FIGURE 1 The sleigh *The Skaters*, after treatment. The coachman sat at the rear, and rider in the seat at the center. A single horse in front pulled the sleigh, hitched to the iron rings on the sides of the runners.

THE USE OF LESS TOXIC SOLVENTS IN THE TREATMENT OF A ROYAL FRENCH SLEIGH, CA. 1720

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ABSTRACT

This paper discusses the use of less toxic solvent mixtures, as substitutes for aromatic solvents, white spirit or naphtha, in the cleaning of painted or varnished surfaces. Evaporation rates and Teas solubility parameters, which are useful in designing such solvent mixtures are among considerations reviewed. The use of several specific azeotropic mixtures, and their relative activities on a variety of varnished, painted or gilt surfaces, are noted. Specific treatments of sculptures and vehicles are discussed, with emphasis on the treatment of a French Royal Sleigh, now in the Coach Museum of the Château of Versailles. A few examples of surface cleaning treatments demonstrate that, in some cases, certain mixtures of relatively less toxic solvents can be used effectively. Certain azeotropic mixtures, in particular, have been useful in removing grime, overpaint or varnish, or in reducing in a controlled manner the thickness of a discolored, early varnish.

* * *

INTRODUCTION

It has been suggested that mixtures of relatively less toxic solvents can replace some of the more toxic solvents used by art conservators (Thorn, 1992). In recent treatments I have tried to find alternatives to aromatic solvents and mineral spirits containing aromatic components, known to be carcinogenic. Certain mixtures were designed as substitutes for aromatic solvents effective in dissolving or removing various coatings during cleaning.[1]

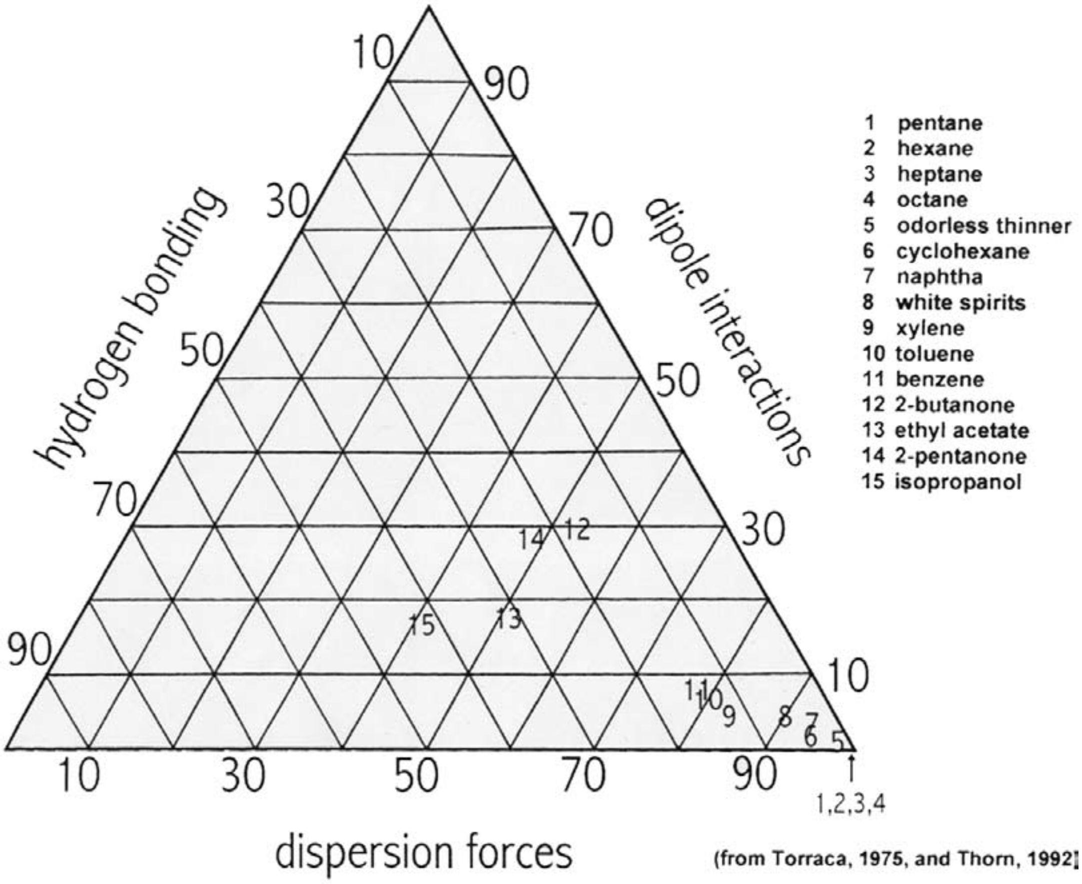
I will discuss the development of such solvent mixtures during the treatment of a royal sleigh in the collection of The Coach Museum of the Château of Versailles (*fig. 1*). Named *The Skaters* for the winter scenes painted on its sides, the sleigh dates from ca. 1720, the Regency of Louis XV. The sleigh's solvent-sensitive polychromy, up to 36 layers (it has been redecorated seven times on top of older materials[2]), makes it an ideal case study for solvent cleaning. In its original form, according to combined documentary and microscopic evidence, the sides of the seat area were covered with gold leaf, with silver leaf applied elsewhere. The scenes of skaters were painted between 1807 and 1816. In the last restoration, a silver-gold alloy leaf was applied overall, except for the painted parts, and red or green glazes were applied to areas of the metal leaf. More recently, and probably to hide scratches, the sleigh was coated with a dark, shellac-based varnish that was removed during the treatment I will describe. This varnish proved soluble in ethanol, but so were other layers of the polychromy, and while toluene could be used to remove the shellac layer in a more controlled fashion, the use of less toxic solvents was preferred because the conservation studio lacked a solvent vapor extraction system. Consequently, removal of the varnish necessitated the use of solvent mixtures.

Before describing how these mixtures were designed and tested, though, let's review solvents and their activities.

SOLVENT RISKS TO SURFACE COATINGS: LEACHING AND OTHER ALTERATIONS

Studies have indicated certain risks to surface coatings, particularly to oil-based paint and varnish films, when exposed to solvents. Some materials are leached from the medium by solvents, leading to micro-voids inside the film (Feller, Stolow, and Jones, 1971; Masschelein-Kleiner, 1981; Michaelski, 1990; Erhardt & Tsang, 1990). This can occur not only in cleaning, but also during the application of varnish, when the drying varnish layer acts as a poultice (Tsang & Erhardt, 1992; Sutherland, 1998). Organic solvents can leach the non-cross-linking oil components of a linseed oil paint film. Certain electrolytes—having an ability to conduct electric current—and solvents that complex with the pigment's surface can detach the binder from pigment particles and even partially dissolve some inorganic pigments. Zinc white in oil films is particularly sensitive to water, and raw sienna films demonstrate loss of pigment when soaked in acetone and ethanol (Tsang & Erhardt, 1992). Water may disturb the paint *surface* more than isopropanol, acetone, toluene, or white spirit, particularly for medium-rich oil films containing burnt sienna (Hedley, *et al.*, 1990).

Evaporation of solvents leaves the surface of the leached film brittle, and the abrasive action of a cleaning swab can disrupt it and expose pigment particles. Similarly, swabbing the paint layer before the solvents have evaporated can disrupt the softened paint, likewise exposing the pigment. Any of these phenomena can result in a blanched appearance.



(from Torraca, 1975, and Thorn, 1992]

FIGURE 2 **Teas diagram of selected solvents.**

To control leaching from the paint film during cleaning, Stolow explains the need to "balance" the swelling power of a solvent and its rate of diffusion in the paint layer (Stolow, p. 106–107, in F, S, & J, 1971). Masschelein-Kleiner emphasizes the need to limit solvent penetration into the cracks and micro-voids, and to limit solvent retention (1981, p. 107–112). The use of relatively fast-evaporating solvents has often been recommended to limit exposure to solvents and minimize leaching (White and Roy, 1998).[3]

SWELLING POWER AND SOLUBILITY PARAMETERS

In predicting the solubility of polymers in organic solvents, it is useful to consider three principal forces as independent: dispersion forces, dipole interactions, and hydrogen bonding. Three-dimensional graphs of solubility data, with each axis representing one of these three forces, have been proposed (Crowley, Teague, & Lowe, 1966; Hansen, 1967). There is no dimension representing ionic interactions between molecules because most organic coatings are not ionic in character. Such three-dimensional graphs were simplified by the two-dimensional solubility triangle of Teas (Teas, 1968; see also Feller, chapter 3, in Feller, Stolow, & Jones, 1971; Toracca, 1978; Thorn 1992). Dispersion forces, located on the horizontal axis, are the weakest of all forces depicted, a fact not made clear by the equal attention given in the diagram to the other, stronger forces (*fig. 2*). Thus, the Teas diagram identifies the nature of the forces of interaction and their relative contribution to overall interaction between specific compounds, rather than the total magnitude of these forces (Ashland Chemical Co., 1984).

The solubility of organic coatings is determined empirically, and plotted on the graph as a solubility region. Teas solubility graphs for synthetic resins used by conservators have been published by Horie (1987). The usefulness of such graphs to conservators was perhaps best described by Mora, Mora, and Phillipot (1975). They plotted the solubility parameters of natural films traditionally used by artists: fresh linseed oil, as well as aged oils, proteins, polysaccharides, resins, and waxes on the Teas diagram. Other researchers have challenged the usefulness of the diagram. Hedley (1980), for instance, showed that Stolow's data on swelling roughly fit the two-dimensional Teas chart, but that a three-dimensional representation better accommodates data from a variety of sources. Michaelski (1990) proposed a three-dimensional graph to most accurately represent the paint swelling data. Molecular mobility is not considered in the diagram and may cause some of the anomalous behavior. Nonetheless, the (admittedly) overgeneralized Teas diagram remains interesting due to its relative simplicity, and the study of hundreds of resins has shown that the accuracy of solubility predictions is at least 90% by this method (Ashland Chemical Co., 1984).

Ionic chemical reactions, particularly in the presence of minute quantities of water, can affect the solubility parameters. Water is readily absorbed from the atmosphere by polar solvents such as ethanol and acetone, and dramatically affects solubility parameters. It has been found, for example, that the bole of water gilding is sensitive to acetone only because of the water typically in the acetone; when molecular sieves of 3 Å diameter are added to absorb the water, the bole is no longer sensitive to the acetone (Augerson, 1995).[4]

Teas explained that the solubility parameters of a mixture of two solvents would be located at a point between the two solvents on his graph, but he did not consider dilution ratios. In practice, dilution ratios based upon the volumetric proportions of the solvents are often closely approximate to those determined empirically. Estimating dilution ratios according to the volumetric proportions was proposed by Crowley, Teague, & Lowe (for examples, see Feller, 1968; Torraca, 1975, p. 50–51). Although predictions are not always accurate, this approach has been used with reasonable success, for example in the formulation of paint strippers (Barton, 1975; Archer, 1991). According to this approach, a 50% by volume mixture of acetone and isooctane would appear at the midpoint of the line between these two solvents on the diagram (point M1 on *fig. 3*). A 1:3 volumetric dilution of acetone to isooctane would appear on that same line, at a distance of one-fourth the length of the line, measured from the point representing the predominant isooctane (point M2 on *fig. 3*).

THEORETICAL APPROACHES TO LIMITING SOLVENT ACTIVITY

Use of a medium strength-solvent, diluted in a relatively weak solvent

A nineteenth-century practice was to begin cleaning with a medium-strength solvent such as ethanol, and then flush the surface with a weaker, "restrainer" solvent (Stolow, chapter 4, F, S, & J, 1971). The introduction of the stronger solvent, already diluted in a weaker solvent is a much safer approach. Ruhemann has used acetone, diluted in mineral spirits, for varnish removal (Ruhemann, 1968, p. 309–313). According to his principle of a "safety margin," he added more than enough mineral spirits than needed to ensure the "safety" of the paint. Masschelein-Kleiner has also suggested certain solvent mixtures for cleaning, the concentrations to be adjusted according to the effects. One mixture for the removal of resinous varnishes contains equal parts of isopropanol and isooctane. Another contains equal parts of toluene and isooctane. In designing such mixtures, the solubility parameters for the mixture should be taken into account (Masschelein-Kleiner, 1981, p. 108–122).

I applied a similar approach when treating an eighteenth-century German sculpture in the Saint Louis Art Museum, *St. Michael, Slaying the Devil*. Insects had damaged the wood, and a tar-like material covered much of the polychromy. Soluble in aromatic solvents such as xylenes, this material was probably creosote, applied to the sculpture to kill insects (Augerson, 1995). Some of it had been scraped off mechanically in a much earlier restoration attempt. Spots remained, with stripes of the paint showing through in adjacent mechanically-cleaned areas. Observation with a binocular microscope indicated that mechanical cleaning had damaged the surface and could do so again easily, making further mechanical cleaning impossible. I was able to remove this material using solvents less toxic than xylenes, a 1:1 mixture of acetone and isooctane (estimated to be at point M1 on the Teas diagram of *fig. 3*).

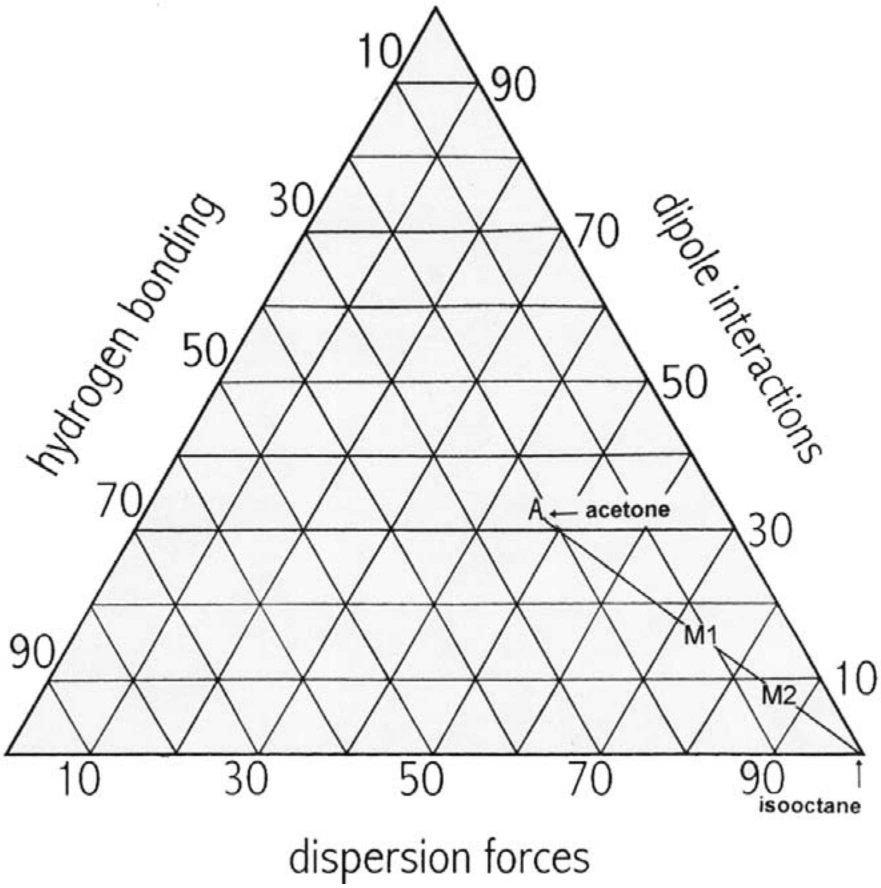


FIGURE 3 **Teas diagram of mixtures of acetone and isooctane.**

However, this cleaning had to be done with great care, and slowly, because one could not pass the solvent-soaked cotton swab over the same area many times without sensitizing some of the adjacent paint, particularly in the areas of the ruddier fleshtones. To avoid this, I passed the swab only a few times over an area, then let it dry for at least a half hour while moving on to other parts of the surface, before returning to pass again over the first area. The reason for my inability to pass more times over the same area was likely due to a progressive build-up of the stronger component, acetone. Isooctane and acetone both evaporate very quickly from the surface, but acetone diffuses more in the paint and penetrates more into the micro-fissures.[5] Using slower-evaporating mineral spirits (in the manner of Ruhemann) instead of isooctane might have reduced this inconvenience, but I chose to use the less toxic isooctane. Another alternative which might have worked is the use of an azeotropic solvent mixture.

The use of azeotropic mixture to control evaporation rates

An azeotropic mixture is a precise mixture of solvents having sufficient intermolecular forces between them that the mixture has a single boiling point (less than the boiling point of either component). The overwhelming advantage of using azeotropes is that the solvents evaporate together, rather than leaving behind a component of lower volatility. Masschelein-Kleiner recommends several azeotropic mixtures containing water, because a water component can be useful in cleaning, but the use of a component with such low volatility as water may be undesirable. (M.-K. 1981, p. 27, see also Hook, 1988; Wolbers, *et al.*, 1990). She recommends the following azeotropic mixtures involving water:

acetic acid (3%)+water (97%),
azeotropic boiling point: 76.6° C

acetone (88.5%)+water (11.5%),
azeotropic boiling point: 56.08° C

ethanol (68.0%)+water (32.0%),
azeotropic boiling point: 76.7° C

methylethylketone (88.0%)+water (12.0%),
azeotropic boiling point: 73.4° C

isopropanol (38.2%)+toluene (48.7%)+water (13.1%),
azeotropic boiling point: 76.3° C

In the paint industry, azeotropic mixtures have been proposed to retain precise control of solvent blend composition during paint evaporation while at the same time replacing solvents prohibited by air pollution laws (Ellis & Goff, 1972). I have tried replacing aromatic solvents and mineral spirits with azeotropic mixtures of less toxic solvents, for surface cleaning.

SOLVENT MIXTURES AS SUBSTITUTES FOR AROMATIC SOLVENTS

In the treatment of the sleigh *The Skaters,* removal of surface grime and a relatively recent, dark varnish were desired. The black surface grime was itself water-soluble, but a wax-resin consolidant had been applied over large areas of the surface, rendering the grime in those areas insoluble in water. It was possible to remove most of the excess consolidant with isooctane, but a thin film remained with encrusted grime. Both the wax-resin consolidant and most of the grime could be removed with toluene, but most of the underlying varnishes would also have been removed. Mineral spirits removed the consolidant without affecting the varnishes but left much of the grime. What was needed was a solvent mixture—preferably of lower toxicity than toluene or mineral spirits—which would remove both consolidant and grime without disturbing the decoration and its original varnishes.

I referred to tables of azeotropes (Kurtyka, 1992) for mixtures of solvents having low toxicity, and calculated their Teas solubility parameters based on volumetric proportions. Accordingly, an azeotropic mixture of 6% isopropanol in n-pentane (weight %) was predicted to behave like odorless thinner or petroleum naphtha containing very little aromatic content (point A1 in *fig. 4*) while evaporating very quickly. It successfully removed the wax-resin consolidant residues and all of the water-soluble surface grime from the sleigh, without disturbing the varnish layers. The mixture was predicted to have only very slight polar character, so how did it pick up the water-soluble grime so well? The isopropanol component is both a proton donor and a proton acceptor, and therefore forms hydrogen bonds with a variety of polar grime molecules. It is likely to be preferentially absorbed by the grime, aiding dissolution. Because isopropanol is an electron donor, having lone pairs of electrons on the oxygen atom, it can interact with grime particles by the formation of complexes. This tendency to complex is likely to be enhanced by its being very diluted in pentane, enabling the dissolution of the grime (Nakanishi and Asakura, 1977). Unlike most detergents, however, it evaporated from the surface and required no rinsing with additional solvents.

The next problem was removal of the shellac-based varnish that had been applied to hide scratches on the sleigh. Several azeotropic solvent mixtures, all having Teas solubility parameters predicted to be close to those of toluene, were tested on the shellac layer and on adjacent coatings. These mixtures are listed as follows, in the order of predicted hydrogen-bonding forces:

azeotrope A1
6.0% 2-propanol (isopropanol) in pentane (wt %)
or 4.8 % isopropanol (volume %), b.p.: 35.5° C

azeotrope A2
28.6% 2-butanone in hexane (wt %)
or 24.8% 2-butanone (vol %), b.p.: 64.2° C

azeotrope A3
34.0% pentanone in heptane (wt %)
or 30.2% pentanone (vol %), b.p.: 93.2° C

azeotrope A4
23.0% 2-propanol in hexane (wt %)
or 20.0% 2-propanol (vol %), b.p.: 62.7° C

azeotrope A5
40.0% 2-butanone in cyclohexane (wt %)
or 38.0% 2-butanone (vol %), b.p.: 71.8° C

azeotrope A6
39.9% ethyl acetate in hexane (wt %)
or 32.7% ethyl acetate (vol %), b.p.: 65.15° C

azeotrope A7
32.0% 2-propanol in cyclohexane (wt %)
or 31.8% isopropanol (vol%), b.p.: 69.4° C

The Teas solubility parameters predicted for these mixtures, as calculated by volumetric proportions, are indicated in figure 4. As purity of the solvents is important to assure an azeotropic mixture, HPLC grade solvents were used, except hexane, which was spectrophotometric grade (Sigma-Aldrich Chemical). The activity of these azeotropic mixtures on several coatings on the sleigh was compared to the activity of acetone and toluene. A comparison of activity was also made on coatings of another vehicle, the coach of the Dauphin, son of Marie-Antoinette and Louis XVI, also in the collection of The Coach Museum at Versailles.

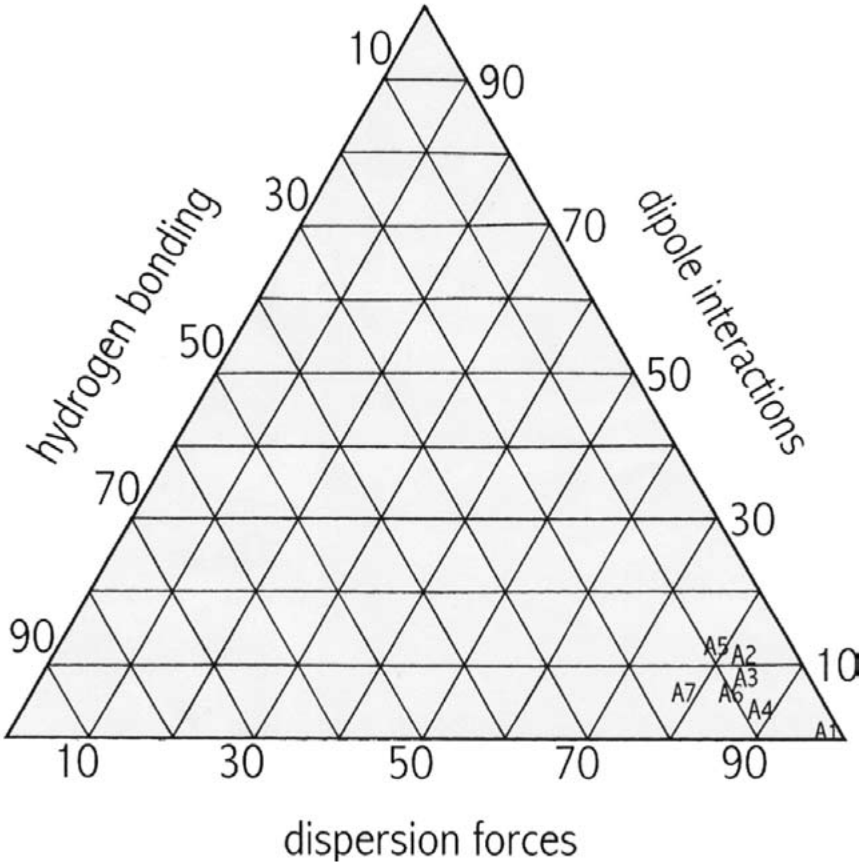


FIGURE 4 **Teas diagram of azeotropes tested.**

TABLE 1: ACTIVITIES OF THE AZEOTROPIC MIXTURES TESTED

Solvent activity is indicated as follows: i=insoluble, vss=very slightly soluble, ss=slightly soluble, s=soluble, vs=very soluble, b=blanching

	Azeotropic mixture, and its effects								
Surface Coating Tested	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**Acetone (control)**	**Toluene (control)**
Wax-resin consolidant (15% dammar in bleached beeswax) with impregnated, water-soluble grime, on the sleigh *The Skaters*	ss	s	s	s	vs	ss	vs	vs	vs
Shellac-based varnish on *The Skaters* camouflaging scratches.	i	i	s b	ss	s	vss	s	vs b	s b
Oil-resin varnish on the surface of the outer gilding on *The Skaters*	i	ss	ss	s b	ss/s	s	s/vs	vs b	i b
Oil-resin mordant of the outer gilding on *The Skaters*	i	s/vs	i	s	vs	s	s/vs	s/vs b	ss/vss
Linseed oil paint on the underside of the runners of *The Skaters* containing yellow ochre and lead-white pigments	i	ss/s	ss	ss/s	s	ss	ss/s	s b	i b
Oil-resin varnish on the surface of the painted scenes of *The Skaters*	i	s b	ss b	ss	ss	ss/s	s	s/vs b	ss
Oil-resin overpaint on the gilt springs of the coach of the Dauphin, containing yellow ochre and lead-white pigments.	i	s/vs	ss	vss	s	ss/s	vs	s/vs b	vss

FIGURE 5 **Cleaning of the painted right side of the sleigh. The shellac-based varnish has been removed from the central area. The scene depicts a skater pushing a lady in a different kind of sleigh, for use on ice. In the far distance is another skater.**

The composition of some of these coatings was characterized. In Table 1, the effects of the seven azeotropic mixtures on such coatings is summarized and compared to rhe effects of toluene and acetone. The azeotrope used for grime removal, A1, consistently had the least effect on the coatings tested. Most of the azeotropic mixtures had less effect than acetone on these surfaces, except the mixtures containing cyclohexane. These generally had more effect; perhaps the molecular mobility of cyclohexane enhanced their strength. The effect of the other azeotropes was too dependent on the substrate to be generalized. Azeotrope A6, for example, had a weak effect on oil paint but a strong effect on the shellac finish.

In removal of the shellac-based finish from the sleigh, it was important not to cut into the layers of varnish, paint and oil gilding below; hence control of the solvents used was more important than strength. Applying two of the azeotropic mixtures with cotton swabs offered the most control. Over painted surfaces, azeotrope A4, the mixture of 23% isopropanol in hexane, worked slowly enough, and well, without any blanching of the shellac-based varnish. The underlying oil-resin varnishes were also slightly soluble in this solvent mixture.

The next step of the treatment was to reduce the thickness of the more recently-applied, shellac-based varnish. This coating was not of uniform thickness and some areas had been missed entirely when it was initially applied. Where this layer was very thick—over most of the surface—it was first thinned with ethanol, carefully applied with cotton swabs. This resulted in a blanched surface after the ethanol evaporated. Thereafter the remainder of this coating was removed while leaving lower layers intact. Removal began next to the non-coated areas, using the 23% isopropanol in hexane mixture. Cleaning continued until the area being cleaned matched the color of the area which had originally been missed. Progressively larger areas of the sleigh's painted surface were cleaned, always stopping at the same point. No blanching to the resulting surface was observed, even in areas that had been blanched by ethanol cleaning (*fig. 5*).

For cleaning gilded areas, the azeotropic mixture had to be changed because it slightly solubilized the mordant of the most recently applied gilding, resulting in small areas of loss of the metal leaf. Again, areas where the shellac-based varnish had collected and was quite thick were first thinned, using ethanol applied with cotton swabs. Thereafter, the azeotropic mixture of 34% n-pentanone in 66% in heptane (azeotrope A3) was used to remove the dark shellac-based layer in a controlled manner, as it was slightly soluble in this mixture. As before, removal was continued until the opacity and darkness of the surface matched those areas where the shellac-based varnish had not been applied (*fig. 6*). While this azeotropic mixture had the advantage of not affecting the gilding's mordant, it did cause slight blanching of the oil-resin varnish on top of the metal leaf, which was very slightly soluble in this mixture. It should be noted that this gilding was of a later date than the painted scene of *The Skaters,* and the oil-based varnishes over them were not the same. The varnish on the painted scenes was slightly soluble in toluene, whereas that over the gilding was not.

When the later-applied, dark shellac-based varnish was apparently all removed, the remaining varnishes on the sleigh still appeared somewhat dark. For both archaeological and aesthetic reasons, their complete removal was not desirable. First, the varnishes of vehicles in the eighteenth and nineteenth centuries, like the paints of automobiles today, represented high-technology waterproofing systems, whose presence on a historical artifact has great archaeological importance. Second, to the great regret of carriage painters (Watin, 1778, p.238, 262–263) the oil-resin varnishes of carriages and sleighs were initially darker than other varnishes such as those used on furniture, and so to remove them entirely would not approximate the original appearance of the paint or gilding.

Consequently, the early varnishes on the sleigh were not removed, but were judiciously reduced in thickness, to a point that aesthetically appeared reasonable. This thinning was done using the same solvents used to slowly remove the dark shellac-based varnish. On the painted areas, the mixture of 23% isopropanol in hexane was employed; over gilding the mixture of 34% n-pentanone in heptane was used. Thus, the painted scenes of figures skating could be better read, and the metal leaf appeared more brilliant, but neither lost a certain patina of thin varnish. This gave a pleasing, warm tone to the piece and rendered the metal leaf, a gold-silver alloy, more golden in appearance (*figs. 6 & 7*). The solvents used over the gilding caused very slight blanching, but it was evident that cleaning of these areas was not possible without at least a small degree of blanching (toluene also caused very slight blanching, although it did not remove the varnish). With the application of a protective varnish of a 7% solution of Paraloid B 72 (Rohm & Haas) in toluene to the gilded areas, the blanching was no longer visible.

This protective varnish could not be applied to the painted scenes on the sides of the sleigh, because the early varnish there was slightly soluble in toluene. This was not as a result of the cleaning solvents applied during treatment. An untreated area where the shellac had not been applied appeared similarly sensitive to toluene, and five months after cleaning (when all solvents had presumably evaporated), areas of the cleaned surface were still slightly soluble in toluene. I decided not to apply any protective varnish at all on this area, as it seemed unnecessary at this time, particularly since the solvent mixture caused absolutely no blanching of the surface.

It is important to note that even the least active of the azeotropic mixtures used was a strong solvent for relatively fresh overpaint, apparently of unpolymerized oil, found on figures of a crèche from a church in Belleville, Illinois. Also, some carriage paints may remain easily removable in toluene and remain sensitive to even the weakest of these azeotropes, even after very long aging. This is the case of a green paint on the undercarriage on the coach of the Dauphin. Believed to be early in date, this paint contains primarily orpiment and Prussian blue pigments in an oil-resin binder. Preliminary tests (of solubility and GC-MS) indicate that it may contain a copal resin (Augerson, *et al.*, 2000).

FIGURE 6 Cleaning of a gilt runner of the sleigh. Region 1, grime cleaned using azeotrope A1; region 2, shellac-based varnish removed using ethanol, followed by azeotrope A3; region 3, early oil-resin varnish thinned using azeotrope A3.

FIGURE 7 Detail, during cleaning. Prior to the painting of the scenes of skaters, the sleigh was referred to (in the Royal and Imperial inventories) as *The Dragon* for this carved decoration at the front.

CONCLUSION

Azeotropic mixtures can be useful to control the evaporation of a relatively strong solvent diluted in a relatively weak solvent, which helps control overall solvent activity. These can be designed by the following procedure:

1. Determining with single solvents or Teas diagrams for the substrate the areas of solubility of the materials to be removed, and the areas of sensitivity of underlying layers.

2. Determining from the Teas diagram what solvent mixtures will do the job, keeping in mind individual solvent toxicity levels (Thorn, 1992), individual solvent characteristics (Masschelein-Kleiner, 1981) and the sensitivities of the underlying layers.

3. Finding from tables of azeotropes (Horsley, 1973; Kurtyka, 1992) those mixtures predicted to be in the desired region of the Teas diagram (converting proportions by weight to volumetric dilution ratios, and plotting them on the graph).

4. Testing the azeotropic solvent mixtures on the layer to be removed and on the layers underneath.

With testing and caution, certain mixtures of relatively less toxic solvents can sometimes be used to replace aromatic solvents and mineral spirits containing aromatic components, as demonstrated in the cleaning of the sleigh *The Skaters*.

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About the Author

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NOTES

1. The conservator often prefers adhesives or varnishes in *solution* – a homogenous mixture of particles in solvent, dispersed so finely that it appears clear. This *solvation* is dependent on concentration. For convenience, some studies have defined a polymer solute as "soluble" in a given solvent if it yields an homogenous, single-phased solution at room temperature (or 25° C) and at a polymer concentration of 10% by weight (Feller, in F, S, & J, p. 34; de la Rie, 1993). In solvent cleaning, the conservator is concerned instead with "removability." Coatings may not be "soluble" in a given solvent, but may still be "removable" if they form a gel or a colloidal dispersion when cleaning with solvents applied to cotton swabs. Although it may perpetuate a misnomer, the term "soluble" is used in the presentation of data in Table 1, following the convention of most conservators, rather than the technically correct term "removable."

2. The analysis of the polychromy (DeMailly, Augerson, Hugon and Nowik, 1998) will be discussed in much greater depth in future publications. Four different techniques for the application of metal leaf divide the seven restorations into four époques. Every 30 or so years, Royal and Imperial inventories of the collection gave descriptions of the sleigh's decoration that can be correlated with the microscopic examination of cross sections.

3. Masschelein-Kleiner noted, however, that if a solvent is too fast-evaporating, its use might cause blanching. Depending on ambient relative humidity, the cooling of the surface with rapid solvent evaporation can cause moisture condensation on the surface, followed by blanching. This might explain the blanching sometimes observed during cleaning with acetone, which has a very fast initial phase of evaporation. To avoid this phenomenon, Masschelein-Kleiner prefers using methylethylketone (1981, p. 111–113).

4. The pores of the molecular sieves admit water molecules, which adhere to and collect on interior surfaces. (Manchanda, 1973). Placed in your working solvent jar, they should be changed for fresh ones once they've absorbed a maximum amount of water. I usually place about 30 mg of molecular sieves in about 100 ml of solvent (in a jar of about 140 cc volume). I keep the lid covered when not dipping with my cotton swab, and usually change the molecular sieves after about 12 hours of use (of repeated dipping into the jar with swabs). I take care to keep the level of solvent above the level of the molecular sieves in the bottom of the jar, so they absorb water from the solvent (and not from the air above the solvent level in the jar). The molecular sieves can be "recycled" by driving off the water in an oven at a temperature greater than 100° C (let the organic solvents evaporate from the sieves before placing them in the oven).

5. In the tests of Masschelein-Kleiner (1981, p. 31–38), involving the application of pure solvents to a varnished paint surface, after six minutes of evaporation, less than one per cent of the isooctane remained, whereas 5% of the acetone remained and was slow to leave.