACKING.

**ARCHIVAL AIDSO DOCUMENT REPAIR TAPE (2.2CM WIDE) AND TRANSPARENT MENDING TAPE (1/2" WIDE) ARE THE SAME TAPE CALLED BY DIFFERENT NAMES.

***CALCIUM CARBONATE DETECTED BY APPLICATION OF IN HCL TO TAPE SAMPLE AND OBSERVING EVOLUTION OF BUBBLES.

Fig 1. A method for identification of paper backings of pressure-sensitive tapes.



*SOLUBLE IN TETRAHYDROFURAN

**BEILSTEIN TEST USES A COPPER WIRE ON WHICH A SMALL AMOUNT OF BACKING SAMPLE IS BURNED. A GREEN FLAME INDICATES PRESENCE OF CHLORINE.

Fig 2. A method for identification of plastic film backings of pressure-sensitive tapes.

	APPEARANCE											SOLUBILITY				CARRIER TYPE						
	ADHESIVE IS COLOURLESS	ADHESIVE IS SLIGHTLY YELLOW	PAPER IS TRANSLUCENT AND STAINED AMBER	CARRIER IS BRITTLE AND AMBER COLOURED	OOZING/MIGRATION OF ADHESIVE FROM UNDER CARRIER	ADHESIVE IS EXTREMELY STICKY OR WEAK AND CHEESY	ADHESIVE HAS RESINOUS SMELL WHEN HEATED	CRYSTALLINE FORMATIONS ARE VISIBLE IN ADHESIVE	SERRATED EDGE FROM DISPENSER - INTROUDCED 1932	PAPER CONTRACTED FROM CARRIER SHRINKAGE	CARRIER GONE	SWELLS IN WATER AND LOW ALCOHOLS	DISSOLVES IN HEXANES, BENZINE, CYCLOHEXANE	DISSOLVES IN ETHYL ACETATE, TOLUENE	DISSOLVES IN TETRAHYDROFURAN, METHYL ETHYL KETONE, METHYLENE CHLORIDE	IMPREGNATED CREPE PAPER - INTRODUCED 1928	CELLOPHANE - INTRODUCED 1931	CELLULOSE ACETATE - INTRODUCED 1953	POLYVINYLCHLORIDE - INTRODUCED 1953	POLYPROPYLENE - INTRODUCED 1966	LIGHTWEIGHT TISSUE PAPER - INTRODUCED MID-1970s	BUFFERED PAPER - INTRODUCED 1984
INTRODUCED 1961 - SYNTHETIC POLYMER	Y								Y			Y				Y		Y	Y	Y	Y	Y
INTRODUCED 1928 - RUBBER - INDUCTION STATE		Y					Y		Y				Y			Y	Y	Y	Y			
RUBBER - OXIDATION STAGE					Y	Y	Y		Y	Y				Y		Y	Y	Y	Y			
RUBBER - CROSSLINKED STAGE			Y	Y			Y	Y	Y		Y				Y	Y	Y	Y	Y			

Fig 3. Factors helpful in the identification of pressure-sensitive tapes.

have rubber-based adhesives, however some acrylic-based masking tapes have become available. Ultra-clear tapes with polypropylene backings, such as Permacel J-Lar™, are relative newcomers. They are extremely strong due to the biaxial orientation of the polypropylene tape backing, and are very clear because of the acrylate adhesive.

A major challenge confronting the tape industry today is the increasing use of recycled and alkaline papers. The surface characteristics of recycled paper made from heavily-beaten fibers require tape adhesives with higher initial tack. Highly alkaline papers, such as those filled with calcium carbonate, require adhesive formulations designed to stick to sheets of high pH [13].

Industry standards and tape testing

The development of quality control and standard test methods for pressure-sensitive tape began at 3M in the 1930's. Currently, several organizations worldwide develop test methods for systematic evaluation of tape products [14]. While developed for industry, the test methods can tell conservators how a tape is intended to function and approximately how long it is intended to last. Most pressure-sensitive tapes are not manufactured for longevity, but rather for specific end uses. Significantly, 3M has written a caveat (available upon request), which states that no 3M tape product should be considered appropriate for "archival" use[15]. As long as a tape product meets requirements of standard test methods, the manufacturer can substitute components at will, and without notice to the consumer[16].

Stability of pressure-sensitive tape and associated effects on paper

The stability of pressure-sensitive tape can be evaluated by examining deterioration processes and characteristics of the tape components.

Rubber based adhesives

Elastomer The aging behavior of rubber-based transparent mending tape was investigated by Robert Feller in 1982 [17]. He characterized a three-stage deterioration process. During the first stage, the oxidative induction period, the adhesive grows increasingly sticky. The second stage is characterized by significant chain scission of the rubber polymers and the tape adhesive becomes "weak and cheesy". The small molecules which result can migrate into a paper adherend, causing translucency. During the third stage as oxidation progresses, the adhesive becomes crosslinked, brittle, and discolored, creating deeply-penetrating amber-colored stains in paper. Embrittlement of the paper adherend often occurs as well.

Experimentation has demonstrated that diffused daylight shortens the induction period and accelerates the oxidation reaction of rubber[18]. The projected light exposure expected from the exhibition of paper objects bearing rubber-based tape should be carefully evaluated to minimize any potential increase in damage to the object[19].

The volatile oxidation products of the rubber adhesive are carbon dioxide, water, formic acid, and formaldehyde. The solid oxidized products are amorphous acid substances and cross-linked material containing small amounts of peroxides[20,21]. The presence of these by-products in degraded rubber-based adhesives may cause oxidation and acidic hydrolysis of the paper adherend. It has been observed that, following solvent extraction of embedded adhesive, the remaining stain can sometimes be diminished by treating the area with alkaline water [22]. This suggests that acidic compounds that are absorbed from the tape, or generated from paper deterioration which was initiated by the tape, are dissolved.

Tackifier: The poor aging properties of resins and rosins used as tackifiers contribute to the instability of rubber-based adhesives. Wood rosin is a thermoplastic acidic resin and is susceptible to oxidation due to the presence of conjugated double bonds in its structure. Upon aging, wood rosin discolors brown, develops small crystals in the adhesive that are visible to the eye, and can ooze from under the tape backing due to lowered viscosity [23].

Chemically-modified rosins, such as esterified rosins, discolor less than wood rosins. As the molecular structure of these resins becomes more saturated, the aging stability of the adhesive improves. Wetzel and Alexand propose that oxidation occurs at first during manufacture, when the resin/rubber blend is exposed to heat in the presence of air. They theorize that this process probably causes initial oxidation of the resin because the resin molecule usually contains more activated positions than does the rubber. Oxidation of the resin results ultimately in the formation of peroxy radicals which often react with the rubber elastomer to decrease molecular weight and increase polarity [24]. The adhesive becomes very sticky, and the rubber molecules become small enough to migrate into a paper adherend. In terms of tape removal, as the adhesive polarity increases with oxidation, increasingly polar solvents are needed to dissolve the compound.

In the late 1950s, terpene resin tackifiers entered the pressure-sensitive adhesive industry due to their superior aging properties. They are derived from turpentine and other natural sources, including citrus peels. Their market début was shortly followed by petroleum resins in the late 1960s [25]. Tapes that predate the introduction of terpene and petroleum resins are likely to be the least chemically-stable because of their wood rosin or modified rosin content.

Plasticizer: Plasticizers may cause physical changes in rubber-based pressure-sensitive tapes by migrating and/or volatilizing from the adhesive mass or the plastic film backing. Migration is promoted by fluctuations of temperature because a plasticizer's solubility parameter is dependent on heat [26]. The paper adherend can be rendered translucent by migration of the plasticizer such as mineral oil, lanolin, and the phthalate and phosphate plasticizers. The degradative characteristics of plasticizers in rubber-based adhesives are not well understood.

Filler: Pigment fillers are used to color adhesives or to mask a tendency to yellow on aging. Titanium dioxide is most commonly used due to its white color and opacity. This pigment became available on the American market between 1916-1919, although the date of its introduction to the tape industry is not clear. Certain types of titanium dioxide are known to catalyze the oxidative degradation of other adhesive components [27], as well as the paper adherend. It is commonly used in masking tape backings and adhesives.

Antioxidant: Antioxidants contained in rubber adhesives can be a source of staining. The amine antioxidants, which guard efficiently against aging, stain the adhesive and materials in contact with the adhesive. The most widely used antioxidants are the phenolic types [28]. The phenolics are largely nonstaining, although upon oxidation they form highly colored quinoid structures. Butylated hydroxytoluene (BHT) is the most heavily used phenolic [29].

Synthetic polymer-based adhesives

Elastomer: Polyacrylates of a particular co-monomer composition are inherently tacky and pressure-sensitive without any compounding with tackifiers or plasticizers. Due to the saturation of the polymer these adhesives are more resistant to aging than rubber-based adhesives. They are unlikely to discolor amber brown or become hard.

To make the adhesive stronger, stiffer, and less tacky, acrylic polymers can be crosslinked by multivalent metallic ions such as zinc [30]. Reversible tape adhesives (i.e. 3M Post-It Notes and Removable Magic Tape #811) are highly cross-linked products. As described by Satas, small amounts of polar comonomers, which are often included in the adhesive formula to provide cross-linking sites, may cause adhesion strengthening with time [31]. Removal of acrylic-based tape may become more difficult if postponed.

Acrylic-based pressure-sensitive adhesives also are subject to "cold flow"– the movement of the adhesive mass at room temperature. This increases the difficulty in reversing the tape/paper bond over time. Acrylic adhesives can also cause translucency in paper. Furthermore, polymers with significant crosslinking through ionic bonding do not go into solution, but only swell in solvents [32]. At times, complete solvent extraction of acrylic tape adhesive from paper may not be possible.

Vinyl acetate/acrylic ester co-polymers constitute a special group of pressure-sensitive adhesives. These adhesives are less polar than polyacrylates. They usually exhibit high tack and may have slightly poorer aging properties than acrylic adhesives [33]. As with acrylic adhesives, Skeist points out that the adhesive bond of vinyl acetate/acrylic ester co-polymers strengthens with time [34].

Chemical changes during accelerated aging tests of both "archival" and office tapes with synthetic polymer adhesives, are often monitored by pH measurements [35]. However, as Burgess has stated, it is important to interpret the results carefully, as pH is expressed as a logarithmic scale. Products that start out being neutral (pH 6 to 7.2) will show relatively large decreases in pH (i.e. change in pH greater than 1 unit) as a result of any significant increase in acidity of the sample. On the other hand, tapes that are already acidic (i.e. pH 4.5) may not show a significant change in pH. Typically, acidic tapes will result in a pH change of less than 0.5 units during accelerated aging [36].

Tackifier: Acrylic adhesives do not require tackifiers to have excellent pressure-sensitive properties. Nevertheless many manufacturers add rosin esters, polystyrenes, and other materials to change or vary adhesive properties [37]. As with rubber-based adhesives, the tackifier can promote chemical instability.

Plasticizer: Acrylic adhesives may also be plasticized with phosphate, phthalate, and sulfonamide plasticizers, to name a few examples. The adhesives are vulnerable to the loss of plasticizer through migration and volatilization [38,39]. Butyl benzyl phthalate is used widely for acrylics because of excellent compatibility [40]. Acrylic tapes have been observed to cause bleeding of some inks, a condition possibly associated with the plasticizer contained in the adhesive.

Tape backings

The potential instability of pressure-sensitive tape backings warrants consideration as a secondary influence on tape deterioration. Some of the backing materials which can be unstable are cellophane, cellulose acetate, polyvinyl chloride, and impregnated crepe papers.

Cellophane: Cellophane, also known as regenerated cellulose, is a plastic film. It is hygroscopic, can become quite brittle when dry, and soft in humid conditions [41]. Cellophane is dried under tension during manufacturing, which promotes the tendency of this hygroscopic material to shrink [42]. Shrinkage of cellophane tape can cause the paper adherend to break or tear, particularly if already embrittled by absorbed, cross-linked adhesive. The volatilization of degradation products from cellophane tape backings may affect other paper objects which remain in contact with the tape backing for extended periods. Fluorescence may be observed in paper stored in contact with sheets bearing cellophane tape. Using long wave ultraviolet light, the fluorescence is seen as a rectangular band, identical in size to the tape strip on the opposite sheet.

Cellulose Acetate: Cellulose acetate can undergo heat- and light-catalyzed oxidation which results in discoloration, loss in tensile strength, and the production of volatile by-products such as carbon monoxide, carbon dioxide, water, and acetic acid. Plasticizers, pigments such as titanium dioxide, and acids such as bound sulfuric acid (a residual processing compound) may catalyze the reaction. Commonly used plasticizers for cellulose acetate include dimethyl and diethyl phthalates, methyl phthalyl ethyl glycolate, triacetin and aromatic phosphates, and sulfonamides. Dimethyl phthalate and triacetin are highly volatile. Diethyl phthalate, dibutyl phthalate, dioctyl phthalate, and dibutyl sebacate oxidize and evolve peroxides and acidic by-products [43], although their associated effects on paper have not been investigated.

Polyvinylchloride: Polyvinylchloride film has general-purpose applications as a tape backing. The plastic is unstable and is subject to heat- and light-catalyzed oxidation and de-hydrochlorination. Hydrogen chloride is liberated and functions as a catalyst for discoloration and crosslinking of the film. PVC film generally contains acid acceptors – alkaline compounds which suppress the degradative effect of hydrogen chloride. However, acid acceptors can deplete over time. PVC film also contains plasticizers (i.e. phthalates, phosphates, esters of aliphatic dibasic acids, and polyesters) and extenders (i.e. chlorinated paraffins, aliphatic and aromatic oils) [44]. Dibutyl

Fig 4. Pressure-sensitive tape time line

1845 – natural rubber first used for medical tapes
1902 – Minnesota Mining and Manufacturing Co. (3M) founded
1908 – Cellophane invented (first extrusion of xanthate)
1909 – first Kraft paper manufactured in U.S.
1918 – styrene-butadiene used as an elastomer
1924 – Celanese USA produces first Cellulose acetate
1923 – 3M introduces first masking tape
1930 – 3M introduces first "Scotch" brand Cellophane tape
1932 – Borden invents first tape dispenser (3M)
1939 – polyisobutylene developed as an elastomer
1953 – cellulose acetate patented as a tape backing
1959 – 3M patented pressure-sensitive acrylate adhesives
1950s (late) – terpene resins introduced as tackifiers for pressure sensitive tapes
1961 – 3M introduces Magic Mending #810 frosty and #800 clear tapes
1966 – Hercules introduces J-Lar polypropylene tape (now marketed by Permacel)
1960s – petroleum resins introduced as tackifiers
1962 – Neschen introduces Filmoplast P
1964 – Neschen introduces Filmoplast P-90
1970s – development of Document Repair Tape at British Library
1984 – F Neschen Filmoplast P & P90 first buffered with calcium

phthalate, an early plasticizer for polyvinylchloride, was so volatile that shrinkage and stiffening of the plastic was common. For many years, dioctyl phthalate was the plasticizer of choice due to its relatively low volatility and resistance to extraction, in spite of its chemical instability.

Masking tapes: Masking tapes are made with impregnated crepe paper or flatback paper. Impregnated crepe paper is saturated with an elastomer compound to improve its strength, so that the paper will not split or tear. Tape color can be controlled by the addition of titanium dioxide into the backing impregnant, or even into the adhesive. Initially, natural rubber and styrene-butadiene were used as impregnants to saturate paper backings in preparation for application of the rubber-based adhesive mass. Water-based latex impregnants were developed later and include styrene-butadiene rubber, nitrile-butadiene rubber, acrylics, and neoprene. Components of the rubber-based adhesive (i.e. the tackifier resin) may migrate upwards into the impregnated crepe paper, possibly because of the similar solubility parameters of the adhesive and impregnant. This movement can result in a loss of the masking tape's tack and adhesion upon aging [45]. It is plausible that the impregnant may be susceptible to degradative mechanisms akin to rubber-based adhesives.

Removal of any tape backing accelerates the rate of adhesive oxidation due to the increased exposure to air. The backing should not be removed until the conservator is able to perform a full tape removal treatment. A parallel can be drawn with natural rubber which forms an oxidized crust on the exterior, sealing itself against oxygen diffusion to the center [46].

Preservation planning

The potential for damage from pressure-sensitive tapes has motivated many conservators to give taped items top treatment priority. However, for collections with large scale tape problems, it is necessary to distinguish those items in greatest danger in order to best utilize resources.

The following approach assumes that the items in a collection must be retained and preserved, rather than duplicated and discarded as is sometimes the policy in archives. Several factors can influence the establishment of a prioritization system for determining tape removal treatments that can be delayed, versus those which require immediate attention. The five major factors to be considered in assessing items with tape attachments are the type of tape, the condition of the tape, the kind of paper to which the tape is attached, the kind of media affected, and the purpose of the tape attachment.

Making the distinction between general tape varieties is paramount to successfully performing triage on large collections affected by tape. To aid in the identification of tape backings and adhesives, diagnostic tools have been devised which utilize visual appearance, chemical and physical tests, and generic descriptions of the aging characteristics of commonly encountered tapes. Common paper and plastic film backings are distinguished in two "flow charts" (Figs 1 and 2). The introduction date of particular tapes can be extremely useful in the identification process. The identification of adhesives is related to the dating of tapes in a table format (Fig 3). A time line of the major advances in tape manufacturing is provided as well (Fig 4).

In general, rubber-based tapes pose a larger threat to paper because of their greater tendency to oxidize and become acidic, as compared to synthetic polymer-based tapes. However, if newly applied tapes of both varieties appear on objects of similar composition and value, the difficulty in dissolving synthetic-polymer pressure-sensitive adhesives should be weighed. Because the adhesive bond increases with time, the synthetic-polymer tape may be considered most harmful in the short term. In contrast, the induction period for rubber-based adhesives protected from light may be on the order of 1½ - 2 years [47]. Furthermore, rubber-based adhesive can be extracted from paper with solvents until it has reached an advanced state of degradation.

The condition of a pressure-sensitive tape gives important clues in assigning conservation priorities. Ideally, it is desirable to remove all tapes as shortly after application as possible, assuming that tape removal is ethically appropriate and feasible. Removal of rubber-based tapes requires increasingly polar solvents as aging progresses. If such a tape in the "sticky" stage of deterioration is encountered, it is advisable to remove it promptly before its solubility parameter changes dramatically. By doing so, penetration of the adhesive into the paper may be averted, because it is in this stage that the movement begins. Furthermore, translucency of a taped paper object occurs well ahead of marked discoloration. Considerable difficulty in tape adhesive removal can be expected when the "highly discolored" stage has been reached [48]. During treatment, the potential for staining the paper object increases when it is necessary to use polar solvents, as well.

Synthetic polymer tapes usually do not discolor excessively, although the adhesives can migrate into the paper, causing translucency. These tapes do not appear to become extremely acidic with age. Considering the long term forecast, these tapes will remain more stable than their rubber-based cousins.

Although the adhesive content is of primary concern when judging the relative stability and condition of a given tape, the tape backing can also contribute to damage of the paper. Backings, especially cellophane, can shrink so excessively that tearing of the paper adherend can occur. Cellulose acetate is also known to be dimensionally unstable, but generally shrinks less. The adhesive exposed along the backing edges can attract dirt and also stick to adjacent items. Paper backings, with the exception of impregnated masking tape backings, do not shrink appreciably.

Soft, fibrous, lightly sized papers are more likely to be penetrated by tape adhesives than calendared or heavily sized papers. Paper objects in this category should be deemed most vulnerable to tape attachments and given top priority for tape removal treatment.

Many transparent papers impregnated with resins are very sensitive to polar solvents. If possible, tape removal should be performed prior to the stage when polar solvents are required because these solvents tend to induce staining of paper. Likewise, groundwood or other poor quality papers are vulnerable to solvent treatments because of the potential for movement of degradation products and rosin sizing. These short-fibered papers are susceptible to mechanical damage as a result of treatment, particularly if embrittled with age. Finally, acids generated by groundwood papers can accelerate the rate of tape deterioration, whether rubber or synthetic polymer-based. As a rule, papers in a degraded condition should have high priority for tape removal, if treatment is possible. However, the poor condition of the paper may prohibit safe treatment.

Media such as ball point pen, porous pointed pen, and typewriter inks can bleed when exposed to tape adhesives, especially the synthetic polymers. These items require priority treatment, as well. The potential harm to media from tape removal treatment must also be considered.

Some tapes are original and integral to the paper object. Establishing the provenance of the tape is essential in making treatment decisions in these cases. A treatment solution may call for a compromise between removal and retention of the tape, depending on the curatorial and conservation criteria.

Updated treatment strategies

The following treatment methods stress minimal solvent use and techniques which maximize the conservator's control at all stages of tape removal. Dry and mechanical treatments are preferable to solvent and solvent vapor techniques which mobilize tape adhesives, potentially driving these residues further into the paper adherend. Furthermore, the effects of solvents on paper will be variable depending on the character of the paper. The toxicity of solvents plays a role in treatment choices as well [49].

Use and control of heat

Both backings and adhesives of most pressure-sensitive tapes often can be removed by softening with heat. Hairdryers, specialized hot air guns, and heated microspatulas have all been used for this purpose. Tape adhesives soften in a range, depending on the type of adhesive and its state of deterioration. It is very important to prevent the adhesive from flowing into the paper because of exposure to excessive heat.

A microscope slide warming tray (Fisher Scientific) is very useful for introducing the most controlled heat into generalized areas while freeing both hands to perform the treatment. Slide warming trays are used in the preparation of microscope slides to warm samples during staining. They are available in different sizes, and produce heat of a constant temperature, uniformly over the surface. A rheostat and a temperature gauge provide heat ranging between 0-150° C, in increments of 10° C.

The precise control that a warming tray provides is extremely desirable in removing tape from heat sensitive materials. For instance, the emulsion of silver gelatin photographs is vulnerable to desiccation and breakdown of the protein when exposed to certain levels of heat. A heated metal spatula may cause ferrotyping of the emulsion. Blueprints are susceptible to decolorization with excessive heating.

In all instances, a small area of the object should be tested to determine the optimum temperature for removal and to observe that no adverse reaction will occur from exposure of the paper, media, or emulsion layer in the case of photographs, to that temperature. The object should be supported on a blotter so that it does not rest in direct contact with the warming tray. Non-taped areas are protected from heat by secondary layers of blotter, thus limiting the heat application to the taped area.

A hot plate, used with a rheostat, is an alternative to the microscope slide warming tray, however the temperature may not be maintained as consistently.

Following removal of the backing, a crèpe rubber square can be used to reduce the bulk of the adhesive mass, while the object is warmed by a slide warming tray or hot plate. Reworking the area with a vinyl eraser, such as Faber-Castell Magic Rub™, will more thoroughly diminish the adhesive residue, due to the dissolving/mobilizing action of the dioctyl phthalate plasticizer in the vinyl. The solubility parameter of this plasticizer in vinyl erasers is similar to that of methylene chloride [50].

Use of Cellulose Powder

The use of Whatman cellulose powder is an effective aid in removing tape adhesive. Cellulose powder is sprinkled onto the adhesive mass, thereby supplying a porous substrate which absorbs and binds the adhesive while it is removed by manipulation with the fingers, a spatula, crepe rubber square, or vinyl eraser. This technique can greatly reduce the amount of mechanical action required to remove adhesive residues. Areas with slight stickiness remaining may be lightly dusted with cellulose powder to prevent blocking to storage enclosures or to other objects.

Use of Fuller's Earth

The effects of a Fuller's Earth poultice can be gauged by performing a small scale test to demonstrate the effectiveness of the treatment, while minimizing the probability of developing tidelines. The efficiency of a

Fuller's earth poultice can be carefully controlled by depositing a small pile of the poultice (about 1 cm. in diameter) within the perimeter of the tape residue, flattening the pile with a spatula, and adding a droplet of the chosen solvent or solvent mixture to the center of the pile. Polyester film is placed on the reverse of the paper object to ensure evaporation from the adhesive side. Tidelines, should they occur, will more likely be restricted to the already tape-stained area by poulticing "in miniature". Proceed with the treatment using increasingly larger poultices, as seems appropriate. The objective is to control the movement of the solvent and dissolved adhesive residues. Keep in mind that the increased quantity of solvent increases the solvent efficiency and ability to dissolve larger quantities of adhesive.

Use of Solvent

Once the optimal solvent for the removal of an adhesive residue is isolated, it may be advantageous to poultice with a somewhat less effective solvent first. Partial removal of the adhesive residue is accomplished by the less effective solvent, thus leaving fewer degradation products to be moved by the final application of the optimal solvent.

Use of GORE-TEX^{R} to Remove Tape Backings

The deteriorated, crosslinked state of a tape may make removal of the backing with heat unfeasible. The use of GORE-TEX^{R} (W. L. Gore & Associates) fabric and solvent vapors may be very effective in these cases. The GORE-TEX^{R} and solvent-saturated blotter are placed on the reverse of the paper object, where the solvent vapors penetrate the paper from below and are not inhibited by the tape backing. The GORE-TEX^{R}, blotter, and object are sandwiched between polyester film, and the whole is lightly weighted. To remove the tape backing, a corner of the upper sheet of polyester is lifted to work locally along the strip of tape, while the rest of the package contains the solvent vapors.

Need for further research

The complex nature of pressure-sensitive tapes underscores the need for specialized knowledge and ongoing study of these materials. The mechanisms of aging are not clear. Further research is needed regarding the effects of pressure-sensitive tapes on paper. The long-term aging behavior of synthetic polymer-based tapes is not well understood; nor are the aging properties of plasticizers and other additives with respect to paper. The nature of paper deterioration as a consequence of absorbed, crosslinked rubber-based adhesive has not been investigated. Oxidation and acidic damage are suspected. Keeping abreast of changes and trends in the tape industry will certainly guide the conservator in facing future challenges, as well.

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Résumé

Une étude approfondie de l'histoire de la fabrication des rubans autocollants et des normes de l'industrie donne des indications sur la résolution des problèmes de conservation souvent associés à ces matériaux. La stabilité chimique et les propriétés physiques des rubans adhésifs autocollants sont régies par la composition du support comme de l'adhésif. Les rubans sont généralement composés d'élastomères, d'agents d'adhérence, de plastifiants, d'antioxydants, de matières de charge et d'impuretés.

Il est utile de connaître la composition du ruban pour mettre au point des méthodes pratiques d'enlèvement des rubans autocollants, de leurs résidus adhésifs et des taches associées, présents sur les documents d'archives et les oeuvres d'art sur papier. Bien qu'il ne soit souvent pas possible de connaître la formule exacte d'un ruban donné, il est possible de réaliser une identification selon des catégories génériques. Cette information est utile pour prévoir le mode de dégradation du ruban et ses effets sur le papier lors de l'élaboration de stratégies de conservation et de priorités de traitement pour les collections présentant des rubans autocollants.

Pour faciliter l'identification, il est fourni un programme de diagnostic faisant appel à l'aspect visuel, à des essais chimiques et physiques, àl'analyse instrumentale et à des descriptions génériques des caractéristiques de vieillissement des rubans courants. Une chronologie des principaux développements enregistrés dans l'industrie du ruban vient enrichir le guide de diagnostic, en raison de son rapport avec la conservation.

Des développements récents dans la méthodologie de traitement sont présentés à partir d'exemples concrets. Parmi ceux-ci, on peut mentionner l'élimination de papier-cache adhésif noir d'une impression à la gélatine argent moderne, un traitement sans solvant pour une quantité importante d'archives et l'utilisation contrôlée de solvants pour éliminer des taches de ruban adhésif d'un ensemble de pastels réalisés sur papier de couleur.

Zusammenfassung

Eine eingehende Studie der Geschichte der Herstellung druckempfindlicher Klebstreifen und Industrienormen gibt einen Einblick in die Lösung der häufig mit diesen Materialien verbundenen Erhaltungs-/Konservierungsprobleme. Die Chemikalienbeständigkeit und physikalischen Eigenschaften von druckempfindlichen Klebstreifen hängen von der Zusammensetzung des Trägers und des Klebstoffes ab. Zu den Bestandteilen von Klebstreifen gehören im allgemeinen Elastomere, Klebrigmacher, Plastifizierer, Antioxidationsmittel, Füllstoffe und Fremdkörper.

Eine Kenntnis der Zusammensetzung von Klebstreifen ist bei der Entwicklung praktischer Methoden zur Beseitigung von druckempfindlichen Klebstreifen, ihrer Klebstoffreste und damit verbundenen Flecken aus Archivmaterial und Kunstwerken wertvoll. Während es häufig unmöglich ist, die spezifische Formel eines gegebenen Klebstreifens festzustellen, ist eine Identifiatkion ihrer generischen Kategorien möglich. Diese Informationen sind nützlich zur Vorausschätzung des abbauenden Verhaltens von Klebstreifen und seiner Wirkungen auf Papier bei der Planung von Erhaltungsstrategien und Behandlungsprioritäten für mit Klebstreifen zusammengehaltenen Sammlungen.

Zur Unterstützung der Identifkation wird ein Diagnoseplan angegeben, der visuelles Erscheinen, chemische und physikalische Tests, Meßgerätanalyse und generische Beschreibungen der Alterungsmerkmale von häufig angetroffenen Klebstreifen nutzt. Ein zeitlicher Überblick über die Hauptentwicklungen in der Geschichte der Herstellung von Klebstreifen in Verbindung mit der Konservierung ergänzt den Diagnoseleitfaden.

Kürzliche Entwicklungen in der Behandlungsmethodik werden mit Hilfe von Fallgeschichten präsentiert. Hierzu gehören die Beseitigung von schwarzem Kreppband von einem modernen hektographischen Braundruck, eine lösungsmittelfreie Behandlung einer großen Gruppe von Archinvunterlagen und die kontrollierte Benutzung von Lösungsmitteln zur Beseitigung von Klebstreifenflecken aus einem Satz Pastellen auf farbigem Papier.