RESEARCH INTO NON-TRADITIONAL
GILDING TECHNIQUES AS A SUBSTITUTE
FOR TRADITIONAL MATTE WATER-GILDING

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To my wonderful Sons,
Mark and Daniel,
who have supported me in the most difficult time,
and who have been, and always will be
my best inspiration.
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Statement of Authentication

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material for a degree at this or any other institution.

............................................................

(Signature)
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## ABBREVIATIONS

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<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>BCIN</td>
<td>The Bibliographic Database of the Conservation Information Network</td>
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<tr>
<td>C</td>
<td>Temperature in Celsius</td>
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<td>CCI</td>
<td>Canadian Conservation Institute</td>
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<tr>
<td>DEB</td>
<td>Diethylbenzene</td>
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<tr>
<td>D/I</td>
<td>Distinctiveness of gloss</td>
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<tr>
<td>EA</td>
<td>Ethyl acrylate</td>
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<tr>
<td>EMA</td>
<td>Ethyl methacrylate</td>
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<tr>
<td>FTIR</td>
<td>Fourier transform infrared spectroscopy</td>
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<tr>
<td>fd</td>
<td>Dispersion force (fractional parameter in the Teas graph)</td>
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<td>fh</td>
<td>Hydrogen bonding force (fractional parameter in the Teas graph)</td>
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<td>fp</td>
<td>Polar force (fractional parameter in the Teas graph)</td>
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<td>h</td>
<td>Hour</td>
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<td>IIC</td>
<td>International Institute for Conservation</td>
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<tr>
<td>MMA</td>
<td>Methyl methacrylate</td>
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<tr>
<td>MCIN</td>
<td>Conservation Information Network – Materials Database</td>
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<tr>
<td>PEOX</td>
<td>Poly(2-Ethyl-2-Oxazoline)</td>
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<tr>
<td>PEA</td>
<td>Poly(ethyl acrylate)</td>
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**pH** A measure of the acidity or alkalinity of a solution

**PMA** Poly(methacrylate)

**PVAC AYAA** Polyvinyl acetate resin AYAA

**PVAC AYAF** Polyvinyl acetate resin AYAF

**PVAC AYAC** Polyvinyl acetate resin AYAC

**PVAC AYAT** Polyvinyl acetate resin AYAT

**PVAC** Poly(vinyl acetate) resin

**PVC** Pigment Volume Concentration

**Rh** Relative humidity

**RSG** Rabbit Skin Glue

**Tg** Glass transition temperature

**w/w** Weight by weight

**w/v** Weight by volume
This thesis examines the current practice of using traditional gilding techniques for compensation of losses in gilded objects and the problems that these traditional techniques generate for conservators undertaking visual examination and technical separation of such new in-gilding from original substrates. Although, non-traditional gilding materials and techniques have been available as alternatives since the 1980s, research has, until now, been required in order to determine the working properties of such synthetic materials under the demands made of them in gilding conservation. The research presented here aims to determine which polymers are sufficiently stable and reversible to successfully compensate original matte water gilded surfaces, thereby meeting the professional standards and conservation principles required by the conservation profession. The work involved methodical assessment of several stable synthetic materials used successfully in other conservation fields. Experiments undertaken as part of the study indicate that of the numerous synthetic polymer materials available to conservators, acrylic dispersion Plextol®B500, acrylic resin Paraloid®B-72 diluted in aromatic solvents, and polyvinyl acetate resin AYAF are the potentially the most useful.

In the second stage of the research, the optimum concentrations of the solutions and the methods for activating the dried films were elucidated. Experiments showed that if applied using appropriate methods, all three synthetic polymers selected can be successfully used for compensation of losses in matte water gilding. Nevertheless, of the materials currently available to conservators, Plextol®B500 applied as an acrylic dispersion was shown to be the most versatile polymer available in terms of its activation and provided best surfaces for the application of gold leaf.
The final sections of this work concerned testing of the aging behaviour of surfaces formed using the three selected synthetic materials, and comparing them with the aging characteristics of gilding using the traditional method. Results of measurements made using specially prepared frames exposed to extreme variations in humidity for twelve months in two different environments revealed no significant differences between the visual characteristics of gilding either visual appearance of the non-traditional and traditional gilding. These final tests demonstrated conclusively, for the first time, that synthetic materials may be used successfully in compensation of losses in matte water gilded surfaces.


1.0 INTRODUCTION

The main aim of restoring or conserving a work of art is to stabilise its condition so that it may be appreciated for many generations to come. In order to achieve this goal, conservators are expected to abide by the principles of ethical behaviour accepted by professional conservation organisations around the world including Australia. These professional bodies demand that all actions by those involved in the conservation of cultural material ‘must be governed by an unswerving respect for the physical, historic and aesthetic integrity of the object’ (AICCM, 1986). If any restoration is required, therefore, treatment should be limited to well documented areas and to ‘the minimum extent necessary’ to re-establish the cultural values of an object (AICCM, 1986). In order to meet these strictures, the conservator is thereby obliged ‘to use techniques, which affect the object least, and materials, which can be most easily and completely removed without hazard to any original part.’ (AICCM, 1986). Despite these guiding principles, the concept of reversibility is associated with continuing controversy, with varying views expressed as to whether, in the interests of preservation, the survival of the object should take precedence over questions of reversibility and whether any intervention or conservation treatment can truly be reversible. In general practice, therefore, a conservator strives to make all feasible attempts to ensure that the methods used in any conservation process are reversible and the materials selected for this treatment can be easily removed from the object, if required.

In contrast to general conservation practice, in which modern synthetic materials are preferred for their predictable mechanical properties, in the field of gilded objects conservation treatments are usually still carried out using traditional materials and methods. This practice, however, renders the entire conservation process difficult to reverse without damaging the original substrate. In simple terms, it is probable that the original gilding will respond to the same solvents as the materials used in conservation treatments and therefore, in most cases, the
division between the restored and the original surfaces is difficult to define. Consequently reversal of conserved areas of gilding carries the risk of causing further damage to original layers. Even if conservation treatments were carried out in agreement with the minimum intervention policy, the current practice of using traditional materials and methods for the conservation of degraded gilded surfaces would seem to contravene the principle ethical requirement of reversibility mentioned above. If therefore, suitable synthetic replacements for traditional gilding materials and techniques can be identified, they would seem to be preferable for preserving the integrity of surviving portions of many valuable gilded surfaces.

Non-traditional gilding techniques were introduced into the field of gilded objects conservation as an alternative to traditional methods in the 1980s. Nevertheless, despite the obvious benefits of such synthetic materials in terms of their traceability and the claims made for their reversibility, the employment of such materials still meets great resistance from conservators. The arguments against the use of synthetic polymers within gilded object conservation constitutes an extreme instance of a continuing general controversy associated with the use of synthetic polymers within conservation in general. In the absence of exhaustive research regarding the unknown long-term impact of any treatments using synthetic polymers, many conservators rightly feel uneasy employing such materials for the conservation of valuable and historically significant objects. In the case of gilded object conservation, prior to the current study little research has been done in the field of non-traditional in-gilding techniques and only a few papers have been published on this subject. In such circumstances, conservators lack the technical information required to make informed decisions regarding the conservation of gilded objects and in this light their conservatism is entirely understandable. Some conservators have, however, taken the arguments against synthetic materials still further and opined that non-traditional restorations do not match the effects and properties of traditional materials. Therefore, although the restored areas are to the trained eye readily identifiable, they are said also to create an unpleasant ‘plastic’ appearance of gilded surfaces that if extended over large
areas would be visually incompatible with the original (Schmuecker, 2002).

Despite objections, the replacement of traditional materials with suitable, traceable, synthetic alternatives remains a worthwhile goal. Indeed, growing recognition of this fact has led some conservators to attempt to use synthetic polymers to compensate for losses within traditional gilded surfaces, particularly where those polymers that are generally recognised by conservators as stable and they are extensively used in other conservation fields. In this regard, Thornton’s (1991) reports of the successful use of Paraloid®B72 acrylic copolymer¹ for burnished gilding, the acrylic emulsions Rhoplex®AC33² and N580³ for oil gilding and acrylic emulsions, Hyplar®⁴ and Liquitex®⁵ for high-gloss gilding, are particularly significant. The same researcher observed that losses in aged burnished water gilded surfaces can either be in-gilded by laying gold leaf on an already polished surface or else by using bole foundation compound with a synthetic binder such as polyvinyl alcohol (Thornton, 1991).

Of all the traditionally gilded surfaces, losses of matte water gilded surfaces have proved the most difficult to compensate using non-traditional techniques and materials. Most acrylic emulsions or resins furnish the surface with a glossy appearance. Some success has however, been noted using acrylic emulsions, such

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¹ Paraloid®B-72 is a copolymer of ethyl methacrylate and methyl acrylate (70:30). It is one of the most stable thermoplastic resins used in conservation for a variety of aims including picture varnish, consolidant for matte paint, oil paintings and wall paintings, in-painting medium, consolidant for wood, plaster, stone, and ethnographic objects, adhesive for ceramic and glass, fixative for pencil, charcoal, and chalk drawing and pastels (Samset, 1998).
² Rhoplex®AC-33 is an acrylic dispersion based on a copolymer of ethylacrylate (EA) and methylacrylate (MA), with 1% of acrylic acid, at the 42% solid contents concentration (De Witte, Florquin, and Goessens-Landrie, 1984; Stringari and Pratt, 1993). It has been used as an adhesive and consolidant in the conservation of wallpaper, bone and ivory artefacts, as well as in the treatment of polychrome wooden objects, and ethnographic objects.
³ Rhoplex® N-580 is an acrylic dispersion based on n-butylacrylate homopolymer at 54-56 % (w/w) solid contents concentration (MCIN). Rhoplex N-580 has been used as an adhesive and consolidant in textile and wallpaper conservation.
⁴ Hyplar® is an acrylic dispersion manufactured by M.Grumbacher, Inc., New York, N.Y. It is used by calligraphers for producing raised, burnished gold letters and has been recommended in conservation of gilded surfaces for in-gilding losses in high gloss gilding (Thornton, J., 1991).
⁵ Liquitex® is an acrylic dispersion based on the copolymer of ethylacrylate, methyl methacrylate, and ethylmethacrylate, at 38% solid content concentration (Thornton, J., 1996)
as Liquitex® Matte Acrylic Medium and Liquitex® Matte Acrylic Varnish laid down on a foundation of matte varnishes and mediums based on acrylic resins that can be solved in mineral spirits (Moyer & Hanlon, 1996, Sawicki, 2001). In order to achieve the matte coating required, coatings were applied over the gesso, left to dry and then gold leaf was applied to the surface that had previously been activated by exhalation. Although experiments showed that in the period following treatment all of the materials applied could be easily removed with acetone or xylene without damaging the original surface, serious questions regarding the long-term aging properties of Liquitex® materials remain. Despite assurances from the manufacturers regarding the mechanical properties and ultraviolet resistance of Liquitex® products, reports within the conservation literature have noted that that discolouration of Liquitex® Acrylic Matte Medium occurs over a relatively brief period of time under ambient environmental conditions of temperature, relative humidity, and light. Research has shown that these undesirable changes are the result of a detrimental chemical reaction between the support and the polymer media (Hamm, Gavett, Golden, Hayes, Kelly, Messinger, Contompasis, Suffield, 1991). In addition, changes in the appearance and in the chemical and mechanical properties of films of Liquitex® Acrylic Gloss Medium have been studied during natural aging in the dark and in accelerated thermal and light exposure tests by Withmore and Colaluca (1995). The tests showed that even under dark storage conditions, films of Liquitex® acquire a haze and slight yellow discolouration within a few weeks whilst the tensile properties of the Liquitex® films only stabilise after approximately 50 days following formation. Finally, at room temperature, it has been shown that these polymer films tend to slowly cross-link with the result that the degraded films are only partially soluble in benzene and butanone, with the attendant OH&S difficulties associated with handling and storing these dangerous materials. It is worth noting, however, that Liquitex® Acrylic Gloss Medium also shows very high resistance to photochemical degradation under near-ultraviolet light, at least in the short and medium term. Nevertheless, prolonged exposure to near-ultraviolet light has been shown to cause very slow scission and oxidation of the polymer, which is responsible for a gradual increase in solubility and hardness of the film. It has
been noted that severely degraded of Liquutex® films are prone to sudden losses of tensile strength (Withmore and Colaluca, 1995).

In the view of the current state of our knowledge on non-traditional gilding techniques, it is evident that further research and methodical tests are required in order to investigate the most stable materials and techniques that can be used to compensate losses in gilded surfaces. This project aims to fill a significant gap in studies on non-traditional in-gilding techniques related to matte water gilding. Although matte water gilded surfaces are present on many gilded decorative art objects, they are a particular characteristic feature of backgrounds within medieval paintings on wooden supports, icons, and flat undecorated mouldings and slips in frames. It is also noteworthy that in England and Australia, many 19th century watercolour frames often contained a distinctive broad inner slip gilded using the matte water gilding technique. The research presented here aimed to select stable synthetic polymers that are used successfully in other conservation fields and to outline reversible methods of application that are suitable to compensate original matte water gilded surfaces and at the same time, meet the standards and principles of the conservation professions.

Chapter two provides a brief overview of current practices in loss compensation for the conservation of gilded surfaces. The chapter thereby establishes the background for the research. Chapter three presents the results of Stage I of the research, which involved methodical testing of several synthetic materials in their suitability as a base for gilding. The selections of appropriate materials were made on the basis of the available technical information and the conservation literature assuming that the application of gold leaf should change neither the properties of polymers nor their aging characteristics. The chapter provides details of the methodologies established for the selection procedures, descriptions of experiments and a discussion of the results achieved.

The materials determined to be the most successful in terms of their application were tested further in the Stage II of the research in regards to their variations
in the concentration of resin solutions, selection of the most appropriate solvents for both the resin and an activation of dry films, and resin activation methods. Chapter four presents and discusses these results further in terms of both test sample materials and also case studies involving conservation of several gilded frames.

The final chapter describes *Stage III* of the experiments involving long-term age-testing of the behaviour of the gilded surfaces formed using non-traditional materials. Although the accelerated aging tests do not imitate natural aging conditions exactly (see: Chapter 5.1), they do give an indication of the tested material’s resistance relative to traditional materials. The tests analyse changes in visual appearance of gilded surfaces caused by extreme humidity fluctuations or humidity/temperature changes due to day/night cycles.

It is hoped that by conducting such a comprehensive study of non-traditional gilding techniques conservators might attain greater confidence in the working properties of these materials and methods and will be provided with reliable results and data which, in future, will assist them in making appropriate conservation decisions.
2.0  COMPENSATION OF LOSSES ON GILDED SURFACES:
REVIEW OF CURRENT METHODS AND PRACTICES

Despite the greater care accorded to the treatment of gilded objects within museum collections, adherence to the precepts of reversibility, particularly in regards to retouching, is often questionable. Whilst this summary is not intended to present an exhaustive report on current methods of compensation of losses in gilded surfaces, it provides an overview of present techniques thereby establishing a background for the research with respect to current policies and theories on this subject. The Bibliographic Database of the Conservation Information Network (BCIN) and the Research Resources of the Getty Conservation Institute list over thirteen hundred papers written in various languages associated with gilding on varied backgrounds, approximately one third of which relate to gilding on wood. Many papers regarding gilded objects restoration focus on issues of traditional materials and techniques and their application. In contrast, little consideration is given to modern alternatives. For the purposes of the current research, although these sources have been consulted, the bibliographic references have been restricted to the most relevant professional publications written since 1985. As shown below, a review of the literature reveals the criteria for success or failure of treatments of gilded surfaces are not necessarily as clear–cut or objective as one might imagine from a purely scientific perspective.
2.1. Description of the traditional matte water-gilding technique

Traditional water gilding (matte and burnished) requires a substrate of a smooth gesso and bole. Traditionally gesso is generally made of either unslaked or slaked gypsum (calcium sulphate), although many Northern European artisans often preferred chalk (calcium carbonate), or used a mixture of both fillers. The dried gesso foundation is sanded until the surface reaches smoothness reminiscent of silk. This prepared surface is then coated either with a weak solution of gelatine, glue, or glair\(^6\), or with a weak solution of yellow bole with such binder. Several layers of bole of creamy consistency are then applied in order to build up a smooth opaque foundation.

Bole is natural clay characterised by its high iron oxide content, mixed with proteinaceous binder. Depending on the concentrations of various added constituent minerals, the colour of bole employed in gilding can vary from white (kaolin, hydrated aluminium silicate, \(\text{Al}_2\text{Si}_2\text{O}_3(\text{OH})_4\)), yellow (yellow ochre, Limonite, from \(\text{Fe}_2\text{O}_3\times 4\text{H}_2\text{O}\), an almost lemony yellow, to \(\text{Fe}_2\text{O}_3\times \text{H}_2\text{O}\), closer to brown-yellow), red (red ochre, Haematite, \(\text{Fe}_2\text{O}_3\)) or black (carbon, C). In the Middle Ages and during the Renaissance other colours were also be used such as blue (azurite, basic copper carbonate, \(\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2\)), and green (green earth, Terra Verde, hydrosilicates of Fe, Mg, Al, K) (Hassal, Sheldon, 1994). An explosion of varied background colours in gilded objects occurred in the 18th century. By contrast, slips (flats) in 19th century gilded frames were usually composed of a characteristic brown background made of a mixture of red and black bole.

Original binding materials used in bole layers consist of either animal glues (parchment size, gelatine, later rabbit skin glue) or glair made of egg white. The

\(^{6}\) Glair is made of a bitten egg white mixed with water.
dried bole foundation is wetted with ‘gilders water’ in order to ‘activate’ the proteinaceous binder. Following ‘activation’, gold leaf is laid down immediately on the wetted surface. The addition of ethanol to the ‘gilders water’ reduces the surface tension and allows gold leaf to be ‘sucked down’ on to the surface. A small amount of weak gelatine solution (or other binder) in the ‘gilders water’ helps with adhesion of gold leaf to the substrate.

Gold leaf laid down on the gesso and bole foundation may either be burnished or else left matte. Solid gilded surface, whether burnished or matte, has usually required double gilding, but particularly, modern sheets of gold leaf have many more imperfections (small pinholes), and therefore two layers are required in order to achieve a surface with the proper colour and sense of substance (Leonard, 2003). Once the first layer of gold leaf is dry, the second leaf is applied in a similar manner. When the both completed gilded layers are dry, the surface is usually protected with a layer of ‘ormolu’\(^7\), a weak solution of animal glue with the addition of up to 10\% of diluted seedlac or shellac, which complements the distinctive deep matte appearance of the gilded surface.

In-gilding conservation, treatments employing traditional techniques are fully compatible with original surfaces. A skilled conservator can blend-in the in-gilded

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\(^7\) There is some confusion in understanding the term ‘ormolu’.

According to the Encyclopaedia Britannica, this term comes from French dorure d’or moulu: “gilding with gold paste”, and is a gold coloured alloy of copper, zinc, and sometimes tin, in various proportions but usually containing at least 50 percent copper. Ormolu is used in mounts (ornaments on borders, edges, and as angle guards) for furniture, and for other decorative purposes. The earliest ormolu was produced in France in the mid-seventeenth century, (Encyclopaedia Britannica, Inc, (1996) CD-ROM). In old manuals, with reference to frames, the term describes diluted seed-lac coloured with gamboge and dragon’s blood, (F. Scott-Mitchell, 1905), or a mixture of diluted seed-lac with the addition of parchment size, which was a traditional coating for matte gilding, (1876, The Gilder’s Manual). Malcolm Green (1979) described ormolu as seed-lac diluted in pure alcohol. According to Professor Jonathan Thornton (1996), ormolu is the traditional coating over the un-burnished matte water gilt flats and nowadays is prepared as a mixture of one part diluted seed-lac and four parts diluted rabbit skin glue, rather than parchment size. In this paper, by the term ‘proteinaceous ormolu’ I refer to coatings consisting of a mixture of seed-lac and animal glue.
section, thereby rendering the restored area unnoticeable. As noted earlier, however, the very success of the technique in terms of its invisibility makes it very difficult to identify and remove without causing damage to the original substrate.

2.2. Ethical Considerations from the Historical Perspective

From the conservator’s point of view, ‘retouching’ is a matter of aesthetic presentation for a work of art. As such, it neither prolongs the life span of an object nor contributes to its preservation. As Wendy Samet (1998) noted, retouching is the most visible and from a perspective outside of the profession, the most comprehensible and yet also most criticised aspect of a conservator’s work. It is of little wonder therefore, that the concept of retouching figures so prominently within ongoing discussions and periodic reviews of conservation policies and practices.

The problem of what constitutes moral, ethical practice and success in terms of treatment within conservation is a vexed one, particularly when one considers how much it has changed through time. In terms of current conservation ethics, it is little exaggeration to state that the restoration treatments by Giuseppe Molteni, 19th century restorer from Milan who corrected ‘naive inaccuracies of the Old Masters’ (Bomford, 1994) in several paintings from the National Gallery, London, would be considered as acts of barbarism. In line with 19th century philosophical aesthetic ideals and following then current conservation practice, Molteni ‘successfully’ removed original parts from paintings and repainted them to his discretion, as he deemed appropriate. Despite the fact that the alterations were well documented by Molteni, and the materials used for retouching were reversible, in 21st century terms the integrity of the paintings was altered beyond repair and from a historical perspective the paintings were ruined. Fortunately,
over the following hundred years, conservation techniques and practices have changed considerably. By the 1920’s, art historians had adopted an entirely different concept of the integrity of an art object under which the ‘natural’ marks of the passage of time were viewed as an intrinsic component of the object’s cultural history and worth. From this perspective, any retouching or attempt to hide damage:

‘was unacceptable intrusion into a painter’s work, however damaged it was.’
(Bomford, 1994).

The Romantic belief held by some scholars that a work of art should be presented in its pure and authentic form, was still current in some parts of the world up to beginning of the 1970s. Using this practice, conservators stripped artworks of all, mostly 19th century, restorations, exposing all losses, abrasions and flaking, even if in doing so this sometimes caused irreparable damage to the unprotected surfaces (Aronson, 2003). The middle of the last century, however, saw a further shift in conservation practice towards a policy that condoned visible retouching with uniform colours. This movement, which led to the development of the \textit{tratteggio} retouching technique (Bomford, 1994), was based on Brandi’s theory that:

‘losses in painting are disturbing because they have a tendency to form a pattern for which the work of art becomes merely a ground, and as such, they destroy the integral aesthetic unity.’ (Samet, 1998)

The \textit{tratteggio} technique of in-painting aimed to minimise losses and restore unity to the surface. It consisted of a system of lines in three different colours devised to remain unnoticeable from a normal viewing distance but distinct at close range. It was formulated on the idea that three dominant tones from the painting, applied with small strokes in the correct proportions, can create a neutral colour that blends perfectly with the painting (Samet, 1998). \textit{Tratteggio} was followed by \textit{chromatic selection} and \textit{chromatic abstraction}, developed by Umberto
Baldini and described in his two volumes of the *Theory of Restoration* in 1978 and 1981 (Ciatti, 2003). *Chromatic selection* involved hatched-line integration involved the application of pure colours based on adjacent painted areas, still following the lines of the specific form on the painting. *Chromatic abstraction* on the other hand, consisted of a cross-hatched layer applied in four colours derived from the additive synthesis of colours (yellow, red, green, and black). In contrast to chromatic selection, this layer did not reconstruct any of the form (Ciatti, 2003). Although developed for painting surfaces, a variation of this technique called *gold selection* was developed by Baldini for the compensation of losses in gilding (Nicolaus, 1999). By means of three colours, yellow, red and green, applied with thin strokes, losses in the gilded surface were to blend into the original gilding.

In spite of the enthusiasm, with which the technique was greeted, by the 1980's one of the developers of the chromatic abstraction technique, Ornella Casazza, was later forced to admit that the technique had not been entirely successful (Samet, 1998). Furthermore, Marco Chatti (2003) acknowledged that the restoration of the Maesta of the Maestro di Citta di Castello, in the Pinacoteca Civica, originally said to have been completed in 1988 according to Baldini’s methodology of *chromatic selection* and *chromatic abstraction*, in fact required the integration of losses in the gold-leaf background using shell gold or powdered gold in order

‘to obtain the same degree of light refraction and to avoid any opacity of the integrated areas resulting from the imperfect reflection of light on the painting’s surface.’ (Ciatti, 2003)

The method is exemplified best in the 1997 restoration of the *Madonna and Christ Child* polyptych attributed to Segna di Bonaventura in the Montalcino Museum, where losses in gilded surfaces were first covered with powdered gold, followed by a light and transparent gold colour selection (Ciatti, 2003).
By the end of the 1990’s widespread dissatisfaction with then current conservation practice led Wendy Samet (1998) to state that the assumption that any technique will produce uniform, unprejudiced and even impersonal reconstructions based solely on the objectivity imposed by the technique has good intentions, but is in her opinion, naive. Samet expressed serious doubts whether the imposition of a rigorous, technical process such as trattegio could ever filter out the conservator’s personality any more effectively than an effort by that conservator to exactly match the original surrounding paint. Samet concurred with Paul Philippot’s view that the judgment and sensitivity of the restorer are critical to any successful reconstruction and that despite any inherent problems:

‘Critical interpretation clearly cannot be limited to verbal judgment; it must take shape in the concrete act, the execution of the retouching, and must be realised according to the imaginary plan in which one intuitively reconstructs the form. This is where restoration is essentially a work of art requiring practical cultivation of the visual imagination. Despite its critical nature, it cannot, in the final analysis, be divided between pure intellectual decision and pure technical execution. This where the peril, the drama of the restorer, is revealed.’ (Samet, 1998)

Philippot also stated however, that in future the intuitive reconstitutions should remain essentially objective, suppressing as much of the practitioner’s personality as possible (Samet, 1998).

A similar viewpoint was expressed by Dianne Dwyer Modestini (2003) who does not see in imitative retouching any contradiction to Brandi’s second principle allowing for:

‘the reestablishment of the potential unity of a work of art as long as this is possible without producing an artistic or historical forgery and without erasing
Applying this theory to the conservation of gilded objects, it becomes obvious that gilding reintegration involving traditional techniques contradicts basic ethical principals inasmuch as they will produce a surface indistinguishable from the original that will henceforward be difficult to separate. In addition, a practice of regilding of the entire surfaces, although these days more common in the private studios than in the museum environment, will remove or destroy the historical integrity and original interpretation of a gilded object in the same way as repainting does for a painting or decorative art item.

Modestini stated that imitative restoration has developed mischievous fame not from careful reconstructions but

> ‘from wholesale repainting with resulting personal reinterpretation, often deliberate falsification, designed to upgrade attributions and conceal the ruins that some dealers, famously Duveen, offered to their unwitting clients.’

(Modestini, 2003)

In recent years, although the concept of retouching continues to be discussed within the scholarly literature, nevertheless trends continue to revert towards more or less deceptive reconstructions. In contrast to earlier eras, however, greater importance is now placed on accepting fundamental principles regarding the reversibility of materials used, distinguishing them from the original substance, and to limiting retouching to areas of damage. As noted by Samet, however, in English-speaking countries and most of the rest of Europe, invisible in-painting, or in-painting that seeks to visually restore losses as closely as possible to original has become a normal practice. Indeed, the ability to do so has become a measure of a practitioner’s competence and excellence. In defining what is original and what is not, a conservator relies on ‘before-compensation’ photographs and ultraviolet light examination to detect in-painting and to identify excessive
retouching not confined to areas of lost paint (Samet, 1998).

Changes in ethical considerations regarding conservation methods are not limited to the retouching of paintings and serve to highlight the sometimes divergent opinions on restoration related to other objects. As noted by Michael Gregory (1991), during the restoration of frames nineteenth-century craftsman saw no need to conserve the original colour of bole or the subtlety of the original gilding. Economic considerations often dictated that frames with dirty or worn gilded surfaces were regilded using the oil gilding technique, which was much cheaper than the time-consuming technique of water gilding. Thus, originally finely cut, water gilded and burnished Rococo frames were often restored through the application of a coat of gesso, then water gilded again and subsequently restored through the application of yet a third coat of gesso and oil gilded. At present, surface abrasions in painted or gilded objects are considered evidence of age and therefore current conservation practice dictates that it is historically and aesthetically accurate to leave them in situ without in-painting or in-gilding. If however, damage to a gilded surface is so great as to require in-gilding, it is be important to look for alternative conservation techniques that can be recognised in future examinations of the object. It is hoped that the current thesis will broaden conservators’ options regarding ethically sound conservation practice and assist them in making appropriate decisions.

It is now generally recognised that the diversity of objects requiring conservation does not allow for the employment of a uniform philosophy for all treatments and that the requirements for each object should be considered on their individual merits. For example, as Samet (1998) noted, abrasions and wear present different issues within painted or gilded furniture conservation than within paintings, where the same signs of deterioration could be taken as evidence of damage or over-cleaning. Despite divergent opinions regarding acceptable approaches to conservation, the principles laid down within Brandi’s theory on restoration remain highly respected by many professionals. Accordingly, it is these principles that are used to judge the success of non traditional in-gilding
techniques developed as part of this thesis. According to Brandi, successful restoration is required to recreate the unity that the object has lost through the passage of time or through previous restorations or alterations (Vasccaro, 1996). In order to achieve this goal, restoration should not aim to destroy traces of aging and human intervention. It should also retain a focus on aesthetic principles to remove erroneous completions and disfigurements or inappropriate alterations. Brandi stated that in order to respect the complex historical nature of a work of art, the act of restoration must allow for signifiers of a true historical event of the past. Therefore, whilst restoration should re-establish potential unity, it should also retain respect for the ‘patina’, which we can think of as the build-up of time on a work of art (Brandi, 1996). Nevertheless, in terms of gilded objects, as noted by Philippot (1996) this notion of ‘bole decay’ is difficult to assess objectively and it must be acknowledged that not everything that has happened to an object in the past can be recognised as equally significant.

‘What makes history is the meaning of the event, the meaning that we recognise in a particular context.’ (Philippot, 1996)

Philippot (1996) provides a good example of these ethical problems raised in the restoration of the Nordlingen altar attributed to Friderich Herlin. This fifteenth century altar was broken into pieces by the Iconoclasts of the sixteenth century, and then repaired in 1683 according to Protestant aesthetics - without painted wings - and fitted within a Baroque frame. In recent times, under the influence of the growing public fervour for conservation, the Protestant parish considered returning the altar to its original 1462 state, using the painted wings that fortunately had been preserved in the city museum. After examination and discussion, however, it was decided to preserve the seventeen-century repair, not only for its historical importance, but also because the preservation of the Baroque frame would have been compromised if it were to lose its sense of existence.

In the past, gilded objects have frequently had gesso reapplied and surfaces have either been regilded or repainted with bronze paint within various media. The
debate over the restoration of gilded surfaces is one constantly associated with questions regarding whether overpainting layers should be removed, and if so, how far this removal should be extended within the conservation or restoration process. Andrew Oddy (1994), for instance states that

‘restoration carried out before about 1920 must be examined and recorded, and only removed when neither the curator nor the conservator feel that it serves any documentary purpose’. (Oddy, 1994)

Unfortunately, many early frames lost their delicate patterns and their ornaments became clumsy as a result of reapplied gesso, repainting or regilding, which occurred over the turn of the nineteenth century and the first two decades of the twentieth century. In contrast to the ideas of Oddy, however, present day practices suggest that this altered surface should no longer be accepted and left in situ as evidence of former styles of aesthetic appreciation in the history of conservation. Instead, overpainting layers and previous – often crude - repairs should be removed and the original integrity between the frame and the painting restored.

Another question frequently deliberated within the conservation literature and pertinent to the assessment of the success of any non-traditional treatment is how far the newly in-gilding may permissibly be distressed in order to match the surrounding original materials. It seems generally accepted that the areas touched up using gold leaf should match the existing finish. Colin Jenner (1994) noticed that it is common practice to distress – i.e. rub off - new gilding in the restored areas, in order that these in-filled areas match the surrounding finish. In his opinion, however, if complete regilding is carried out, which is occasionally necessary, then it should not be distressed, as to do so may mislead people who would interpret it as an aged surface. Nevertheless, the same worker condones the toning down of new gilding in order that the restored areas do not detract from other objects within the surrounding room, and to accentuate the depths of carvings. It is his belief that picture frames frequently have their finish
artificially tampered with in order to do justice to the perceived subtle tones of an aged canvas or panel, when the real cause of the problem is a greater amount of ambient light in galleries today in comparison with when the frame was made (Jenner, 1994).

2.3. Current Practice

For a considerable time a gap has existed between the ethics applied to the treatment of objects within public and those within private collections. In contrast to the dilemmas faced by conservators working on publicly-owned museum collections, even today, gilded objects in the possession of private owners or art dealers will most often be regilded rather than simply being in-gilded or stabilised, thereby, as noted above, losing their historical integrity. Furthermore, outside of museums, restorations of gilded furniture or gilded frames are often entrusted to local craftsmen who, in order to comply with the wishes of the object’s custodian, may be forced to carry out what they consider harmful or destructive restorations based on stripping the original surfaces and regilding or repainting. Within the private sector, treatment reversibility is often a completely unfamiliar concept.

It is clear from a review of the literature that the method of retouching depends upon a number of individual factors including the age, type, function, and significance of a gilded object, as well as the type of original gilding present on the surface and its state of preservation. Nevertheless, with the exception of early paintings and polychrome sculptures, which predominantly involve colour integration methods, in most cases retouching of gilded surfaces is carried out using various traditional gilding techniques.

Under current museum-based practice, greater losses in gilded surfaces are usually isolated with various varnishes, in-filled with putties based mostly on chalk and
animal glue, sometimes with the addition of X-Ray dense fillers such as barium sulphate. These losses are then in-gilded using either traditional bole and water gilding techniques, or else, depending on the nature of the restored surface, traditional oil-size and oil gilding.

Small losses of gold foil in the gilded surface may also be compensated using yellow bole or watercolours; watercolours with the addition of gold powder or iridescent mica powders; gold powder or mica powders in gelatine, rabbit skin glue, or in gum Arabic; shellgold; or Paraloid®B72 with pigments. Occasionally, other water-based paints are involved, such as tempera, gouache, or acrylics.

Variations in these methods obviously occur depending on the object-specific problems. When, for instance, the original bole is present, Dianne Dwyer Modestini (2003) recommends the application of a thin layer of wax, which is left to dry and then polished with a soft lint-free cloth. This thin polished layer of wax is then activated by exhalation just prior to application of gold leaf. After a few minutes, the surface may be polished again with a cotton cloth, achieving the appearance of antique burnished gold. Dwyer Modestini (2003) also noted that losses in mordant gilding are not always replaced using the same method, and when they are, they are often associated with powdered gold combined with weak size or gum. Modestini admitted that there is often no solution to the problem of whether to restore damaged gold in a manner that does not compromise the integrity of the original gilding. Although in the past, restorers would not have hesitated, today no responsible restorer

‘would scrape down an original silver ground, apply new gesso, regild, and retool’ (Modestini, 2003).

As noted earlier, since 1980s, for certain forms of gilding, non-traditional methods have been developed and are preferred by some conservators as a means of differentiating restored areas and preserving the integrity of the underlying original object. For compensation of losses of gilding or ‘gold varnish’ in
Baroque gilding, for instance, Christine Cession (1990) recommends Paraloid® B-72 copolymer with pigments, or Savynil® colours (made by Sandoz). Whilst for retouching polychromy on Gothic and Baroque altars in a non-museum environment, Manfred Koller (1990) recommends original gilding techniques for greater losses, watercolours for small lacunae, and advises to leave burnished gilding unvarnished, for reverse silvering, relief brocade applications or weak gilding he recommends protection using a soft acrylic varnish such as B-72 copolymer.

Myriam Serck-Dewaide (1991) noticed that in the process of restoration of gilded and polychromed European sculptures some conservators fill the losses, reconstruct the missing areas and regild pieces either partially or entirely. Although she acknowledged that such procedures could be accepted in the conservation of gilded furniture and architectural decoration, in her opinion such practice should be abandoned for old sculptures because it is excessive and falsifies the original surface. Serck-Dewaide also noticed that retouching of coloured glazes over gold or burnished silver requires a particular technique. In order to achieve this she recommended Paraloid® B72 copolymer in a 10-15% concentration mixed with Sandoz or Ciba-Geigy tinting colours to obtain a glaze close to the original and yet removable without affecting the original.

At present, some conservators consider the application of protective coatings over gilded surfaces necessary in order to avoid the potential harmful influence of a polluted environment as well as for the greater possibility of handling and moving of the object. The varnish most commonly used is applied as solution of acrylic resin Paraloid®B72 copolymer. Various solvents for Paraloid®B72 have been recommended in order to control the evaporation rate and to influence the durability of the lacquer film. Koller (1990) suggests a 3% concentration in equal parts of acetone, xylene and cellosolve acetate. Serck-Dewaide (1991) recommends a 10% B-72 solution in toluene or xylene with or without colorants. Christine Cession (1990) prefers to use ethanol, although she accepts other solvents such as toluene, or p-xylene may be required, depending on the
sensitivity of the polychromy to ethanol. Other protective varnishes mentioned in the professional literature are closer to traditional materials, based on natural resins such as mastic, dammar, or shellac, or else an acrylic resin such as Soluvar®.  

Elke Ollermann (1995) has questioned the need to revarnish the original gilded surface in the course of conservation treatment in order to protect it against atmospheric pollutants and abrasions. Drawbacks of such coatings relating to irreversible surface change and problems encountered when undertaking routine revarnishing are well known. Ollermann argued for alternative treatments involving keeping the integrated original surface intact wherever possible and employing only preventative measures to reduce the risks of damage from atmosphere, climate, pollution, and from regular control and care.  

Likewise Serck-Dewaide (1991) stated that, if the original glazes or glue layers are preserved and the object is kept in a protective environment, no surface coating should be required. In contrast, if works are kept in an environment without climate control, or if the watercolour retouchings are numerous, else if the original burnished gilding is worn, then a thin coat of a liquid mixture of microcrystalline wax and polyethylene wax is applied over the surface for protection. According to Serck-Dewaide, the application of B-72 copolymer-based varnish is justified in instances where a work still has traces of original varnish, and if the metal leaf risks oxidation, or if an object is handled frequently.

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8 Soluvar® is a 1:1 mixture of F-10, poly n-butyl methacrylate, and B-67, polyisobutyl methacrylate, 40% solids in a slow-drying petroleum distillate. It is manufactured by Binney and Smith, Easton, Pennsylvania. The matte varnish is achieved with the addition of fumed silica. Soluvar is removable with non-polar solvents such as petroleum ether. (Jonathan Thornton, 1991, “The use of non-traditional gilding methods and materials in conservation”, in Gilded Wood, Conservation and History 217-230).
Hans Westhoff (1991) has noted that after restoration treatment, gilded sculptures receive a protective coating that is often applied too densely, and this, in his opinion, can lead to optical falsification of the surface appearance. Westhoff also remarked that protective coatings change their appearance with time, requiring a periodic replacement that can endanger the original surface. He admits however, that if the sculpture is kept in an unprotected environment such as a church, varnish coating provides essential protection against dust and accidental damage due to unskilled cleaning. Therefore, such varnishes require reversibility, elasticity, good adhesion and colour stability. In his opinion a thin layer of dammar varnish fulfils all of these requirements.

As noted earlier, due to problems with the visual and technical separation of new in-gilding from the original substrates, for the last twenty years controversy has surrounded traditional gilding techniques employed for the compensation of losses in gilded objects. Some conservators have therefore sought to develop alternative materials or techniques application that would facilitate detection of new in-gilding under ultraviolet light. Wladyslaw Slesinski (1989) described a method developed by Maria Roznerska involving the application of a new in-gilding dye solution that fluoresces under ultraviolet light. Blancophor®, an optical dye, forms clear solutions with water and ethyl alcohol. Slesinski (1989) noticed that 0.05% aqueous solutions of dye and Gum Arabic could be used for the same purpose, as could an alcoholic solution of dye of a similar concentration with the addition of sugar. According to Slesinski (1989), the application of such a solution is preceded by wetting the gilded surface with a 2% water solution of a surfactant, such as Tween®80, in order to reduce the surface tension of new gilding. It was further suggested that the application of Blancophor® solution could also be improved with the small addition of a wetting agent within the applied solution. The known destructive influence of water solutions on bole foundations can be eliminated through the application of an isolation layer of varnish prior to applying the dye solution. Slesinski (1989) also mentioned that Blancophor® could also be added to final varnishes such as mastic, shellac, or indeed Paraloid®B72 copolymer, thereby eliminating the need for an isolation
coating.

As noted in the previous chapter, non-traditional gilding techniques as an alternative to traditional methods were first introduced into gilded object conservation during the 1980s. Nevertheless, to the knowledge of the author, no methodical research involving testing of the suitability of various synthetic materials for the purpose of loss compensation in conservation of gilded objects has been published in the conservation literature. Several papers have appeared in the professional journals presenting the results of *ad-hoc* experiments involving mostly singular studies of specific materials. These contrast with two particularly important publications by Jonathan Thornton (1991) who conducted systematic experiments with varied conservation and commercially available products to describe the technique of gilding on wax fills involving pressure application of gold leaf. He indicated that the results achieved were suitably matte and could be employed for simulating aged and damaged gilding. He also noted the possibility of replicating burnished gilding by first polishing the fill, and then laying gold leaf on the surface wetted with a solvent mixture (Thornton, 1991). Louise Bradley (2000) has also conducted experiments with gilding on wax using mixtures of Microcrystalline wax M80A and Paraflint®\(^9\) wax in various proportions and has concluded that pressure gilding (gold leaf pressed to the wax) works better in the softer mixtures of up to 50M:50P, whereas spirit gilding (gold leaf applied to the surface wetted with solvent) was more successful with the harder mixtures from 30M:70P to 10M:90P. It is important, however, to note that in the experience of the current author, gilding on wax is more suitable for small loss replacements in flat surfaces, and therefore this material was not included in the experiments conducted as part of this thesis, which focused on testing materials that would potentially imitate traditional matte water gilding techniques.

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\(^9\) Paraflint H1 is a brittle, white synthetic Paraffin wax, solid saturated hydrocarbons CnH2N+2, with a melting point of +97°C. It is manufactured by Schumann Sasol Pty. Ltd., South Africa. It is sold in flake or pastilles form (Bradley, L., 2000).
As noted earlier, Thornton (1991) has developed various innovative methods for compensating losses in gilded surfaces, based on acrylic emulsions such as Hyplar®, Liqutex®, and Rhoplexes®. Such emulsions are surfactant-stabilised suspensions of high-molecular-weight, stable acrylic resins in an aqueous medium (Thornton, 1991). According to Thornton, a mixture of equal parts of Rhoplex®AC33 and Rhoplex®N580 successfully imitates the properties of oil-gold size and has many advantages over traditional materials as it is easily reversible, stable, and offers almost no restrictions regarding gilding time. The previously noted advantages of these synthetic dispersions and previous positive practical experience using both materials led to the inclusion of Rhoplex® mixtures in the first stage of the experiments conducted here. The two other acrylic emulsions mentioned by Thornton (Hyplar® and Liqutex®), apparently can also be used to recreate high-gloss gilding. The coatings were applied over the gesso, left to dry, and gold leaf was then applied to the surface and activated by exhalation. The gilded surface could be burnished with agate after several minutes.

The literature contains a single study regarding the replacement of traditional methods of matte water gilding using non-traditional materials. Moyer and Hanlon (1996) have described the apparently successful treatment of the eighteenth-century French *boiserie* mirror, involving compensation of losses in matte water gilding, by applying gold leaf over the foundation of Liquitex® Matte Medium mixed with appropriate hues of ochre watercolour paint and applied after a barrier coat of Soluvar® Matte Medium diluted 1:1 with mineral spirits. The non-glossy surface achieved with this method was then activated by exhalation. The authors suggest that this mordant could be made suitably transparent or opaque and could blend in with areas of original gilding still preserved on the frame. Nevertheless, the success for this innovation in terms of non-traditional gilding was qualified. The authors noted problems with colour matching and the viscosity of the polymer solution was too great to flow sufficiently and therefore failed to provide the impeccably smooth surface required for gilding. In addition, Liquitex® formed a poor bond with the Soluvar® Matte Medium and some
problems were encountered with wetting of the surface if the applied Liquitex® mixture was thinned with too much water. Moyer and Hanlon also noticed that with age cross-linking of acrylics could also create problems for the future reversibility of this material.

Liquitex® varnish has also been used for the conservation of gilded surfaces by Louise Bradley10 and its properties compared with another acrylic dispersion, Primal®224511, in gilding tests of a duplicate of the 19th century watercolour mount. Unfortunately, Liquitex was found not be as receptive to the gold as Primal®2245. The final reproduction mount was cut in 8ply museum rag board, sealed with two coats of Liquitex® acrylic medium, and coated with one layer of Primal®2245. The surface was then gilded with 23karat patent gold leaf, gently rubbed onto the dry acrylic coat. Subsequently, a second layer of Primal®2245 was painted on and gilded in a similar manner.

Despite varied results and reservations regarding properties of this commercially available product, the above experiments with varied Liquitex® mediums led to the inclusion of Liquitex® Matte Medium in the first stages of experiments in this thesis, for comparative purposes.

It has been suggested that acrylic emulsions may be used successfully with a combination of iridescent mica pigments to provide a matte finish. Iridescent mica pigments are mica flakes or platelets coated with very thin layers of titanium dioxide and ferric oxide. According to Thornton (1991) however, iridescent mica powders have poor covering or hiding capabilities due to the transparency of mica. Although when combined with acrylic media, they have a low gloss

10 Private communication with Louise Bradley, Conservation Framer, via e-mail from 29/11/2002.
11Primal®2245 is an acrylic dispersion of EA-MMA-EMA made by Rohm and Hass Company, Philadelphia, PA 19105, USA.
compared with oil and water gilding, they are chemically stable and therefore retain their original colour and remain reversible in organic solvents. These materials are more suitable however for small retouching of losses in gilded surfaces, as they retain an appearance slightly reminiscent of shiny paint.

As noted earlier, depending on the solvent chosen, the acrylic copolymer Paraloid® B72 can create a variety of different surfaces suitable for gilding (Thornton, 1991). The surface can be left matte or else burnished with agate. Firstly, the surface is coated with B-72, allowed to dry completely and then the film is activated with a solvent prior to laying the gold leaf in a manner similar to the water gilding practice. When the free solvent has evaporated, the gold leaf is either pressed on firmly and burnished with agate to imitate burnished water gilding, or polished with cotton wool in order to achieve sheen similar to oil gilding. Thornton observed that the solvent-activated surface does not retain its tack for very long, and therefore this technique is appropriate only for flat or slightly curved surfaces. He also noted that the hardness of the B-72 film depends on its solvent and that the mixture of solvent necessary to reactivate the dry film must be chosen for the purpose of only slightly softening the film but not dissolving it. He further noted that less volatile solvents used for diluting B-72 are more appropriate since they will allow brush strokes to level out the applied film. Consequently, he recommended a 20% solution of B-72 in lacquer thinner, which can then be reactivated either with petroleum ether, or if reactivating occurs days or weeks after application, a mixture of 25% ethanol and 75% petroleum ether. Based on these results, Paraloid® B72 solutions were included in the experiments conducted here.

Thornton (1991) has also observed that losses in aged burnished-water gilded surfaces can be in-gilded by laying gold leaf on bole foundation compound with a synthetic binder, such as polyvinyl alcohol. The advantages and disadvantages of polyvinyl alcohol are well documented within the conservation literature (de Witte, 1977, Falvey, 1981, Horie, 1990, Hebrard and Small, 1991, Bicchieri, Bortolani and Veca, 1993, Petersen, Heyn and Krumbein, 1993). In terms of
gilded surface conservation, gold leaf that was applied over this medium can be burnished even several days after gilding. Hebrard and Small (1991) conducted gilding tests using polyvinyl alcohol as a substitute for rabbit skin glue in both gesso and bole, for imitation of burnished water gilding. They obtained the best results using polyvinyl alcohol of low molecular weight in solutions of low concentration.

Polyvinyl alcohol is also a component of Colnasol® adhesive, supplied in Kölner® products\textsuperscript{12}, which are commercially available modern gilding materials. According to Thornton (1991), cellulose ether is also used as a binder in Kölner® Burnishing Clay. Kölner® techniques have many desirable properties such as good covering power, thereby allowing covering of dents or irregularities of any surface. Unfortunately, Kölner® materials have a low internal strength, and excessive burnishing pressure will cause cracking and flaking of the gold leaf.

Thornton (1991) also described the use of epoxy resins for imitation of burnished surfaces. Epoxy resin diluted with acetone can be applied over a surface burnished with agate and the wiped off leaving only a slight residual layer. Gold leaf can then be applied and the epoxy given time to harden. There are obvious drawbacks to this method associated with undesirable general properties of thermosetting resins such as difficulties with reversibility and corrosion of copper due to the amine-based hardeners that are sometimes used in epoxy resins. Therefore, this technique should not be used with copper-based gold leaf imitation materials (Thornton, 1991).

Thornton (1991) has also experimented with gilding on thermosetting resins, concluding that a cast made of thermosetting resin can be gilded in three ways. In the first method, bronze or gold powder is dusted onto the tacky surface of a silicone rubber mould onto which the resin is poured. After removal from the

\textsuperscript{12} Kölner® gilding materials are distributed by gilder’s and artist’s suppliers.
mould, the cast will have a low gloss metal surface that can be burnished to a higher gloss after the resin has fully hardened. The second method involves activating the cast surface with a solvent mixture just prior to application of the gold leaf. The surface is firstly polished with a chrome oxide polisher and then wetted with a mixture consisting of ethanol (non-active diluent), methylene chloride (active solvent) and diacetone alcohol (to retard evaporation). Gold leaf is applied with a gilder’s tip and left until the solvents evaporate and the surface hardens again. Unfortunately, mistakes in application cannot easily be corrected, and as with B-72 copolymer, noted above, this method is suitable only for flat or gently rounded surfaces such as architectural details. The third method of gilding polished casts involves application of an epoxy resin, followed by gilding in the manner described above.

2.4. Informative Judgment

As Melucco Vasccaro (1996) noted, too often loudly heralded technological breakthroughs in conservation practice have, in the absence of exhaustive testing, subsequently proved disastrous and impossible to reverse. Whilst it is widely acknowledged that complete reversibility is a chimera, many treatments leave the original material changed forever. Acknowledging this fact, we should continue to work according to Brandi’s criterion of minimum intervention, accepting however that any

‘alteration may be acceptable if it is not disfiguring, if it does not destroy historic or artistic features, and if it effectively increases the chances of the objects survival’, and ‘above all, […] if it does not hinder future treatments.’ (Vasccaro, 1996)

Furthermore, we must acknowledge the conservator’s action often determines the appearance of the object, and consequently its interpretation. By doing this, as
Philippot (1996) observed, a conservator is forced to apply critical judgment on the work of art and in the same moment provide

‘a given direction for the imaginary contemporary museum. Awareness of this fact requires limiting interventions as much as possible and searching for the greatest possible degree of reversibility.’ (Philippot, 1996)

As noted by Bomford (1994), the conservator will always be placed in an invidious position caught between the needs of the art historian to know how much of an object is original and the viewer/custodians who wish to see an image uninterrupted by loss or damage as well as at the same time upholding professional conservation standards and ethical principles. As noted earlier, both arguments are aesthetic and dictated by either historical or academic requirements. It is certainly true that stabilisation of an object is the primary priority of a conservator. If however, the state of deterioration of an object requires greater levels intervention on the part of the conservator, the safest approach seems to be to adopt the degrees of individual discretion proposed by Bomford (1994) based on clear ethical principles. Regardless of a conservator’s assessment concerning the fragility of an object or the impermanency of the materials that it was made from, few curators or viewers are pleased nowadays with the concept of 'dignified decay', particularly if the object was acquired for a significant amount of money. In most such cases, intervention in terms of treatment that preserves whatever is left of the object and restores whatever has been lost is permissible and, of necessity, will commonly include irreversible actions even if reversible materials are used. In cases involving loss compensation of gilded objects, aesthetic priorities will often prevail and contemporary conservation practice is most likely to involve the use of gold leaf instead colour-matching watercolours. In these terms it would seem to be of considerable benefit to future generations if conservators were better able to make informed judgments regarding the stability of the materials they use and potential reversibility of all treatments they apply. There would seem to be considerable benefit therefore, in the generalised adoption of reversible non-traditional gilding techniques for all restorative
conservation. Such practice will however, only be adopted if the conservator is provided with reliable results of methodical comparative research into all aspects of both traditional and non-traditional in-gilding techniques and materials. The next chapter presents the methodologies of the experiments conducted to enable such informed judgements to be made.
3.0 STAGE I: SELECTION OF APPROPRIATE MATERIALS AND INITIAL TESTING OF THEIR SUITABILITY FOR GILDING

3.1. Criteria for selection of polymers suitable for testing

The selection of materials suitable for testing was carried out according to the physical characteristic properties of polymers. The basic criteria included:

- **Stability**

  The materials were required to be of an acceptable conservation standard. They should not change the physically or chemically on setting and should have minimal shrinkage due to solvent loss. They should not change the objects physical properties so as to affect the colour, texture and appearance of the object. The material should remain at least as chemically stable as traditional materials over a long period and under variable environmental conditions.

- **Reversibility**

  The material should remain totally removable in the future without harm to the original matte water gilded surface.

A second selection was carried out according to the properties required for the project, taking into account features such as:
• **Solvent Selection**

Varying solvent compositions affects many aspects of the created film including application characteristics (e.g., rate of drying, levelling, brushability), physical properties (e.g., hardness, strength, elongation, and adhesion to the substrate), and aesthetic properties (e.g., gloss-matte) (Samet, 1998). Although it was accepted that the materials applied could be soluble in water (applied as water dispersion or dissolved in water), it was essential that a dried film would be soluble in organic solvents, which would make it safe to use on original matte water gilded surfaces. Hence, materials that created films soluble only in water were excluded from the testing program. Although the solvent selected as a vehicle for the polymer was of fundamental importance from the aesthetic point of view, from an OH&S perspective, aliphatic solvents or aliphatic solvents with low aromatic contents such as white spirits are the safest to use on water-gilded surfaces in order to minimise long-term exposure and therefore, where possible, the polymer resins selected for testing were those soluble in these solvents.

• **Viscosity**

The polymer material selected should have as low a viscosity as possible in order to ensure easy application by brush and creation of very thin and even films on the surfaces. Low viscosity systems entail a balance of a number of factors affecting intermolecular bonding, such as the degree of polarity, solubility and density. *A priori*, polymers with low molecular weights were preferable else polymers with higher molecular weight were used in low concentrations within slow or medium evaporating solvents. As noted later, due to the rate of evaporation of volatile solvents, the viscosity of applied polymer films rapidly increased as a function of molecular weight polymers and could result in a rough-textured coating (Feller, Stolow, Jones, 1985) inappropriate for gilding. In addition, the tensile strength of resins and their plasticity increases as a function of
viscosity. In general, due to their lower degrees of intermolecular hydrogen bonds and dipole-dipole interactions, empirical evidence suggests that low-viscosity grade polymers will be more brittle than those of higher viscosity grades (Feller, et al., 1985).

- **Glass Transition Temperature (Tg)**

  The glass transition temperatures (Tg) of materials suitable for gilded surfaces are selected as close to ambient temperatures as possible, in order to reduce the shrinkage and stress resulting from changes in environmental conditions (particularly RH) and thus the differential interactions between wood-gesso-polymer. Glass transition temperatures greater than room temperature may cause polymer films to crack. In contrast, a Tg below ambient temperature is likely to cause the polymer to flow and pick up dirt (Horie, C.V., 1987). A Tg at around, or slightly above, ambient conditions is also required for the formation of coherent film within which polymer molecules coalesce.

- **Elasticity (Young’s modulus)**

  As noted above, polymer layers are required to respond to the movement of object materials (wood-gesso) without causing stress to the original substrate. A strong polymer with high Young’s modulus will resist stretching caused by humidity induced wood expansion/shrinkage and will tend to be pulled off, with potentially damaging results for the underlying original material attached. In such circumstances, a weak polymer with a high modulus of elasticity will crack (Horie, C.V., 1987). In contrast, a polymer with a low Young’s modulus is likely to undergo plastic deformation and stretch irreversibly. Subsequent contraction of the wood will lead to bubbling or wrinkling of the film. As noted above, shrinkage and stress is best managed by ensuring that the glass transition temperature of the polymer is around ambient temperature.
• **Compatibility with materials the object is made from**

The material should be compatible with a gilded surface, gesso and bole foundation layers and capable of wetting these materials and grafting to them.

• **Compatibility with pigments or other paints**

As noted earlier, the conservator should be able to mix appropriate pigments and paints with the polymer to create a low sheen surface and thereby imitate original bole layers.

• **Low sheen/matte appearance of film**

As noted earlier, one of the principle drawbacks with synthetic materials used for matte water gilding is their shiny ‘artificial’ appearance. Suitable polymers should create a low sheen/matte appearance on the surface prior to gold leaf application. Gloss and high gloss surfaces prior to gilding will result in a shiny surface after application of gold leaf. The gloss or sheen of a transparent coating can be reduced with matting agents by creating surface irregularities that scatter light from the surface of the dried film and/or by making the overall dried film less transparent and therefore less prone to second order internal reflections (Wolbers, 1998). Commercially, such additives are comprised of metal soaps with or without fumed silica and involve the creation of a flatting agent/ solvent paste in grinding mills (Wolbers, 1998). In the conservation laboratory it is difficult to imitate such an environment and in order to create less transparent films, it is usual to stir small amounts of microcrystalline wax or 0.5-1.0% of fumed silica to the polymer. In this study, however, these materials are not recommended since it is known that such additives alter the adhesion properties and the suitability of polymers for gilding, rendering objective comparisons difficult. It was accepted that if results regarding the properties of a particular polymer were promising, but the level of gloss of
the created film too high, further research into the addition of matting agents would be required to overcome this problem.

- **Adhesion properties**

The selected polymer should have good adhesion properties, i.e. the solution should spread easily over a flat surface, and it should wet the surface entirely. In order to ensure good wetting behaviour on the surface, the surface tension of the liquid applied must be slightly higher than that of the substrate. In addition, a solution of polymer should be given time to penetrate before it hardens. A low-viscosity liquid is more likely to flow readily into the pores of the foundation.

Selections of appropriate materials were made on the basis of the available materials science technical information and the conservation literature. Choices were based upon the perquisite that the application of gold leaf should change neither the properties of polymers nor their aging characteristics. The materials considered for testing included those that:

- had previously been mentioned in conservation literature as a substitute for traditional matte water gilding (Moyer, C., and Hanlon, G., 1996)

- had previously been mentioned as a substitute for traditional burnished water gilding or oil gilding, (Thornton, 1991, 1991,)

Matte Paint

Matte paint is often characterised as paint with a high pigment volume concentration (high PVC). Such paints may have poor cohesive and adhesive properties and can often be found be in a powdery, friable and flaking condition. Consolidation of such surfaces is problematic, since consolidants that are easily absorbed into paint and fill voids between pigment particles may also cause irreversible changes in the appearance of the matte surface. Therefore, like matte water gilding, consolidation of porous matte paint demands materials and treatment methods that minimise changes in appearance, introduce the minimum number of consolidants necessary to create adhesion between paint particles and the substrate, and are also compatible with paint and its support (Hansen, Walston, Bishop, 1993). Like paint, degraded gesso foundation can also be in a powdery or flaking condition and any consolidant that remains on the surface can change delicate matte gilding into a surface with a shiny, ‘plastic’ appearance. In view of this, some materials and methods used successfully for the consolidation of powdery matte paint were included in the experiments.

The consolidation process of a highly matte PVC paint can be achieved by:

a) using a low-volatility solvent such as diethylbenzene

b) adding multiple applications of a dilute solution.
c) using gelatine or cellulose ethers as consolidants.

d) using small particle size dispersions of acrylics, (Hansen, Sadoff, and Lowinger 1993).

e) using saturated vapour atmospheres.

For the purpose of this study, only factors a, b, and d were relevant to the conservation of gilded surfaces and considered in the selection of materials.

**Varnishes**

Some solvent-type varnishes used for painting conservation have properties deemed useful in gilded surface conservation, such as adhesion to substrate, low viscosity of the solution applied, a low sheen appearance, ability for levelling and the possibility to 'reform' the applied film. Varnishes based on high viscosity polymers (high molecular weight) tend to give semi-matte finishes and, in addition, can be reformed simply by moistening the area with a suitable solvent. Low viscosity polymers (low molecular weight) tend to flow in such circumstances and form a glossy ring at the edge of the treated area (Feller, Stolow, Jones, 1985). This could potentially distort the adhered gold leaf.

In comparison, varnishes based on low molecular weight polymers require less solvent to form a low viscosity solution. Through evaporation of solvents such varnishes continue to flow at high solids concentrations and tend to create well-levelled smooth, glossy surfaces. At the stage when the varnish no longer flows, such varnishes have relatively little solvent content. Further loss of solvent does not influence the appearance of the varnished layer and the surface is deemed to be stable. Long-chained high molecular weight polymers that have a much greater solvent content during application retain significant amounts of solvent at the 'no flow' stage. Further solvent evaporation results in reproduction of the structure of the paint layer, thereby creating a less gloss surface (Feller, Stolow, Jones, 1985, Nicolaus, K, 1999).
The rate at which a solvent evaporates during the application of varnish also influences its handling properties and final appearance. A coating that due to quick evaporation of solvent does not level completely forms a matte surface (Feller, Stolow, Jones, 1985). Dried films formed from resins dissolved in slow evaporation rate solvents have more glossy finishes than those of the same resin dissolved in solvents that evaporate more quickly. Rapid solvent evaporation can however, result in a rather rough surface that is unsuitable for gilding purposes.

An appropriate surface for gilding requires a varnish possessing levelling properties, one that dries to a low sheen film. Such a surface should be achievable either using either a low molecular weight polymer in a solvent with a relatively rapid evaporation rate, or with a high molecular weight polymer dissolved in a slow evaporation solvent.

### 3.2. Materials selected for the project

Based on the criteria above, the following materials were selected for the project:

#### 3.2.1. Acrylic dispersions:

##### 3.2.1.1. Rhoplex®AC-33/N-580 (1:1)

A mixture of equal parts of Rholpex® AC-33 and N-580 has been used successfully in the conservation of gilded objects to imitate traditional gold size in the oil-gilding technique. The advantages of this material include its reversibility.

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13 Basic data on all selected materials are included in Table 1.
in a range of organic solvents (xylene, toluene, and acetone), its stability and the lack of restrictions regarding gilding time.

The properties of Rhoplex® emulsions (or Primal® in the U.K. and Europe) were noted to vary depending on their chemical composition and molecular weight, both of which determine the films’ hardness. Rhoplex® N-580 dispersion is based on n-butylacrylate homopolymer at 54-56 % (w/w) solid content concentration (MCIN)\textsuperscript{14}. It is a fluid emulsion that forms a very flexible film that when dry, retains a permanently sticky surface. It has, therefore, been used both as an adhesive and as a consolidant in textile and wallpaper conservation. The long term stability of Rhoplex® N-580 has been evaluated by Shashoua (1992). Tests of to colour stability, reversibility, tack, pH, bond strength and reactivity with metals, measured before and after aging, showed that Rhoplex® N-580 has promising stability and forms strong bonds with organic materials. Unfortunately however, Shashoua also showed that Rhoplex® N-580 may not be fully reversible without risk of damage to weak or friable objects.

Rhoplex® AC-33 dispersion is based on a copolymer of ethylacrylate (EA) and methylacrylate (MA), with 1% of acrylic acid, at 42% solid content concentration (De Witte, Florquin, and Goessens-Landrie, 1984; Stringari and Pratt, 1993). It is a highly viscous liquid that after drying forms a flexible film (MCIN). Like Rhoplex® N-580, Rhoplex® AC-33 has been used both as an adhesive and as a consolidant in the conservation of wallpaper, bone and ivory artefacts as well as in the treatment of polychrome wooden objects. This acrylic dispersion was included in an evaluation of resins for adhesion of flaking paint on ethnographic objects conducted by Horton-James, Walston, and Zounis in 1991. In their sophisticated programme the properties of both new and aged resin films were tested and AC-33 dispersions performed well with regard to solubility, percentage

\textsuperscript{14} Information obtained from the Conservation Information Network - Materials Database.
elongation at failure, and colour stability. Nevertheless, in aging tests a change in pH was observed in aged AC-33 films, indicating hydrolysis and chain scission was occurring over time. Feller (1985) also noted increased insolubility of AC-33 in toluene with age, not caused by cross-linking but rather by changes in solubility parameters due to partial oxidation.

The 50:50 mixture of AC-33 and N-580 was included in testing in order to evaluate this polymer system for conservation of matte water gilded surfaces.

3.2.1.2. Plextol® B500 (mixed 1:1 with water/ethanol [4:1])

Plextol® B500 is an acrylic dispersion based on the copolymer of ethylacrylate, methyl methacrylate, and ethylmethacrylate, at 50% solid content concentration (De Witte, Florquin, and Goessens-Landrie, 1984). It is purchased as a liquid of medium viscosity which, due to its stability and reversibility, has been commonly used as an adhesive and consolidant in a variety of conservation fields. For the last thirty years it has also been used in painting conservation as a lining adhesive (Duffy, 1989). Accelerated aging studies involving Plextol® B500 have been conducted on several occasions in the past, with inconsistent results. Of all the polymers available to conservators, Plextol® B500 is notable as the resin most resistant to peel strength changes over time. It can however, discolour if exposed to UV light or to thermal aging (Duffy, 1989). Horton-James did not observe such changes in accelerated aging tests conducted on 19 resins in 1990. He did however, acknowledge that Duffy's concerns could be caused if higher energy UV light was emitted by the sun-lamp bulb used for accelerating aging. No colour changes or changes in elongation that would indicate loss of flexibility were recorded in Horton-James' tests. The empirical evidence to-date confirms that Plextol® B500 is highly stable and maintains its reversible properties over time. Amongst the 19 resins tested, this material was shown to be the best available
consolidant for powdering matte paint.

Since 1991, diluted Plextol® B500 has also been used in the consolidation treatment of gilded objects. There is, however, no record in the conservation literature of its use as a gold leaf adhesive. Its adhesive properties and stability, in conjunction with the slight moisture sensitivity of fresh film characteristic of most water dispersions (Feller, 1985), indicates some potential in this regard, particularly since, in theory, the newly formed film can be activated by exhalation. Furthermore, the yellowing of the resin over time, noted by Duffy, may not be a factor for gilded surfaces since the adhesive is hidden from the deleterious effects of light under gold leaf.

The viscosity of Plextol® B500 in the form provided by manufacturers is too great to create levelled films suitable for gilding. Therefore, for the purpose of this test and in order to form a low viscosity solution that could be applied over the gesso surface and form a thin evenly distributed film layer, Plextol® B500 was diluted in the ratio 1:1 with distilled water with ethanol (4:1); ethanol being added to improve the wetting properties of the applied mixture.

### 3.2.1.3. Liquitex® Matte Medium

Liquitex® dispersions are based on similar chemical components to Plextol® B500 at a lower solid concentration (38%) (De Witte, Florquin, and Goessens-Landrie, 1984). Liquitex® Media are available in different viscosities (low, medium, high, extra high) and sheens (gloss and matte). The physical properties of the Liquitex® medium and varnishes have already been described earlier\(^{15}\). Of the synthetic materials available to conservators, Liquitex® Matte Medium has thus far created surfaces that have been the closest to traditional matte water

\(^{15}\) See: Introduction, pages 1-4, 1-5, and Chapter 2, pages 2-24, 2-25
gilding, and despite shortcomings regarding its aging characteristics, this material has been included in the current testing program for the purpose of comparison.

3.2.2. Acrylic Resin: Paraloid® B-72

Paraloid® B-72 (Acryloid® B-72 in UK and Europe) is one of the most stable thermoplastic resins used in conservation and widely used for a variety of purposes including picture varnish, consolidant for matte paint, oil paintings and wall paintings, in-painting medium, consolidant for wood, plaster, stone, and ethnographic objects, adhesive for ceramic and glass, fixative for pencil, charcoal, and chalk drawing and pastels (Samset, 1998). Chemically, it is a copolymer of ethyl methacrylate and methyl acrylate (70:30). It is soluble in a variety of solvents including aromatic hydrocarbons (xylenes, toluene), acetone, ethanol, isopropanol, chlorinated hydrocarbons, and cellosolve, amongst other solvents (Welsh, 1981).

Paraloid® B-72 is more flexible than traditionally used dammar and is therefore considered to be a medium-hard, relatively flexible thermoplastic acrylic resin. Nevertheless, the solvent selected for transport can greatly affect the final flexibility and strength of any film created using this resin. For example, a tensile test of solution cast films has shown that Acryloid® B-72 in acetone has a low extendibility threshold (under 10% strain-to-break) compared to film formed from solutions of B-72 in toluene (over 100% strain-to-break) (Hansen, Walston, Bishop, 1993).

Aged B-72 films remain clear, colourless and are resoluble (Samset, 1998). It has, however, been noted that variations in the toluene/xylene content of the applied solution can influence the final appearance of B-72 varnishes. In particular, increasing the ratio of toluene to xylene may decrease the gloss of any formed film. In addition, a greater matte appearance can also be achieved
either via the addition of 0.5 - 1% of fumed silica, or up to 4% of microcrystalline wax. Suggested matting agents include ethylene/vinyl acetate polymers, e.g. Elvax®40W (Du Pont) up to 10 % solids (C.V. Horie, 1987)

The properties of Paraloid® B-72 single it out as one of the best materials for consolidation of powdery matte paint. Successful consolidation treatments have been noted using B-72 in diethylbenzene (Welsh, 1980; Hansen, Lowinger, Sadoff, 1993). Higuchi (1987) noted the benefits of using a mixture of p-xylenes and alcohol (25-30%) as a solvent for B-72 for the consolidation of gesso foundations consisting of shell white in animal glue frequently used in polychromed wooden sculptures in Japan during the Edo period. He observed that the solution became tacky (ready to be attached to paint) only a few minutes after application.

Experiments in using B-72 as a substitute for traditional gilding mediums were mentioned by Jonathan Thornton (1991), and have been discussed earlier (see above)\[16\].

In the current study three solutions of B-72 were included:

- one recommended by Thornton (1991) consists of 20% solution of B-72 (w/v), with the adjustment of replacing lacquer thinner with toluene for greater matte appearance (Samet, 1998),

- one used successfully in the consolidation of matte paint solutions of 5% (w/v) in diethylbenzene (Welsh, 1980)\[17\], and

\[16\] See: Chapter 2, page 2-26

\[17\] Diethylbenzene is an aromatic hydrocarbon belonging to the same family as toluene (methylbenzene) and xylene (dimethylbenzene), and similarly to xylene it has three isomers. With a high boiling point (180-184\degree C) it is characterised with a slow evaporation rate. It has a strong odour, but is less toxic in vapour form than toluene and xylene and is also a slightly weaker solvent than these two (Welsh, 1980).
• a 10% solution of B-72 in xylene (w/v) (Samset, 1998); (a varnish solution commonly used for consolidation treatment in objects conservation, including conservation of gilded objects)

The created film was then left to dry and reactivated with:

• a mixture of Shellsol®A/ Shellsol®T (11.5:88.5%) (ratio of petroleum benzene)\textsuperscript{18} and ethanol (75:25%), for better surface wetting.

### 3.2.3. Poly(vinyl acetate) Resin: AYAF

Polyvinyl acetate resins are thermoplastic resins that are widely known to have excellent stability, flexibility, and adhesive properties. In conservation they are used extensively as varnishes, consolidants, and adhesives. Polyvinyl acetate resins are composed of repeated units of vinyl acetate monomer and are available in a wide range of molecular weights, which determine their ultimate hardness, flexibility and viscosity. PVAc with a low molecular weight can be applied either as a highly viscous liquid, or a soft, low melting solid. By increasing the molecular weight of the polymer the resin becomes tougher as the tensile strength, ability to elongate and melting point also increase (Samet, 1998).

PVAc resins are soluble in a range of solvents including aromatic hydrocarbons, alcohols containing some water (5%), ketones, esters, glycols and chlorinated hydrocarbons. They are, however, insoluble in aliphatic hydrocarbons. They also swell slightly with the addition of water (Samet, 1998).

\textsuperscript{18} Petroleum ether has the same evaporation rate as toluene of n-Bu-Ac=2.0, and a combined aromatic content of ~11.5% (Whitten, 1998, 276)
PVAc resins form highly flexible films. Due to the polymer film’s low Tg, this flexibility is retained for many years thus enabling the resin film to retain its cold flow properties for a long period (Samet, 1998).

PVAc varnishes are less glossy than a number of other synthetic resins and natural resin varnishes. They have lower refractive indices and do not saturate, level out or darken paint layers. They also produce films of intermediate gloss and show lower ‘distinctness-of-image gloss’ (D/I) values than substrates with low gloss (Pocobene, 1998).

PVAc resins have excellent aging properties and are among the most stable polymers used in conservation. Although Thomson (1963) indicated that there was no evidence to suggest that these resins crosslink, Horie (1987) observed that uncharacterised minor chemical alterations can occur over time. Despite this, even after 30 years of natural aging, AYAF remains fully soluble in the same solvent in which it was originally dissolved (Feller, Stolow, and Jones, 1985). It has also been noted that PVAc varnishes show little adhesive strength and can often be easily peeled off (Samet, 1998, 198, after de la Rie, 1988). AYAF has been used successfully in the consolidation of matte paint, using a 5% concentration of resin in ethanol (Hansen, Lowinger, Sadoff, 1993, Hansen, Volent, 1994).

For the current study, a 5% concentration of AYAF resin in methylated spirit was included in the testing process. Dried films of this material were activated firstly by exhalation (see above) and subsequently by wetting the surface with a xylene/ethanol mixture.

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19 Methylated spirit was selected for better solving abilities of AYAF
3.2.4. *Hydrogenated Hydrocarbon Resin:*

*Regalrez®1094*

Regalrez®1094 was introduced for use in picture varnishes in the 1990s. It is a hydrogenated hydrocarbon-based resin that when formed into a film, shows remarkable stability, particularly with the addition of the light stabiliser Tinuvin®292 (de la Rie, 1993). Although its low molecular weight suggests that it is a relatively brittle resin, the addition of 1-3% of Kraton®G1650 rubber to the weight of resin can reduce films’ brittleness, improve the ‘brushability’ of the applied solution and can also significantly reduce the natural high gloss of the resin. The resin’s gloss appearance can also be modified by using low concentration solutions in relatively fast drying solvents, such as petroleum ether (Samset, 1998). Regalrez®1094 is soluble in both aromatic and aliphatic hydrocarbon solvents. One such recommended solvent is an aliphatic hydrocarbon with a low percentage of aromatic content such as Shell® Mineral Spirits 135\textsuperscript{20} or Low Aromatic White Spirits\textsuperscript{21} (Caryle/Bourdeau, 1994). Regalrez®1094 is known to be an exceptionally stable resin. Accelerated aging tests performed at the National Gallery of Art, Washington, using a xenon arc weatherometer with both unstabilised and stabilised Regalrez®1094, showed that no solubility changes occurred in a solution of Kraton®G1652 and 2% Tinuvin®292, even after 2,269 hours of aging (de la Rie, 1993). It should be noted, however, that although unstabilised films also retained good solubility, they also became very brittle with time.

Whitten and Proctor (1998) have, however, noticed that Regalrez®1094 holds a few drawbacks in terms of its use within conservation. Whilst it was possible either to reapply a brush varnish over the first formed Regalrez®1094 film or else apply any other varnish that is soluble in hydrocarbon solvents, as required in gilded objects conservation, nevertheless, attempts to ‘go back’ or re-brush areas

\textsuperscript{20} US, b.p. 162.2°C, total aromatic content: 15.1%, relative evaporation rate: 0.1 vs. nBuAc = 1.0

\textsuperscript{21} UK, b.p. 160°C, 17% aromatics, relative evaporation rate: 0.19
during application may cause pooling to the underlying layer of Regalrez®1094 (Samset, 1998). In terms of gilded objects, this creates significant problems for the reactivation of films formed from Regalrez®1094.

On the basis of its properties as a varnish i.e. high degree of stability and low molecular weight, Regalrez®1094 was selected for further analysis. Studies of Regalrez®1094 suggested that the resin may be applied successfully at the much high concentrations required for gilding. Despite this, little is known of the adhesive properties of Regalrez®1094, and of all those resins selected for further study it was the only one that had not been used as an adhesive in the past. For the purpose of this research, a 25% solution of Regalrez®1094 with the addition of Kraton®G1650 and Tinuvin®292 was prepared according to the recipe recommended by CCI (Caryle/Bourdeau, 1994)\(^\text{22}\).

3.2.5. Poly(2-Ethyl-2-Oxazoline): Aquazol®500

Poly(2-Ethyl-2-Oxazoline), PEOX, has been known commercially under the name Aquazol® from the beginning of 1990. It is soluble in a wide range of solvents including water, and is miscible with a wide range of common polymeric materials (Wolbers, McGinn and Duerbeck, 1998). It has also been used as a hot melt adhesive in the packing industry. Wolbers, McGinn and Duerbeck (1998) recently conducted accelerated light-aging tests on films of Aquazol®50 and Aquazol®500 the results of which demonstrated the materials’ remarkable stabilities in terms of both colour and pH, as well as resistance to thermal decomposition. FT-IR data obtained on the freshly applied and aged Aquazol®

\(^{22}\) 25% of Regalrez®1094 in white spirit/polymer mixture:
- Regalrez®1094 46.0g (23%)
- Kraton®G1650 4.0g (2%)
- Tinuvin®292 1.0g (2%)
- White sprit 150.0 ml
indicated that samples remained chemically unchanged. It was, however, noted that the molecular weight of both polymers reduced over time as a result of chain scission of the aged polymer. The tensile strength data also indicated that Aquazol® is a rather weak adhesive, and therefore can only be useful in instances where weak forces are at work on adhesive joints (Wolbers, McGinn, Duerbeck, 1998). Although both of the aged Aquazol® samples retained their solubility in the initially used solvent (water), of those tested, acetone was found to be the best re-solubilisation agent. Wolbers, McGinn and Duerbeck also tested both the Young’s modulus and elongation-at-break values for the polymer. The results indicated that Aquazol® is a highly plastic polymer and therefore despite the fact that the stress/strain curve was influenced by changes in RH, could potentially be a much better consolidant for paints on wooden supports than those adhesives used traditionally.

Wolbers, McGinn and Duerbeck conducted several case study tests regarding the effectiveness of Aquazol®50 and Aquazol®500 as consolidants applied as varying concentration solutions, evaluating the materials’ working characteristics, ability to flow and penetrate, ability to relax flakes, overall security on drying and visual effect on surrounding design materials. The best results reported were those obtained using a 20% solution of Aquazol®500 in a 1:10 ethanol: water mixture (the addition of ethanol was required to maximise the penetration and wetting abilities of the consolidant). It was noted that effective consolidation of paint-to-wood or paint-to-paint cleavages could be successful, regardless of the substrate, with a single application of the solution.

The known properties of Aquazol®500 indicated that it can perform well as an adhesive for gold leaf and therefore, a 20% solution of Aquazol®500 in a 1:10 ethanol-water mixture was included in the current testing program.
Table 1: List of materials selected for testing including basic relevant information [1].

<table>
<thead>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mn</td>
<td>Mw</td>
<td>in DEB</td>
<td>11.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Paraloid®B-72</td>
<td>Copolymer of ethyl methacrylate (EMA) and methyl acrylate (MA)</td>
<td>11,397</td>
<td>65,128</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhoplex®AC33 (Primal®AC33 in Europe)</td>
<td>66%PEA/33%PMA/1% acrylic acid [5] dispersion at 42% (w/w) concentration [7]</td>
<td></td>
<td></td>
<td>5</td>
<td>16</td>
<td>medium to high</td>
</tr>
<tr>
<td>Rhoplex®N580 (Primal®N580 in Europe)[6]</td>
<td>N-butylacrylate homopolymer, dispersion at 54-56% (w/w) concentration</td>
<td></td>
<td></td>
<td>-42</td>
<td></td>
<td>&lt;125</td>
</tr>
<tr>
<td>Plevtol®B500 [7]</td>
<td>PEA/MMA/EMA dispersion at 50% (w/w) concentration</td>
<td></td>
<td></td>
<td>10&lt;2</td>
<td></td>
<td>low [8]</td>
</tr>
<tr>
<td>PVA AYAF</td>
<td>Poly(vinyl) acetate resin</td>
<td>51,370</td>
<td>113,000</td>
<td>24</td>
<td></td>
<td>1.466</td>
</tr>
<tr>
<td>Regalrez®1094</td>
<td>100% hydrogenated oligomers of styrene and alpha-methyl styrene</td>
<td>630</td>
<td>900</td>
<td>33</td>
<td>43.8</td>
<td>1.519</td>
</tr>
<tr>
<td>Liquitex® Matte Medium [7]</td>
<td>EA-MMA-EMA dispersion at 38% (w/w) concentration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
2. Mw - weight average molecular weight; Mn - number average molecular weight; Tg - glass transition temperature.
4. Viscosity grade in centipoises of a solution of the resin in toluene at 70°F (21°C) and a concentration of resin of 20% by weight, according to: Feller, R.L., N. Stolow, and E.H. Jones, 1985.
Stage I: Preparation of samples

Photo 1 - Stage I: preparation of samples for traditional gilding

Photo 2 - Stage I: Samples after matte water-gilding, prepared for tests using varied synthetic materials
3.3. Preparation of samples

Samples of radiata pine wood of approximately 200 x 100 mm were coated with a 6% rabbit skin glue solution in water (w/v) and then with several layers of traditional gesso (calcium carbonate mixed with 5-8% rabbit skin glue, w/v). The dried surface was then sanded (using wet and dry) in order to prepare it for traditional matte water-gilding. Approximately half of each sample was covered with traditional bole with a gelatine binder, and then double gilded in a traditional manner (photographs 1 & 2). The remainder of each sample was left covered in white gesso for gilding using a selected test material. Sections gilded using polymers were deliberately overlapped with areas gilded traditionally in order to test the appearance and relative of reversibility of both traditional and modern synthetic materials.

Each polymer was tested on five samples each prepared in the following way:

- **Sample A:**
  
  A polymer solution was applied directly to a gesso and gouache paints foundation that would imitate bole and was then gilded. Such a technique could be convenient in situations involving deep losses that have subsequently been in-filled with gesso or composition material (a common occurrence). In such circumstances, isolation layers could be applied prior to application of gesso.

- **Sample B:**
  
  A polymer solution was mixed with gouache paints/ or pigments, applied over the gesso surface without any isolation layer and then gilded.

- **Sample C:**
  
  A polymer solution was mixed with gouache paints/ pigments and then
applied over gesso previously isolated with a similar polymer.

• **Sample D:**

A polymer solution was applied over a foundation consisting of gouache paints imitating bole foundation and gesso isolated with 10% B-72 in xylene (w/v) (Paraloid®B-72 in this form is commonly used in the conservation of gilded objects to create an isolation layer prior to in-filling or in-gilding.)

• **Sample E:**

A polymer solution was mixed with gouache paints/ or pigments, and applied over a gesso surface previously sealed with 10% B-72 in xylene (w/v).

Samples A and D were abraded slightly with very fine sandpaper, prior to the application of a final coat of gouache paints. The dried surface of paint was then buffed with a tough short-haired brush in order to remove roughness in the surface caused by air bubbles (i.e. in a manner similar to the preparation of bole foundation in the traditional matte water gilding technique). Following the application of polymer/gouache paints or polymer/pigment mixtures, when the surface was touch-dry, buffing was also performed on samples B, C, and E.

The gold leaf application technique employed was determined by the properties of the polymer, and could include

- laying the gold leaf on a surface that retained tacky, or
- laying gold leaf on a surface wetted with a solvent, or mixture of solvents, to activate tackiness, or
- laying gold leaf on a surface with tackiness activated by exhalation.
3.4. Testing criteria

The selected polymers were evaluated for:

- **Suitability for gilding**

  The applied material should either preserve tackiness for some time or else it should be possible to revive the material’s tackiness by wetting or humidifying the surface.

- **Working abilities**

  The application technique should be reasonably easy to perform and harmless for the operator. It should also be the most appropriate for future conservation treatments. Although many resins used as consolidants or varnishes can be applied as a spray, areas that require in-gilding are frequently very small or do not have regular borderlines. In such cases, brushing is a more convenient means of application than spraying and therefore it was decided that any polymers selected should have good brushing abilities.\(^{23}\)

- **The appearance of dried film prior to gold leaf application**

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\(^{23}\) An additional test was carried out in order to evaluate the difference in the appearance of dried film composed of B-72 in toluene and xylene. Two samples with gesso layers received three coats of gouache paints simulating a bole foundation. The second layer of paint was slightly sanded with very fine paper prior to the application of the final coating. When the surface dried, one sample was coated with a 10% B-72 solution in xylene (w/v), while the second was coated with 10% B-72 in toluene (w/v). Both solutions were applied by brush. No difference was observed in the appearance of the two dried films when examined by the naked eye by three conservators under the same light conditions using varied angles of reflection. This test indicated that variations in the appearance of both films could exist from a spray application (Samet, 1998), but that it has little meaning when the varnish is applied by brush.
The applied material should create a smooth low sheen/matte surface. No brush strokes should be apparent on the finished surfaces. The surfaces tested were compared with those of bole foundations prepared in the traditional manner for matte water gilding.

- **Adhesion of gold leaf.**

- **The appearance of the gilded surface, specifically regarding the level of gloss and texture in comparison to the portion gilded using traditional method.**

- **The appearance of the gilded surface after the application of a traditional protective coating (ormolu – 5% (w/v) rabbit skin glue + 10% of diluted seedlac or shellac), in comparison to a surface gilded in the traditional technique coated with the same mixture.**

- **The removability of the dried film.**

Removability tests were performed two-to-four weeks after gilding and carried out with cotton swabs dipped in various solvents of increasing polarity applied to surfaces of approximately 0.5 - 1 cm². The reaction of the polymer and the gilded surface was observed using a stereo microscope. Prior to solvent application, the ormolu protective coating in the tested areas was removed with saliva. The solvents selected for testing included a Shellsol®A/ Shellsol®T mixture²⁴, toluene, xylene, xylene/acetone, acetone, ethanol, and methylated spirit. The solubility parameters of the selected solvents and their fractional solubility parameters are included in table 11. These solvents are those generally selected for the removal of overpainting layers from original gilded layers. Although, in theory, they are safe to use on water gilded surfaces, in a

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²⁴ 11.5:85.5%; approximate ratio of low aromatic white spirit
number of treatments it has been observed that their prolonged application can result in either removal or damage to original gilded surfaces. This problem is particularly acute when treatments involve strongly polar and/or strongly hydrogen bonded solvents such as acetone and ethanol and requires the repeated movement of cotton swabs on the gilded surface. As noted earlier, the duration of solvent application is of critical importance to the qualities of the dried film. Consequently, it was resolved that during testing, each operation should not exceed 30 seconds.

The aesthetic qualities of the finished surfaces were evaluated using blind testing conducted by a panel of three expert conservators\(^{25}\) experienced in traditional gilding techniques.

### 3.5. Testing results

#### 3.5.1. Rhoplex®AC33/N580 (1:1, v/v)

(Photographs: 3 to 7)

#### 3.5.1.1. Evaluation of performance during application of polymers

The application of Rhoplex® mixed with gouache paints proved troublesome. Since the medium was quickly saturated by the gesso foundation and the therefore became immobile during application, it proved particularly difficult, for instance,

\(^{25}\) I am grateful to Barbara Dabrowa, Frame Conservator, Art Gallery of New South Wales, Sydney, Australia, and to Tom Proctor, Frame Conservator, Dulwich Art Gallery, London, England, for their assistance in evaluating the results of my experiments.
to apply the mixture correctly over a plain gesso surface. Repeated brush strokes were inhibited proper levelling of the film became impossible to effect. Furthermore, single applications of mixtures containing Rhoplex® resins were liable to separate, creating a rather transparent film with an uneven distribution of pigment. Since it was shown that second applications of the mixture were also liable to remove the previous layers, they were not performed on the samples used for materials testing.

No significant problems were encountered with the application of polymer mixtures over gouache paints used as foundations in samples A and D. It was noted, however, that unless the film was applied as medium viscosity solutions, requiring particularly rapid controlled drying of this material, the suitability of Rhoplex® films was low. Furthermore, the formation of thin films required the operator to carry only very small amount of solutions onto the surface and use long smooth, quick and even brushstrokes without repetition.

3.5.1.2. Evaluation of the appearance of dried film prior to gold leaf application

After application of gouache paints, samples A and D formed an opaque low sheen surface that was suitably level and reminiscent of bole foundation. Nevertheless, after application of Rhoplex® mixtures, the surface of A and D samples were shinier than those of other samples, and also much more gloss than the surface of bole foundation prepared in a traditional manner. Although samples prepared in the manner of B, C, and E had greater matte qualities, their colour was uneven and deemed unacceptable. Overall, sample E furnished the highest gloss surface, followed by samples A, C, D, and B.
3.5.1.3. Application of gold leaf and evaluation of the appearance of the gilded surface

After drying, films formed by mixture of Rhoplex® AC33/N580 retained a slightly tacky surface that was found to be suitable for gold leaf adhesion. Empirical observations of the behaviour of this material suggested that gold leaf would adhere very well to the prepared substrates. Unfortunately, however, in all cases the appearance of the finished gilded surface was rather ‘glossy’ and more reminiscent of oil gilding surfaces rather than those achieved using water gilding techniques. Samples based on regime E had the best surface appearances (polymer mixed with gouache paints applied over the gesso surface sealed previously with 10% B-72 in xylene (w/v)). Nevertheless, even in this instance, slight brush stroke marks were still apparent. The quality of surface appearance decreased in the order of samples E, B, D, C, and A.

3.5.1.4. Evaluation of appearance of the gilded surface after application of traditional protective coating

Although the application of protective films intensified the matte appearance of the surface, it did not change its texture and did little to cover the brush stroke marks, which were still apparent. Despite producing the results bearing comparison to those obtained using traditional techniques, in all instances samples based on regime E retained an appearance reminiscent of oil gilding.

3.5.1.5. Removability of dried film from the part gilded with traditional gilding technique

In all samples Rhoplex® AC33/N580 film responded very quickly (below 30
seconds) to all activating solvents, including the low aromatic mixture of Shellsol®A/ Shellsol®T. Furthermore, films could be easily removed with no harm to the adjacent traditionally gilded areas. It was, however, observed that gilding was more sensitive to more polar solvents (acetone, ethanol, methylated spirit) than non polar.
<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. no barrier coating L2 watercolour paint L3 AC33/N580</td>
<td>No apparent problems</td>
<td>RS</td>
<td>GB</td>
<td>GB</td>
</tr>
<tr>
<td>B. L1. no barrier coating L2. AC33/N580 + watercolour paint</td>
<td>Poor: quick drying, repeat strokes impossible, uneven distribution of pigment</td>
<td>RB</td>
<td>RSB</td>
<td>RB</td>
</tr>
<tr>
<td>C. L1. AC33 L2. AC33/N580 + watercolour paint</td>
<td>Satisfactory, but colour coating is transparent and a building up of layers is impossible</td>
<td>GB</td>
<td>GSB</td>
<td>GSB</td>
</tr>
<tr>
<td>D. L1. 10% B-72 in xylene L2. watercolour paint L3. AC33/N580</td>
<td>No apparent problems</td>
<td>RS</td>
<td>GSB</td>
<td>GB</td>
</tr>
<tr>
<td>E. L1. 10% B-72 in xylene L2. AC33/N580 + watercolour paint</td>
<td>Satisfactory, but colour coating is transparent and a building up of layers is impossible</td>
<td>GB</td>
<td>GB</td>
<td>GB</td>
</tr>
</tbody>
</table>

Legend:

- **E**: excellent, identical with an appearance of the traditional mat water gilding
- **GA**: good matt appearance, but poor adhesion of gold leaf
- **GB**: good matt appearance but brush strokes slightly apparent/or surface uneven
- **GO**: good matt, but oil gilding appearance remains
- **GS**: good although surface slightly shiny
- **GSB**: good although surface slightly shiny and brush strokes slightly apparent
- **RB**: reasonable matt, but brush strokes apparent/or surface uneven
- **RR**: reasonable matt, but surface rough
- **ROR**: reasonable matt, but oil gilding appearance remains and surface is rough
- **RS**: reasonable, but surface evidently shiny
- **RSB**: reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
- **PB**: poor, brush strokes very apparent
- **PS**: poor, surface to shiny
- **PSB**: poor, surface to shiny and brush strokes apparent
- **PA**: poor, gold leaf does not adhere
- **POA**: poor, gold leaf does not adhere properly and oil gilding appearance remains
- **PR**: poor, surface very rough
Stage I: Rhoplex® AC33/ N580

Photo 3 - Stage I: Rhoplex® AC33/ N580; all samples prior to gilding

Photo 4 - Stage I: Rhoplex® AC33/ N580; samples A and B prior to gilding

Photo 5 - Stage I: Rhoplex® AC33/ N580; sample A after gilding

Photo 6 - Stage I: Rhoplex® AC33/ N580; sample B after gilding

Photo 7 - Stage I: Rhoplex® AC33/ N580; sample A after gilding and an application of ormolu
3.5.2.  Plextol®B 500

(Photographs: 8 to 10)

3.5.2.1.  Evaluation of performance during application of polymers

The first attempt at dilution of Plextol®B500 was made with a prepared mixture of water/ethanol (4:1) and appropriate gouache paints. Unfortunately this mixture proved to be slightly immiscible, producing a slight opalescence phenomenon within the emulsion that subsequently turned a red-brown colour bole-like foundation into an unacceptable violet hue. Thus, in order to achieve a suitable tone, in each test Plextol®B500 was first diluted with water/ethanol (4:1) to the required concentration (1:1, v/v) and then minute amounts of appropriate gouache colours were added straight from the tube and mixed thoroughly. It was noticed that opalescence effect of Plextol®B500 could be neutralised using cadmium yellow deep or cadmium scarlet (Winsor & Newton Designers Gouache). Other colours successfully used to achieve colour-simulated traditional bole were cadmium deep red, raw umber, sepia, ivory black, and harannah lake (Winsor & Newton Designers Gouache).

The mixture of Plextol® B500 and gouache paints was filtered through a very fine mesh polyester film, in a manner similar to traditional bole preparations. No problems were encountered when attempting to build up of subsequent layers of foundation in samples based on B, C, and E. In order to achieve an even opaque foundation, three very thin layers of Plextol®B500/gouache paints mixture were applied. The dried surface of such foundations could also be slightly sanded before application of the final, third coating and buffed with a tough short-haired brush prior to application of gold leaf.
3.5.2.2. Evaluation of the appearance of dried film prior to gold leaf application

Surfaces of samples based on methods B, E, and C were consistently of low sheen appearance, reminiscent of that of traditional bole foundations. Surfaces of samples A and D however, had significant reflectivity and thus shine. The texture of all samples was similar to that of traditional bole substrates.

3.5.2.3. Application of gold leaf and evaluation of the appearance of the gilded surface

The dried surfaces created using Plextol®B500 were activated by exhalation just prior to application of gold leaf. Good adhesion of gold leaf was observed on all samples.

In samples using methods B, C, and E the level of gloss and texture of the gilded surface was very similar to the sample sections gilded in the traditional technique. Samples using method C furnished the surface with the best appearance. Samples using methods A and D were slightly more gloss in appearance than the parts gilded in the traditional method.

3.5.2.4. Evaluation of appearance of the gilded surface after application of traditional protective coating

The panel judged the surfaces of all samples to be excellent in appearance, and when compared with the parts gilded in traditional materials; the techniques of application providing similar degrees of gloss and texture. The only drawback of these non-traditional methods was the appearance of joined lines between gold leaves, which were rather more reminiscent of joining lines in the oil gilding
technique rather than matte water-gilding.

3.5.2.5. Removability of dried film from the part gilded with traditional gilding technique

Plextol®B500 films were easily removable from the surfaces gilded using the traditional method with all solvents tested except the Shellsol®A/Shellso® T mixture, to which films showed no reaction in the 30 seconds following application. Each solvent caused dilution or rapid swelling of the film, which could then be easily removed with cotton swabs.
Table 3: Performance of Plextol® B 500

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. no barrier coating</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>E</td>
</tr>
<tr>
<td>L2 watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3 Plextol® B 500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. L1. no barrier coating</td>
<td>Good, but uneven distribution of pigment apparent in the first coat</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>L2 Plextol® B 500 + watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. L1. Plextol® B 500</td>
<td>No apparent problems, building up of layers is achievable</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>L2 Plextol® B 500 + watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. L1. 10% B-72 in xylene</td>
<td>No apparent problems, building up of layers is achievable</td>
<td>GS</td>
<td>GS</td>
<td>E</td>
</tr>
<tr>
<td>L2 watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3 Plextol® B 500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. L1. 10% B-72 in xylene</td>
<td>No apparent problems, building up of layers is achievable</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>L2 Plextol® B 500 + watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:

E - excellent, identical with an appearance of the traditional mat water gilding
GA - good matt appearance, but poor adhesion of gold leaf
GB - good matt appearance but brush strokes slightly apparent/or surface uneven
GO - good matt, but oil gilding appearance remains
GS - good although surface slightly shiny
GSB - good although surface slightly shiny and brush strokes slightly apparent
RB - reasonable matt, but brush strokes apparent/or surface uneven
RR - reasonable matt, but surface rough
ROR - reasonable matt, but oil gilding appearance remains and surface is rough
RS - reasonable, but surface evidently shiny
RSB - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
PB - poor, brush strokes very apparent
PS - poor, surface to shiny
PSB - poor, surface to shiny and brush strokes apparent
PA - poor, gold leaf does not adhere
POA - poor, gold leaf does not adhere properly and oil gilding appearance remains
PR - poor, surface very rough
Stage I: Plextol® B500

Photo 8 - Stage I: Plextol® B500; all samples prior to gilding

Photo 9 - Stage I: Plextol® B500; sample A prior to gilding

Photo 10 - Stage I: Plextol® B500; all samples after gilding
3.5.3. *Liquitex® Matte Medium*

(Photographs: 11 to 13)

**3.5.3.1. Evaluation of performance during application of polymers**

Without dilution, Liquitex® Matte Medium is a viscous substance, which prior trial tests indicated could create problems with forming a thin, even surface. Indeed, the medium indeed proved too viscous to form a thin, well levelled layer and therefore, brush strokes were rather difficult to hide. In order to avoid this problem, the medium required dilution in the proportion 3:1 with distilled water/ethanol mixture (1:1) for samples A and D. For samples in regimes B, C, and E, Liquitex® Matte Medium was diluted in ratio 3:1 with gouache paints dissolved in distilled water/ethanol mixture (1:1). Samples applied using methods A and D received one coat of diluted Liquitex® Matte Medium, 3:1 with distilled water/ethanol (1:1), applied over gouache paints foundation. The mixture of Liquitex® Matte Medium with gouache paints was applied in thin layers twice over the surface of samples using methods B, C, and E, in order to build up appropriate colour of the substrate. The brushability of this material was very good, allowing build up of subsequent layers of foundation without any difficulty.

**3.5.3.2. Evaluation of the appearance of dried film prior to gold leaf application**

Liquitex® Matte Medium mixtures created an excellent foundation reminiscent of the traditional background for matte water gilding; it was well levelled and was judged to have a suitable even texture.
3.5.3.3. Application of gold leaf and evaluation of the appearance of the gilded surface

The dried film of Liquitex® Matte Medium was activated via exhalation prior to gold leaf application. Although adhesion of gold leaf to the substrate was achievable in samples using methods based on C and E, the texture of the surface was very strongly reminiscent of that found in traditional oil gilding. In addition, the gilded surfaces formed had a deeper matte appearance than parts of the samples gilded with traditional materials.

Samples using methods A, B and D had very poor adhesion and therefore the Samples A and D were repeated several times. Whereas samples based on method D received one coat of undiluted Liquitex® Matte Medium applied over gouache paints foundation, samples based in A received two coats of dispersion diluted as described previously. Although following this altered methodology gold leaf adhered very well to the substrate using method D, its surface appearance was that of an oil gilded surface, and therefore no improvement on gilding executed with the Rhoplex® mixtures discussed above. Although adhesion of gold leaf in a sample based on the revised method A was sound, it remained poorer than that obtained with undiluted Liquitex®. The texture of the surface formed was better than obtained in the other Liquitex® tested samples, but the matte appearance was much deeper than had been anticipated.

3.5.3.4. Evaluation of appearance of the gilded surface after application of traditional protective coating

The application of proteinaceous protective coating was found to enhance the spectacular reflectance of surfaces and thus their matte appearance, uniting parts gilded traditionally with new polymer-based gilding. Nevertheless the oil gilding-
like characteristic appearance of tested sections was judged a drawback in all samples. In addition, Liquitex®-based gilded surfaces showed particular sensitivity to the addition of ormolu mixtures, which caused small blistering of the surfaces after one brushing. The blisters partially disappeared only partially on drying.

The surface of samples based on method A showed the best results of all five. It was judged to have an acceptable texture and reasonable degrees of colour matching were achieved.

3.5.3.5. Removability of dried film from the part gilded with traditional gilding technique

The removal of freshly coated Liquitex® films was easy and did not cause any damage to the traditional gilding. Liquitex® films responded well to all solvents tested except the Shellsol®A/ Shellsol®T mixture, to which films showed no reaction in the 30 seconds of application. Each solvent caused dilution or rapid swelling of the film, which could then be easily removed with cotton swabs.
Table 4: Performance of Liquitex® Matte Medium

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. no barrier coating</td>
<td>L2 watercolour paint</td>
<td>L3 Liquitex® Matte Medium 3:1 with distilled water with ethanol (1:1)</td>
<td>No apparent problems</td>
<td>E</td>
</tr>
<tr>
<td>B. L1. no barrier coating</td>
<td>L2. Liquitex® Matte Medium 3:1 with diluted watercolour paints in water/ethanol (1:1)</td>
<td>No apparent problems, building up of layers is achievable</td>
<td>E</td>
<td>POA</td>
</tr>
<tr>
<td>C. L1. Liquitex® Matte Medium 3:1 with distilled water/ethanol (1:1)</td>
<td>L2. Liquitex® Matte Medium 3:1 with diluted watercolour paints in water/ethanol (1:1)</td>
<td>No apparent problems, building up of layers is achievable</td>
<td>E</td>
<td>GO</td>
</tr>
<tr>
<td>D. L1. 10% B-72 in xylene L2. watercolour paint</td>
<td>L3. Liquitex® Matte Medium 3:1 with distilled water/ethanol (1:1)</td>
<td>No apparent problems, building up of layers is achievable</td>
<td>E</td>
<td>1.POA 2. GO</td>
</tr>
<tr>
<td>E. L1. 10% B-72 in xylene</td>
<td>L2. Liquitex® Matte Medium 3:1 with diluted watercolour paints in water/ethanol (1:1)</td>
<td>No apparent problems, building up of layers is achievable</td>
<td>E</td>
<td>GO</td>
</tr>
</tbody>
</table>

Legend:

- E - excellent, identical with an appearance of the traditional mat water gilding
- GA - good matt appearance, but poor adhesion of gold leaf
- GB - good matt appearance but brush strokes slightly apparent/or surface uneven
- GO - good matt, but oil gilding appearance remains
- GS - good although surface slightly shiny
- GSB - good although surface slightly shiny and brush strokes slightly apparent
- RB - reasonable matt, but brush strokes apparent/or surface uneven
- RR - reasonable matt, but surface rough
- ROR - reasonable matt, but oil gilding appearance remains and surface is rough
- RS - reasonable, but surface evidently shiny
- RSB - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
- PB - poor, brush strokes very apparent
- PS - poor, surface to shiny
- PSB - poor, surface to shiny and brush strokes apparent
- PA - poor, gold leaf does not adhere
- POA - poor, gold leaf does not adhere properly and oil gilding appearance remains
- PR - poor, surface very rough
Stage I: Liquitex® Matte Medium

Photo 11 - Stage I: Liquitex® Matte Medium; samples A and B prior to gilding

Photo 12 - Stage I: Liquitex® Matte Medium; samples C, D and E prior to gilding

Photo 13 - Stage I: Liquitex® Matte Medium; samples D and E after gilding
3.5.4. *Paraloid® B-72 in DEB*

(Photograph: 14)

### 3.5.4.1. Evaluation of performance during application of polymers

Initial attempts at the application of 5% B-72 in DEB (w/v) mixed with pigments using methods B, C, and D resulted in formation of very rough surfaces. The drying times of applied solutions were very long, bonding power exceptionally weak and the resultant surface powdering. It was decided to increase the concentration of B-72 in DEB to 10% (w/v) (mixtures with pigments filtered through very fine polyester mesh prior to application). Although the bonding of film surfaces achieved with this variation was much better, the resultant surfaces remained unacceptably rough and the distribution of pigments in the dried layer was consistently uneven. In addition, it proved impossible to build up the subsequent layers of foundation in order to imitate bole.

Testing for methods A & D were based upon 5% solutions (w/v), which were applied twice over gouache paints foundation.

### 3.5.4.2. Evaluation of the appearance of dried film prior to gold leaf application

The surfaces of samples formed using methods A and D, prior to gold leaf application, were smooth with a very good low sheen appearance. Unfortunately in samples based on B, C, and E, the rough texture of the surface formed was judged a completely unsatisfactory background for gilding.
3.5.4.3. Application of gold leaf and evaluation of the appearance of the gilded surface

The system judged best for gold leaf application was found to be based on methods A and D. Nevertheless, in all cases the adhesion of gold leaf to the surfaces was poor. In addition, gilding in parts of the surface where gold leaf did adhere was reminiscent of oil gilding executed on a rough surface in a very unexperienced manner. Consequently, further tests using this material were deemed unjustified.
Table 5: Performance of B-72 in diethylbenzene.

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. no barrier coating</td>
<td>No apparent problems</td>
<td>E</td>
<td>PA</td>
<td>---</td>
</tr>
<tr>
<td>L2 watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3 5% B-72 in DEB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. L1. no barrier coating</td>
<td>After two layers of 5% B-72 in DEB the surface was very rough and powdery. Concentration was changed to 10%, which improved bonding, but the surface was still rough, and a building up of foundation layers was impossible.</td>
<td>RR</td>
<td>POA</td>
<td>PR</td>
</tr>
<tr>
<td>L2. Firstly: 5% B-72 in DEB + pigments, secondly 10% B-72 in DEB + pigments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. L1. 5% B-72 in DEB</td>
<td>After two layers of 5% B-72 in DEB the surface was very rough and powdery. Concentration was changed to 10%, which improved bonding, but the surface was still rough, and a building up of foundation layers was impossible.</td>
<td>RR</td>
<td>POA</td>
<td>PR</td>
</tr>
<tr>
<td>L2. Firstly: 5% B-72 in DEB + pigments, secondly 10% B-72 in DEB + pigments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>E</td>
<td>PA</td>
<td>----</td>
</tr>
<tr>
<td>L2. watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3. 5% B-72 in DEB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. L1. 10% B-72 in xylene</td>
<td>Similar to B &amp; C</td>
<td>RR</td>
<td>POA</td>
<td>PR</td>
</tr>
<tr>
<td>L2. Firstly: 5% B-72 in DEB + pigments, secondly 10% B-72 in DEB + pigments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:

E - excellent, identical with an appearance of the traditional mat water gilding
GA - good matt appearance, but poor adhesion of gold leaf
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RSB - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
PB - poor, brush strokes very apparent
PS - poor, surface to shiny
PSB - poor, surface to shiny and brush strokes apparent
PA - poor, gold leaf does not adhere
POA - poor, gold leaf does not adhere properly and oil gilding appearance remains
PR - poor, surface very rough
Stage I: Paraloid® B-72 in DEB

Photo 14 - Stage I: Paraloid® B-72 in DEB; samples D and E after gilding

Stage I: Paraloid® B-72 in toluene

Photo 15 - Stage I: Paraloid® B-72 in toluene; all samples prior to gilding

Photo 16 - Stage I: Paraloid® B-72 in toluene; all samples after gilding
3.5.5. *Paraloid® B-72 in toluene*

(Photographs: 15 to 17)

3.5.5.1. **Evaluation of performance during application of polymers**

20 % B-72 in toluene (w/v) formed a very viscous liquid, which created some difficulties in application in regards to levelling of the surface and hiding brush strokes.

3.5.5.2. **Evaluation of the appearance of dried film prior to gold leaf application**

Samples under regimes A and D received only one coat of B-72 solution in toluene (w/v) applied over a foundation of gouache paints. The film formed had a distinctive smooth low sheen appearance. Samples B, C, and E received three coats of B-72 mixed with pigments, which was filtered through a very fine polyester mesh prior to application. After drying, the surface achieved retained a rough texture. Despite meticulous care taken in its application in all samples, brush stroke marks were apparent.
3.5.5.3. **Application of gold leaf and evaluation of the appearance of the gilded surface**

Gold leaf was applied on the surface wetted with a mixture of Shellsol®A/ Shellsol®T and ethanol (75:25%) in a similar fashion to previous tests using B-72 in DEB. In methods A and D, lack of adhesion was noticed following the first application of gold leaf in the areas following shallows in brush marks, and only slightly more surface was covered with application of the second layer of gold leaf. Nevertheless, the gilded surface was very smooth, reminiscent of traditional water gilding. A test based on burnishing with agate furnished very promising, though high gloss, results. No problems with adhesion or separation of the gold leaf were observed.

The gilded surface of samples using methods B, C, and E was very rough and produced crinkles characteristic of oil gilding performed on gold size that was too wet.

3.5.5.4. **Evaluation of appearance of the gilded surface after application of traditional protective coating**

Although the matte appearance of all samples was improved following application of ormolu, the texture remained unchanged. Despite the brush marks on samples based on A and D, the gilding was reminiscent of traditional matte water gilding surfaces.

---

26 11.5:88.5%; ratio of petroleum ether
3.5.5.5. **Removability of dried film from the part gilded with traditional gilding technique**

The Shellsol®A/Shellsol®T (11.5:88.5%) mixture was not tested on B-72 since the resin is known to be insoluble in aliphatic hydrocarbons. Although the sample films responded well to all other solvents included in the tests, the strengths of the resultant films varied as a function of solvent, as did the dissolution times. Polar solvents were more effective in dissolving B-72 films, especially toluene, acetone, and ethanol whereas xylene or xylene/acetone mixtures required more time. Nevertheless, all solvents dissolved or caused swelling of the film of overgilding and permitted its partially or complete removal from the tested section without harm to the neighbouring traditionally gilded area within 30 seconds. Areas pigmented with gouache paint-containing coatings required additional treatment with saliva to effect their removal.
### Table 6: Performance of B-72 in toluene

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
</table>
| A. L1. no barrier coating  
L2 watercolour paint  
L3 20% B-72 in toluene | High viscosity liquid, brush stroke marks remain on the surface | GB | GB, GO; after application of second layer GA | GB |
| B. L1. no barrier coating  
L2. 20% B-72 in toluene + pigments | A building up of layers is possible but the surface is very rough due to air bubbles | RR  
RS | PR  
PR | -- |
| C. L1. 20% B-72 in toluene  
L2. 20% B-72 in toluene + pigments | A building up of layers is possible but the surface is very rough due to air bubbles | RR  
RS | PR  
PR | -- |
| D. L1. 10% B-72 in xylene  
L2. watercolour paint  
L3. 20% B-72 in toluene | High viscosity liquid, brush stroke marks remain on the surface | GB | GB, GO; after application of second layer GA | GB, GO |
| E. L1. 10% B-72 in xylene  
L2. 20% B-72 in toluene + pigments | A building up of layers is possible but the surface is very rough due to air bubbles | RR  
RS | PR  
PR | -- |

Legend:
- **E** - excellent, identical with an appearance of the traditional mat water gilding
- **GA** - good matt appearance, but poor adhesion of gold leaf
- **GB** - good matt appearance but brush strokes slightly apparent/or surface uneven
- **GO** - good matt, but oil gilding appearance remains
- **GS** - good although surface slightly shiny
- **GSB** - good although surface slightly shiny and brush strokes slightly apparent
- **RB** - reasonable matt, but brush strokes apparent/or surface uneven
- **RR** - reasonable matt, but surface rough
- **ROR** - reasonable matt, but oil gilding appearance remains and surface is rough
- **RS** - reasonable, but surface evidently shiny
- **RSB** - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
- **PB** - poor, brush strokes very apparent
- **PS** - poor, surface to shiny
- **PSB** - poor, surface to shiny and brush strokes apparent
- **PA** - poor, gold leaf does not adhere
- **POA** - poor, gold leaf does not adhere properly and oil gilding appearance remains
- **PR** - poor, surface very rough
Stage I: Paraloid® B-72 in toluene and in xylene

Photo 17 - Stage I: B-72 in toluene; samples C, D and E after gilding and ormolu

Photo 18 - Stage I: B-72 in xylene; samples A and B after gilding and ormolu

Photo 19 - Stage I: B-72 in xylene; all samples after gilding
3.5.6. *Paraloid® B-72 in xylene*

(Photographs: 18 & 19)

3.5.6.1. Evaluation of performance during application of polymers

No reports of problems observed with the application of 10% solution of B-72 in xylene (w/v) have appeared in the conservation literature. Brushing was easy and levelling was possible with repeated brush strokes.

3.5.6.2. Evaluation of the appearance of dried film prior to gold leaf application

Samples using methods A and D received two coats of clear B-72, and the created surface had an excellent smooth texture of low sheen similar to bole foundation applied in a traditional manner.

Samples using regimes B and C received three layers of B-72/pigments mixture, which was filtered through very fine polyester mesh prior to application. Despite sanding prior to application of successive coatings, and buffing with a tough short-haired brush prior to application of gold leaf, the texture of the resultant surfaces remained rough. Microscopic examination revealed the roughness was caused by air bubbles trapped within the films. The problem might, therefore, in future be avoided with the addition of a surfactant, if a suitable reagent could be found.
3.5.6.3. Application of gold leaf and evaluation of the appearance of the gilded surface

The adhesion of gold leaf using methods B, C, and E was better than that achieved using B-72 in DEB but worse than of 20% B-72 in toluene. Adhesion in samples A and D was improved by double gilding. The surface in these samples achieved an appearance judged excellent, similar in sheen and texture to parts gilded in the traditional technique.

The surface of samples using methods B and C was too rough to proceed with further testing.

3.5.6.4. Evaluation of appearance of the gilded surface after application of traditional protective coating

Samples using A and D were coated with traditional protective coating and surprisingly the appearance of the surface came to resemble that produced in oil gilding. An additional drawback was the appearance of joining lines between ingilded and traditionally gilded areas, which became very apparent following the addition of the protective coating.

3.5.6.5. Removability of dried film from the part gilded with traditional gilding technique

No problems were observed with the removal of the B-72 films from all samples. They proved to be more responsive to the tested solvent than films formed with B-72 in toluene, probably due to thinner coating that was formed with a lower resin
concentration solution.

Table 7: Performance of B-72 in xylene

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
</table>
| A. L1. no barrier coating  
L2. watercolour paint  
L3. 10% B-72 in xylene | No apparent problems | E | GA, after application of second layer E | GO |
| B. L1. no barrier coating  
L2. 10% B-72 in xylene + pigments | No apparent problems | RR | RR | ------ |
| C. L1. 20% B-72 in toluene  
L2. 10% B-72 in xylene + pigments | No apparent problems | RR | RR | ------ |
| D. L1. 10% B-72 in xylene  
L2. watercolour paint  
L3. 10% B-72 in xylene | No apparent problems | E | GA, after application of second layer E | GO |

Legend:

E - excellent, identical with an appearance of the traditional mat water gilding  
GA - good matt appearance, but poor adhesion of gold leaf  
GB - good matt appearance but brush strokes slightly apparent/or surface uneven  
GO - good matt, but oil gilding appearance remains  
GS - good although surface slightly shiny  
GSB - good although surface slightly shiny and brush strokes slightly apparent  
RB - reasonable matt, but brush strokes apparent/or surface uneven  
RR - reasonable matt, but surface rough  
ROR - reasonable matt, but oil gilding appearance remains and surface is rough  
RS - reasonable, but surface evidently shiny  
RSB - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough  
PB - poor, brush strokes very apparent  
PS - poor, surface to shiny  
PSB - poor, surface to shiny and brush strokes apparent  
PA - poor, gold leaf does not adhere  
POA - poor, gold leaf does not adhere properly and oil gilding appearance remains  
PR - poor, surface very rough
3.5.7. *Aquazol®500 (poly(2-ethyl-2-oxazoline) in water/ethanol mixture*)

(Photographs: 20 & 21)

3.5.7.1. *Evaluation of performance during application of polymers*

The 20% concentration solutions of Aquazol® 500 in water/ethanol (10:1) (w/v) recommended in the conservation literature was too viscous for use in gilding. The concentration of polymer was thus reduced to 10% (w/v) in water/ethanol mixture (10:1).

No problems were apparent when brushing the 10% (w/v) polymer solution. It remained, however, a viscous liquid and therefore difficult to work. Nevertheless, repeated brush strokes were possible and the building up of foundation layers was achievable. Some gas particles were released whilst mixing with gouache paints, and the poor wetting properties of the films resulted in a line at the interface at which new and traditional materials met.

3.5.7.2. *Evaluation of the appearance of dried film prior to gold leaf application*

Uneven distribution of pigments was observed in samples using Method B following applications of the first layer of polymer/gouache paints mixtures. In addition, after the application of three layers of foundation, due to air bubbles the surface had a slightly rough texture. Despite meticulous care, in all samples brush strokes proved impossible to remove. The most uniform surface texture was
achieved using Aquazol®500 applied over gouache paint foundations (A and D).

It was observed that Aquazol®500 mixed very well with gouache paints and during application it behaved similarly to traditional bole/gelatine mixtures.

3.5.7.3. Application of gold leaf and evaluation of the appearance of the gilded surface

Gold leaf adhered well to all surfaces. The gilding of samples produced using methods B, C, and E produced a sheen deemed acceptable. Nevertheless, the resultant texture was slightly reminiscent of oil gilding. Samples produced using method D (Aquazol®500 over gouache paints foundation with B-72 in xylene as isolation coating) formed a very smooth surface. Its texture was the closest to traditional matte water gilding of all materials tested. Nevertheless, due to poor wetting properties of the applied polymer solution, the line joining non-traditional and traditional gilding remained obvious.

Sections of the surfaces produced using method D were burnished with agate in order to test burnishing abilities of Aquazol®500 foundation. The burnished surface behaved very similarly to gilding with traditional bole foundations; the foundation was reasonably soft allowing for good compression of gold leaf and foundation, the gloss achieved was very good. No problems with gold leaf adhesion were encountered.
3.5.7.4. Evaluation of appearance of the gilded surface after application of traditional protective coating

A traditional protective coating was applied over samples produced using methods D and E. Surprisingly, the gilding proved to be so sensitive to the water solution that one brush stroke could remove all thin, hair-like wrinkle lines from the gold leaf (characteristic gold beaten marks) rendering the red foundation underneath visible and creating a distinctive web-like pattern on the surface.

3.5.7.5. Removability of dried film from the part gilded with traditional gilding technique

Since the resin is known to be insoluble in aromatic solvents, solubility tests using these hydrocarbons were not conducted. By contrast, polar solvents such as acetone, ethanol and methylated spirits performed very well immediately removing Aquazol® films without harm to the neighbouring traditionally gilded surface.
Table 8: Performance of 10% Aquazol® 500 (poly(2-ethyl-2-oxazoline) (w/v) in water/ethanol

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. no barrier coating</td>
<td>No apparent problems</td>
<td>GB</td>
<td>GA</td>
<td>-----------</td>
</tr>
<tr>
<td>L2 watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3 10% Aquazol® 500 in water/ethanol (10:1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. L1. no barrier coating</td>
<td>No apparent problems</td>
<td>GB</td>
<td>ROR</td>
<td>-----------</td>
</tr>
<tr>
<td>L2. 10% Aquazol® 500 in water/ethanol (10:1) + watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. L1. 10% Aquazol® 500 in water/ethanol (10:1)</td>
<td>No apparent problems</td>
<td>GB</td>
<td>GO</td>
<td>-----------</td>
</tr>
<tr>
<td>L2. 10% Aquazol® 500 in water/ethanol (10:1) + watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>GB</td>
<td>E</td>
<td>GA</td>
</tr>
<tr>
<td>L2. watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3. 10% Aquazol® 500 in water/ethanol (10:1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>GB</td>
<td>ROR</td>
<td>RB, GA</td>
</tr>
<tr>
<td>L2. 10% Aquazol® 500 in water/ethanol (10:1) + watercolour paint</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:

E - excellent, identical with an appearance of the traditional mat water gilding
GA - good matt appearance, but poor adhesion of gold leaf
GB - good matt appearance but brush strokes slightly apparent/or surface uneven
GO - good matt, but oil gilding appearance remains
GS - good although surface slightly shiny
GSB - good although surface slightly shiny and brush strokes slightly apparent
RB - reasonable matt, but brush strokes apparent/or surface uneven
RR - reasonable matt, but surface rough
ROR - reasonable matt, but oil gilding appearance remains and surface is rough
RSB - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
PB - poor, brush strokes very apparent
PS - poor, surface to shiny
PSB - poor, surface to shiny and brush strokes apparent
PA - poor, gold leaf does not adhere
POA - poor, gold leaf does not adhere properly and oil gilding appearance remains
PR - poor, surface very rough
Stage I: Aquazol® 500

Photo 20 - Stage I: Aquazol® 500; all samples prior to gilding

Photo 21 - Stage I: Aquazol® 500; samples C, D and E after gilding
3.5.8. Regalrez®1094

(Photographs: 22 to 25)

3.5.8.1. Evaluation of performance during application of polymers

Low viscosity solutions of Regalrez®1094 behaved very well during brush application. However, samples using methods B, C, and E (Regalrez®1094 mixed with pigment) showed very low bonding characteristics when mixed with pigment particles and formed a surface that had a sandy texture. Following the application of three coats of Regalrez®1094, pigments mixture (filtrated through very fine polyester mesh) samples B, C, and D remained sandy in texture, and pigments particles tended to brush freely off the surface.

3.5.8.2. Evaluation of the appearance of dried film prior to gold leaf application

Two layers of Regalrez®1094 solution were applied over a gouache paints foundation in samples using A and D. Both consistently formed an excellent, well levelled low-sheen surface of smooth texture. However, a region of high gloss was observed on overlapping sections of gold leaf.

3.5.8.3. Application of gold leaf and evaluation of the appearance of the gilded surface

Adhesion of gold leaf to the surface was very poor in all samples and in areas where gold leaf adhered, it formed wrinkles characteristic of a wet oily background. The line joining both traditional and non-traditional types of gilding
remained obvious. Despite having the best appearance of foundation prior to
gold leaf application, when samples using method D were double gilded the
results were poor. A section of this sample was burnished with agate. Peeling of
the gold leaf occurred, indicating poor adhesion.

3.5.8.4. Evaluation of the appearance of the
gilded surface after application of
traditional protective coating

Due to poor gilding results this test was not conducted.

3.5.8.5. Removability of dried film from the part
gilded with traditional gilding technique

No problems were encountered with the removal of Regalrez® films from the
samples using all solvents included in the tests within the time frame deemed
acceptable and without harm to the traditionally gilded areas. As expected, in the
light of the molecular structure of the resin Shellsol®A/ Shellsol®T mixtures and
aromatic solvents were more effective than polar solvents.
Table 9: Performance of Regalrez® 1094

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. no barrier coating L2 watercolour paint L3 25% Regalrez® 1094 with Kraton® G 1650, and Tinuvin® 292 in white spirit.</td>
<td>No apparent problems</td>
<td>E</td>
<td>PA</td>
<td>----</td>
</tr>
<tr>
<td>B. L1. no barrier coating L2. 25% Regalrez® 1094 with Kraton® G 1650, and Tinuvin® 292 in white spirit + pigments</td>
<td>No apparent problems with brushing, but the surface has very sandy texture</td>
<td>RR</td>
<td>POA</td>
<td>----</td>
</tr>
<tr>
<td>C. L1. 25% Regalrez® 1094 with Kraton® G 1650, and Tinuvin® 292 in white spirit L2. 25% Regalrez® 1094 with Kraton® G 1650, and Tinuvin® 292 in white spirit + pigments</td>
<td>No apparent problems with brushing, but the surface has very sandy texture</td>
<td>RR</td>
<td>POA</td>
<td>----</td>
</tr>
<tr>
<td>D. L1. 10% B-72 in xylene L2. watercolour paint L3. 25% Regalrez® 1094 with Kraton® G 1650, and Tinuvin® 292 in white spirit</td>
<td>No apparent problems</td>
<td>E</td>
<td>PA</td>
<td>----</td>
</tr>
<tr>
<td>E. L1. 10% B-72 in xylene L2. 25% Regalrez® 1094 with Kraton® G 1650, and Tinuvin® 292 in white spirit + pigments</td>
<td>No apparent problems with brushing, but the surface has very sandy texture</td>
<td>RR</td>
<td>POA</td>
<td>----</td>
</tr>
</tbody>
</table>

Legend:

- **E**: excellent, identical with an appearance of the traditional mat water gilding
- **GA**: good matt appearance, but poor adhesion of gold leaf
- **GB**: good matt appearance but brush strokes slightly apparent/or surface uneven
- **GO**: good matt, but oil gilding appearance remains
- **GS**: good although surface slightly shiny
- **GSB**: good although surface slightly shiny and brush strokes slightly apparent
- **RB**: reasonable matt, but brush strokes apparent/or surface uneven
- **RR**: reasonable matt, but surface rough
- **ROR**: reasonable matt, but oil gilding appearance remains and surface is rough
- **RS**: reasonable, but surface evidently shiny
- **RSB**: reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
- **PB**: poor, brush strokes very apparent
- **PS**: poor, surface to shiny
- **PSB**: poor, surface to shiny and brush strokes apparent
- **PA**: poor, gold leaf does not adhere
- **POA**: poor, gold leaf does not adhere properly and oil gilding appearance remains
- **PR**: poor, surface very rough
Stage I: Regalrez® 1094

Photo 22 - Stage I: Regalrez® 1094; all samples after gilding

Photo 23 - Stage I: Regalrez® 1094; samples C, D, and E after gilding

Photo 24 - Stage I: Regalrez® 1094; sample B after gilding

Photo 25 - Stage I: Regalrez® 1094; sample E after gilding
3.5.9. PVAc AYAF

(Photographs: 26 to 28)

3.5.9.1. Evaluation of performance during application of polymers

AYAF resin solution performed very well on samples using methods A and D, wetting the surface well and flowing evenly over the surface. Problems with uneven pigment distribution were observed during application of polymer/pigment mixture on the surface in samples using methods B, C, and E.

3.5.9.2. Evaluation of the appearance of dried film prior to gold leaf application

The foundation formed in samples using A and D on the other hand, was even and had an acceptable low sheen appearance. Samples using B, C, and E formed films with a deep matte appearance. Unfortunately, they also had a slightly rough surface texture requiring light sanding with very fine sandpaper prior to gilding.

3.5.9.3. Application of gold leaf and evaluation of the appearance of the gilded surface

The dry surfaces of the prepared samples were wetted with ethanol/diethyl ether (2:1) prior to application of gold leaf. Diethyl ether was added to the solution in order to slow down the evaporation rate of the solution and allow better adhesion of gold leaf.

Samples prepared using method B generally showed poor adhesion of gold leaf,
whereas in areas where gold leaf did adhere the resulting gilded surface had the appearance of gilding on wet oil size foundation. Although a sample using E scheme showed much better adhesion of gold leaf, the surface also simulated oil gilding. Although in samples using methods A, C, and D gold leaf adhered reasonably well on first application, small areas of gilding were missing and required a second gold leaf layer. Using method C wetting of the surface in samples caused removal of the first gold leaf layer. Although no such problems were encountered during second gilding in samples using methods A and D, nevertheless the gold leaf failed to adhere to those same areas of the polymer that were missed in the first attempt. Samples using methods D showed the best results providing promising, low sheen and evenly textured surfaces. The only drawback of this material was the appearance of a line joining traditional and non-traditional types of gilding, exacerbated by the differing surface textures in this part of the samples caused by an uneven distribution of polymer over the traditional gilding.

Sections of a samples prepared using method D were burnished with agate. The surface showed acceptable lustre and no peeling of gold leaf was observed.

3.5.9.4. Evaluation of the appearance of the gilded surface after application of traditional protective coating

When applied over surfaces of samples A, C, and D, protective coatings enhanced the matte appearance of gilding. The level of gloss on the surfaces of both traditional and non-traditional types of gilding was similar in all samples.
3.5.9.5. Removability of dried film from the part gilded with traditional gilding technique

All solvents included in the testing program responded positively to the tests carried out. AYAF layers could be successfully removed from the traditional gilded surface without causing any harm to it once the protective coating of proteinaceous ormolu was eliminated with saliva. Not surprisingly in view of the polymer composition and known properties, Shellsol®A/Shellsol®T mixtures performed worst and were more effective on samples with applied polymer/pigment mixtures. Samples with gouache paints foundations required saliva to remove these layers from surfaces gilded in a traditional manner.
### Table 10: Performance of poly(vinyl acetate) resin AYAF, 5% in methylated spirit (w/v)

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
</table>
| A. L1. no barrier coating  
L2 watercolour paint  
L3 5% AYAF in methylated spirit | No apparent problems | E | GA | GA |
| B. L1. no barrier coating  
L2. 5% AYAF in methylated spirit + watercolour paint | A building up of foundation layers is achievable but surface is very rough and requires sanding between applications of subsequent layers. | GB | POA | --------- |
| C. L1. 5% AYAF in methylated spirit  
L2. 5% AYAF in methylated spirit + watercolour paint | E/GB | PA | --------- |
| D. L1. 10% B-72 in xylene  
L2. watercolour paint  
L3. 5% AYAF in methylated spirit | No apparent problems | E | GA | GA |
| E. L1. 10% B-72 in xylene  
L2. 5% AYAF in methylated spirit + watercolour paint | Similar to B and C | GB | GA | GO | GA |

**Legend:**
- **E** - excellent, identical with an appearance of the traditional mat water gilding
- **GA** - good matt appearance, but poor adhesion of gold leaf
- **GB** - good matt appearance but brush strokes slightly apparent/or surface uneven
- **GO** - good matt, but oil gilding appearance remains
- **GS** - good although surface slightly shiny
- **GSB** - good although surface slightly shiny and brush strokes slightly apparent
- **RB** - reasonable matt, but brush strokes apparent/or surface uneven
- **RR** - reasonable matt, but surface rough
- **ROR** - reasonable matt, but oil gilding appearance remains and surface is rough
- **RS** - reasonable, but surface evidently shiny
- **RSB** - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
- **PB** - poor, brush strokes very apparent
- **PS** - poor, surface to shiny
- **PSB** - poor, surface to shiny and brush strokes apparent
- **PA** - poor, gold leaf does not adhere
- **POA** - poor, gold leaf does not adhere properly and oil gilding appearance remains
- **PR** - poor, surface very rough
Stage I: PVAC AYAF

Photo 26 - Stage I: PVAC AYAF; all samples prior to gilding

Photo 27 - Stage I: PVAC AYAF; all samples after gilding

Photo 28 - Stage I: PVAC AYAF; samples C, D and E after gilding and ormolu
Table 11: Evaporation rates, boiling point, solubility parameters and fractional solubility parameters of selected solvents [1]:

<table>
<thead>
<tr>
<th>SOLVENT</th>
<th>Aromatic content (%)</th>
<th>BOILING POINT IN °C</th>
<th>EVAPORATION RATE</th>
<th>SOLUBILITY PARAMETERS [2]</th>
<th>FRACTIONAL SOLUBILITY PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100ld</td>
</tr>
<tr>
<td>Xylene</td>
<td>98.8</td>
<td>138</td>
<td>0.75</td>
<td>8.8</td>
<td>83</td>
</tr>
<tr>
<td>Toluene</td>
<td>98.0</td>
<td>110</td>
<td>2.3</td>
<td>8.9</td>
<td>80</td>
</tr>
<tr>
<td>Shellsol®A</td>
<td>99.1</td>
<td>165-185</td>
<td>0.20</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>Shellsol® T</td>
<td>0.1</td>
<td>186-214</td>
<td>0.07</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>White spirit</td>
<td>17.0 16-25[3]</td>
<td>152-196</td>
<td>0.19</td>
<td>7.6</td>
<td>90</td>
</tr>
<tr>
<td>Petroleum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzine[4]</td>
<td>-11.5</td>
<td>30-120</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diethylbenzene</td>
<td>184.9 [5]</td>
<td></td>
<td></td>
<td></td>
<td>8.7</td>
</tr>
<tr>
<td>1-methoxypropan-2-ol</td>
<td></td>
<td>120</td>
<td>0.75</td>
<td>9.5</td>
<td></td>
</tr>
<tr>
<td>Diacetone</td>
<td>168.0</td>
<td>0.15</td>
<td>9.2</td>
<td>45</td>
<td>24</td>
</tr>
<tr>
<td>alcohol</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acetone</td>
<td>56</td>
<td>7.8</td>
<td>10.0</td>
<td>47</td>
<td>32</td>
</tr>
<tr>
<td>Propan-2-ol</td>
<td>80.3</td>
<td>1.5</td>
<td>12.0</td>
<td>41</td>
<td>16</td>
</tr>
<tr>
<td>Ethanol</td>
<td>78</td>
<td>(2.4)</td>
<td>12.7</td>
<td>36</td>
<td>18</td>
</tr>
<tr>
<td>Methanol</td>
<td>65</td>
<td>4.1</td>
<td>14.5</td>
<td>30</td>
<td>22</td>
</tr>
</tbody>
</table>

Legend:

1. Data obtained from Horie, C.V., 1987, or Technical Bulletin of Shell Chemical Industries unless marked differently. Evaporation rate measured by evaporating the solvent from a 10% solution of tributyl phosphate (Shell Chemicals Ltd.; 1977a; ASTM D 3539-76) relative to n-butyl acetate (=1). Values in brackets were measured by evaporation of the solvent from filter paper.
3. IPCS International Programme on Chemical safety, Health and Safety Guide No. 103
4. Data obtained from: Samet, 1998
Data obtain from Burke, J., 1984.
Table 12: Removability of polymers from the part gilded in the traditional matte-water gilding techniques.

<table>
<thead>
<tr>
<th>POLYMERS</th>
<th>Shellsol A / Shellsol T</th>
<th>Toluene</th>
<th>Xylene</th>
<th>Xylene /acetone</th>
<th>Acetone</th>
<th>Ethanol</th>
<th>Methylated spirit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraloid B-72 in DEB</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Paraloid B-72 in toluene</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Paraloid B-72 in xylene</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Rhoplex AC 33/N 580</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Plextol B 500</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>PVA AYAF</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Regalrez 1094</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Aquazol 500</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Liquitex Matte Medium</td>
<td>—</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
Stage I: Summary of results

Photo 29 - Stage I: all samples included in the testing. Marks in the middle of each sample left after removability tests.

Photo 30 - Stage I: samples with Paraloid® B-72 in xylene, Aquazo® 500 and Regalrez® 1094

Photo 31 - Stage I: samples with PVAc AYAF and Liquitex® Matte Medium
Stage I: Samples with the best results

Photo 32 - Stage I: samples with the best results: Plextol® B500, B-72 in xylene, Aquazol® 500, PVAC AYAF (marks in the middle of each sample left after removability tests)
3.6. Discussion

The tests carried out showed that non-traditional materials could produce promising results and confirmed that it is possible to simulate matte water gilding surface using alternative methods. Nevertheless all tests conducted on these materials revealed various minor drawbacks in regards to forming an adequate foundation for gilding.

3.6.1. Regalrez®1094

Of all of the resins types included in the testing program, due to its lack of adhesion Regalrez®1094 proved unsuitable for gilding purposes. Although it is possible that if used in greater concentration, the results might prove more promising, nevertheless it is likely that the low adhesive qualities of this material would require thicker film layers of high refractive index and would produce a gloss coating inappropriate for matte water-gilding.

3.6.2. Paraloid®B-72

Overall, the worst results using B-72 were those using 5% B-72 in DEB. The slow evaporation rate of DEB caused deep penetration of B-72 into the foundation layers, leaving the upper surface with little binder, resulting in a poorly performing resin. Although increasing the concentrations of the resin up to 10% improved the performance of B-72, the adhesion of gold leaf remained unacceptably poor and visually unacceptable. Investigation into a better solvent mixture for activation of B-72 might possibly furnish more promising results, however when coupled with the potentially hazardous working environment created for conservators operating with this solvent, the research is unjustified.
B-72 in toluene or xylene performed much better and no visual distinctions could be made between samples of this resin prepared using either solvents. The texture of the surface achieved was slightly better in the B-72 in xylene due to the lower viscosity of the applied solvent, which allowed for better levelling. The degrees of gloss of the gilded surfaces in both solvents were, however, the same\(^{27}\). Generally, the samples with polymer solution applied over gouache paints foundation (A and D) formed a surface possessing a better texture. However although problems with gold leaf adhesion were been noted. It is possible that greater grinding of the polymer/pigment mixture could reduce the roughness of the surface foundation formed in samples using B, C, and E. The incidence of adhesion problems in all samples indicates either that:

- 10% concentration of resin is too low, or:

- more than one layer of varnish is required in order to form an appropriate surface for gilding.

On the other hand, multiple layers or films with greater resin concentration can form a foundation that will be too thick to blend in with the original gilded surface. Resin concentrations of 20% in toluene formed a thicker film on surfaces. Due to greater viscosities of the solutions, it was difficult to apply solutions of this polymer in thinner coats. As noted above, the thickness of the coating formed has significance not only in terms of the visibility of the lining different types of gilding but also in relation to the subsequent reversibility of applied polymer in the long term. The thickness of films will influence the effectiveness of solvents used for removal of these films, as a longer times or stronger solvents are required to dissolve or swell a thick layer of polymer.

\(^{27}\) See footnote no 11 regarding an additional test carried out regarding the appearance of B-72 in xylene and toluene.
No significant differences were observed between samples with or without an isolation layer. It appears that gouache paints foundation itself formed an adequate impermeable layer protecting B-72 against absorption by the gesso background. The good burnishing properties of B-72 foundation are an additional advantage of this material. Nevertheless, further investigation into concentrations of resin applied, solvent types, application methods, and varying solvent ratios of resin in activating mixtures would be required if Paraloid®B-72 copolymer were to be adopted by gilding conservators for compensation of matte water gilded surfaces.

3.6.3. Aquazol®500

A similar conclusion can be drawn from the tests on Aquazol®500. The high viscosity of the 20% Aquazol®500 solution caused problems with application and proper levelling of the formed film. 10% solid resin concentrations formed highly viscous solutions. The formation of such high viscosity solutions by this material at a low solid concentration indicates that if further tests are warranted, it is necessary find an appropriate ratio of solute to solution mixture that would still retain enough adhesion power for attraction of gold leaf. The application of 10% Aquazol®500 solution also highlighted the poor wetting properties of these solutions, particularly when applied onto surfaces gilded with traditional materials. Problems with wetting properties and too great a viscosity of applied resin solution could possibly be overcome using greater amounts of ethanol in the water/ethanol vehicle, or via the addition of another surfactant and/or a lower concentration of solids in the resin/solvent mixture. In this regard, a test using 5% Aquazol® 500 in a 5:1 water/ethanol mixture gave a smooth surface without air bubbles. Nevertheless, problems with adhesion were still experienced.

Aquazol®500 mixed well with gouache paints. The behaviour of this mixture was reminiscent of traditional bole preparations. The surface texture and the level of gloss of the polymer/gouache paints foundation was better than that
achieved with the polymer applied over gouache paints substrate, which provided a greater gloss appearance. The final foundation would probably be better for creation of burnished water gilding (as it proved in small scale tests), following burnishing of the gilded surfaces with agates. The additional advantage of Aquazol®500 is that it can be activated with exhalation, rendering the application of gold leaf an easy procedure. However, the high hygroscopicity of this material has several drawbacks. As tests shown during the application of the traditional protective coating, this material is exceptional sensitivity to water. One brush stroke with a water based solution of rabbit skin glue and seed-lac, which is a mixture traditionally applied over matte gilded surfaces for protection, proved sufficient to remove gold leaf from all thin hair-like wrinkle lines apparent on the surface (characteristic gold beaten marks) making the red foundation underneath visible and forming a distinctive web-like pattern on the surface. The high hygroscopicity of this material excludes the possibility of using a traditional proteinaceous protective coating on restored gilding. Thus, additional investigation into an appropriate hydrophobic protective layer is required in order to select a material which would be compatible with Aquazol®500 and which would form matte appearance of the gilded surface, without turning it into a 'plastic-like' covering. Alternatively, additional experiments with an isolation layer of an appropriate matte varnish that could be applied under the traditional varnish coating are required. In terms of the current study Aquazol®500 was rejected for compensation of losses in gilded surfaces.

3.6.4. **AYAF**

AYAF polyvinyl acetate resin provided good results with foundations prepared on sample using method D, with the resin solution applied over gouache paints and gesso substrate seeled with 10% B-72 in xylene. Nevertheless, adhesion difficulties were encountered, indicating that 5% solution is too weak to provide sufficient adhesion for gold leaf. Methylated spirit, which was chosen as a solvent for this resin due to its better solving abilities, dries too rapidly to allow
good levelling of the forming film, particularly on broad surfaces or in higher solid concentration solutions. Further tests are required with higher resin concentration solutions, in solvents with slower evaporating rates, in order to properly evaluate the capability of this resin for gilding. This system resin burnishes well.

### 3.6.5. Acrylic dispersions

Of all classes of resins included in the testing program, acrylic dispersions using Plextol®B500 showed the best results. Although a mixture of Rhoplexes®AC-33/N-580 achieved satisfactory results, they formed layers of too high viscosity that dry too quickly to allow proper levelling of the polymer film on the surface. Although gas bubble formation of this mixture could also create problems during application, this drawback might be lessened with the addition of a surfactant, such as Aerosol®OT (Thornton, 1991). Nevertheless, the major drawback of using Rhoplexes® mixture for the purpose of compensation of matte water gilding is its rough texture and the resultant oil-gilded appearance final surface. The uneven texture and differing levels of gloss achieved are apparent even if the gilded surface is covered with matte protective coating.

Although previously used for gilded surfaces, surprisingly Liquitex® Matte Medium achieved even worse results. The undiluted dispersion has too high a viscosity to allow easy manipulation of this substance, whilst diluted mixtures evidently lose their adhesion properties, and require multiplying of layers, in order to attract gold leaf. The Liquitex® Matte Medium behaved very well when mixed with gouache paints, but rather poorly during gilding. It appears that the adhesive completely saturated the porous substrate of foundations in samples using methods A, B, and D (gesso or gouache paints) and therefore failed to attract gold leaf. Additional disadvantages of this material are its distinctive oil gilding appearance of the surface, evident at the join lines between the leaves, and the
high hygroscopicity of the formed films, which causes blistering of gold leaf after application of a protective coating.

In contrast, diluted Plextol®B500 (1:1 in distilled water/ethanol mixture, 4:1) produced very encouraging results, mixed well with gouache paints and formed a well-levelled surface of proper texture and good low sheen appearance. In the tests conducted, Plextol®B500 foundations could be activated with exhalation and maintained characteristically good adhesion of gold leaf in all concentrations. Samples in which polymer dispersion solutions were applied over gouache paints substrates (methods A and D) were more gloss than traditionally gilded surfaces after application of gold leaf. Nevertheless, this contrast disappeared after application of a protective layer. Additional tests regarding changes in the behaviour of Plextol®B500 polymer dispersions would increase our understanding of this material for use in the compensation of matte water gilding. Further tests could also include variations in application techniques, which would improve the appearance of joining lines between gold leaves.

3.7. **Conclusions**

The investigation into alternative gilding techniques for compensation of losses in matte water gilded surfaces produced promising preliminary results and indeed showed that gilding performed on foundations based on synthetic polymers can successfully substitute traditional matte water gilding in conservation treatments. The most promising results were achieved using acrylic dispersion Plextol®B500, acrylic resin Paraloid®B-72 diluted in aromatic solvents (toluene, xylene), and polyvinyl acetate resin AYAF in methylated spirit. Nevertheless, it has been recognised that further studies on selected synthetic materials are required in order to achieve greater confidence in their working capabilities. The results of these further investigations are reported in the remaining chapters.
4.0 STAGE II: FURTHER EXPERIMENTS WITH SELECTED MATERIALS

The aim of the next stage of experiments was to further investigate the performance of solvent/resin systems that had proved acceptable in preliminary tests. These included acrylic resin Paraloid®B-72, poly(vinyl acetate) resin AYAF, and acrylic dispersion Plextol®B500. This further research focused on:

- variations in the concentration of resin solutions in order to investigate the best balance between working properties, appearance of formed film and its adhesive properties,

- selection of the most appropriate solvents for resins according to evaporation rate, solubility power, and wetting properties, with regards to appearance and adhesive properties of the formed films,

- resin activation methods, particularly the selection of an appropriate solvent mixture for activation of formed films,

- practical application on the treatment of gilded objects
4.1. **Gilding with Acrylic Resin:**

*Paraloid®B72.*

4.1.1. **Investigation into performance of Paraloid®B-72 depending on varied resin concentrations in the solutions, solvents selected for this resin, and methods of reactivation of dried films.**

As noted in the previous chapter, the performance of B-72 film for the purpose of gilding varies as a function of solvent selection, resin concentration in the solution and solvents chosen for re-activation of the dried film. Whereas solvents with a very slow evaporation rate can drive the resin off the surface into the deeper parts of the foundation layers (B-72 in DEB), high viscosity solutions of volatile solvents with a high evaporation rate can be problematic, resulting in residual brush marks on the gilded surface (B-72 in toluene). The aim of the present testing program is to determine the optimal solvents, optimum resin concentrations and the best methods of application of gold leaf.

Ideally, in order to create a thin, even layer of film that will attract gold leaf, the applied solution should have low viscosity at high resin concentration. By contrast, it has been noted in the conservation literature that even 10-15% solutions of Paraloid®B-72 in aromatic solvents are rather viscous liquids (Phenix, 1992). Phenix also noted that in order to achieve a solution of B-72, which has acceptable working properties, the solvents should have boiling points in the range of 110-170 °C, with solvents toward the lower end of this range likely to form solutions which will be more difficult to handle due to rapid solvent evaporation. Based on the solubility parameter data for B-72, Phenix suggested glycol ether solvents, such as Proxitol®, Methyl Proxitol® acetate (Shell chemicals) and their analogues solvents Ethoxypropanol and...
Ethoxypropanol acetate as suitable replacements for toluene or xylene. He observed that solutions of B-72 in Proxitol® solvents have low viscosity even at relatively high solid contents, and indeed at a concentration of 20% w/v solutions are still insufficiently viscous! Although due to higher boiling points, Methyl Proxitol® Acetate and Ethoxypropanol Acetate may perform as better diluents for B-72 than their related ether alcohols, Phenix observed that the vapours are unpleasant and dangerous from an OH&S working environment perspective. All four solvents have similar hazard properties and the MSDS classifies them as mild irritants. Phenix did not recommend using any of these solvents with B-72 as a varnish or consolidant due to their strong swelling action on aged oil and synthetic polymer paints.

The possibility of forming less viscous solutions of B-72 at higher resin concentrations make glycol ether solvents an attractive choice for the purpose of the current study of my research. It was decided to include B-72 solutions in: 1-methoxypropan-2-ol (propylene glycol monomethyl ether) at resin concentrations of 15%, 17.5%, 20%, in addition to further testing of B-72 in xylene at concentrations higher than in previous experiments.

In the previous sets of tests, B-72 films were activated with a mixture of Shellsol®A / Shellsol®T (11.5:88.5%) (ratio of petroleum benzine)\(^{28}\) and ethanol (75:25%), which was similar to the mixture suggested by Thornton (1991).

Thornton observed that the solvent activated surface does not retain its tackiness for very long. He also claimed that the mixture of solvents necessary to reactivate the dry film must be chosen for the purpose of only slightly softening the film, not dissolving it. Furthermore, less volatile solvents for diluting B-72 would be more appropriate because they allow brush strokes to level out the applied film. Thornton (1991) recommended the use of 20% solution of B-72 in lacquer

\(^{28}\) Petroleum benzine has the same evaporation rate as toluene of n-Bu-Ac=2.0, and a combined aromatic content of ~11.5% (Whitten, 1998, 276)
thinner, which can then be reactivated with petroleum ether, or a mixture of 25% ethanol and 75% petroleum ether if reactivating were to occur days or weeks after application.

Phenix (1991, 1992) analysed the solubility behaviour of B-72 using a variety of solubility parameter systems – the Hildelbrand parameter ($\delta$), the three parameter Hansen system ($\delta_d$, $\delta_p$ $\delta_h$) and the related Teas system; and the Nelson, Hemwell and Edwards system (which utilises the original Hildelbrand parameter, two other parameters, fractional polarity (p) and hydrogen bond accepting index ($\theta_A$)). It was observed that B-72 is generally insoluble in aliphatic hydrocarbons or in very polar solvents such as methanol. He noted that it could be expected that solvents for B-72 should fit between 40 and 87 of the Teas dispersion force (fd) parameter. Those liquids outside these boundaries could be classified as non-solvents. In the data presented by Phenix, ethanol has a Teas fd value of 36, and white spirit, which has slightly higher aromatic contents than petroleum spirit, recommended by Thornton, has a value of 90; both lying outside of the specified boundaries. Phenix observed however, that ethanol, propan-2-ol and n-butanol dissolve B-72 to a limited degree, creating rather cloudy solutions. He noted that Rohm and Haas solubility data states that ethanol disperses rather than dissolves the resin. The same source registers the viscosity of B-72 resin in n-butanol at 20% solids concentration rather than 40% used for any other solvent, indicating difficulty in dissolving B-72 with this solvent.

Phenix’s attempts to dissolve B-72 in propan-2-ol produced hazy solutions of less than 10% w/v solids. He noted that the effectiveness of alcohols to dissolve B-72 is likely to be reduced by absorption of water from the air, and this group of solvents should be regarded as marginal solvents for the resin. In this regard, white spirit solvent has a very moderate influence on the solubility behaviour of B-72. Although low viscosity solutions of Paraloid®B-72 can be made using mixtures of glycol ether solvents and white spirit, the proportion of white spirit is limited and the resin will not fully dissolve in mixtures with high white spirit.
concentrations.

The limitations of higher alcohols and white spirit to dissolve B-72 is a potential advantage for re-activation of the dry film for the purpose of gilding, as these solvents could have a slightly better effect on B-72 film than a mixture used in previous tests. 75:25% ratio of Shellsol®A/ Shellsol®T (11.5:88.5%) to ethanol, which was a used in previous experiments (see previous chapter), produced an adequate ‘suck in’ effect during application. This did not, however, help with adhesion problems. Propan-2-ol has a Teas fd value of 40, and therefore in theory should be a slightly better solvent for B-72 than ethanol. It was therefore selected for the present tests, replacing ethanol in the film reactivating mixture. Softening the film could likely be improved by increasing the aromatic content in the Shellsol®A/ Shellsol®T mixture beyond the ratio (11.5:88.5%) recommended by Thornton (1991). It should be noted, however, that increasing the aromatic solvent content presents significant health risks to the operator. In the present tests the ratio was raised only slightly to the highest recommended level value for low aromatic white spirits (20% of aromatic contents) (Stolow, 1985). Three different ratios of a Shellsol®A/ Shellsol®T mixture to propanol were included in the current testing program in order to investigate an appropriate proportion of solvents in the re-activation mixture. The concentrations of propanol were increased in subsequent mixtures in order to test its effect on the adhesive properties of the formed film. It was noted however, that greater propanol concentrations also significantly affect the evaporation rates of the solution, and these activation mixtures can therefore have an undesirable effect on the appearance of the gilded surface.

### 4.1.1.1. Preparation of the samples

The samples were prepared in a similar manner to those described in Chapter 2 (see photograph: 33). The gesso foundation of each sample was sealed with 10% B-72 in xylene, and coated with three layers of watercolour paints in order to
imitate bole foundation. The second coat was slightly sanded with fine paper prior to the application of the final layer. The final coating was polished with a short firm brush prior to the application of the polymer solution in order to achieve a smooth surface, similar to traditional bole background.

Three solutions of B-72 in xylene were prepared at varied concentrations (w/v):

- Sample A - 10%
- Sample B - 12.5%
- Sample C - 15%

Each solution was applied to the prepared surface of three samples and then left to dry. In this manner, all sample grouped as A were covered with a solution of B-72 at 10% solid resin concentration, all samples grouped as B were coated with a 12.5% solution of B-72, while all samples labelled C were prepared with a film of 15% B-72 in xylene. The dried films thus created were then re-activated with three solvents mixtures of varied ratios of Shellsol®A/ Shellsol®T(1:4) to propan-2-ol, which were as follow (v/v):

25% (first column); 35% (second column); 50% (third column) of alcohol content.

Similarly, three solutions of B-72 in 1-methoxypropan-2-ol (propylene glycol monomethyl ether) were prepared in the following concentrations (w/v):

- Samples A - 15%
- Sample B - 17.5%
- Sample C - 20%
Each solution of B-72 was also applied to three samples, subsequently named sample A (at 15% solid resin concentration), sample labelled B (at 17.5% solid resin concentration), and samples grouped as C (at 20% solid resin concentration). The dry film was re-activated in a similar manner to the test conducted with B-72 in xylene.

4.1.1.2. Testing results

Performance of B-72 in xylene

(See photograph: 34)

Although there was no problem with the application of any solutions of B-72 in xylene, the 15% resin concentration solutions were noticeably more viscous than lower concentrations, suggesting that intermolecular interactions between polymer molecules became significant at above this threshold value. The 15% solution also dried significantly more slowly leaving shiny patches on the surface.

The first three samples were gilded with gold leaf, wetting the surface with a solvent mixture containing 25% propanol. After drying, the results were assessed and unfortunately were deemed poor. Poor adhesion was observed in all cases. Although more of the gold adhered in samples coated with 15% solution of B-72 than with lower concentrations of this resin, the results were still unsatisfactory. The results of all repeat samples indicated that one coat of B-72 did not provide an appropriate foundation to attract gold leaf. It is possible that the resin was partially absorbed by the gouache paints foundation causing poor adhesion of gold leaf.

The tests were repeated with a foundation consisting of two coats of B-72 solutions. The residue of gold leaf was removed from each sample with ethanol, and then a second coat of an appropriate B-72 solution was applied. The
appearance of the samples following this second coat of resin was variable. Samples following method A had a matte appearance with small semi-gloss patches, samples using regime B were mostly semi-gloss with small matte patches, and samples produced following procedure C had an evenly distributed semi-gloss appearance.

Although application of gold leaf was associated with a characteristic ‘sucking’ effect in all cases, it was also observed that the gold leaf had a tendency to ‘sink down’ through the applied solvents above the gold leaf, particularly on surfaces wetted with the Shellsol®A/ Shellsol®T(1:4)-and-propan-2-ol mixtures of ratios higher than 25% of alcohol contents. During drying, unacceptable wrinkles formed on the gilded surfaces in all of samples. This phenomenon could be almost completely eliminated if some time was allowed for the partial evaporation of solvents between the application of the wetting mixtures and gold leaf.

After the application of gold leaf, surfaces wetted with a mixture consisting of 25% propanol required the longest drying time and gave the smoothest surface texture.

The results after the application of gold leaf were as follows:

- Sample As were still characterised with a lack of adhesion of gold leaf.

- Sample Bs preformed slightly better, but a significant number of areas still stayed uncovered with gold leaf.

- Sample Cs had only a few patches left uncovered.

All samples were double-gilded and evaluated again. The results were only slightly better, with samples A and B still unsatisfactory and covered with many ungilded patches, and sample C almost completely covered, but still showing
small areas with missing gold leaf.

Table 13: Performance of B-72 in xylene activated with mixture of 25 % propan-2-ol with Shellsol®A/Shellsol®T (1:4).

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>E</td>
<td>E</td>
<td>PA</td>
</tr>
<tr>
<td>L2. Watercolours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3. 10% B-72 in xylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>E</td>
<td>GS</td>
<td>PA</td>
</tr>
<tr>
<td>L2. Watercolours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3. 12.5% B-72 in xylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>PA</td>
</tr>
<tr>
<td>L2. Watercolours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3. 15% B-72 in xylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 14: Performance of B-72 in xylene activated with mixture of 35 % propan-2-ol with Shellsol®A/Shellsol®T (1:4).

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>E</td>
<td>POA</td>
<td>POA</td>
</tr>
<tr>
<td>L2. Watercolours</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>L3. 10% B-72 in xylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>E</td>
<td>PA</td>
<td>PA, ROR</td>
</tr>
<tr>
<td>L2. Watercolours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3. 12.5% B-72 in xylene</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>E</td>
<td>GA, ROR</td>
<td>GA, ROR</td>
</tr>
<tr>
<td>L2. Watercolours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3. 15% B-72 in xylene</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B-72 in xylene L2. Watercolours L3. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>E</td>
<td>PA</td>
<td>PA</td>
</tr>
<tr>
<td>B. L1. 10% B-72 in xylene L2. Watercolours L3. 12.5% B-72 in xylene</td>
<td>No apparent problems</td>
<td>GS</td>
<td>PA, ROR</td>
<td>PA, ROR</td>
</tr>
<tr>
<td>C. L1. 10% B-72 in xylene L2. Watercolours L3. 15% B-72 in xylene</td>
<td>No apparent problems</td>
<td>GS</td>
<td>1. GA, ROR 2. GA, ROR</td>
<td>ROR</td>
</tr>
</tbody>
</table>

Legend to all:
E - excellent, identical with an appearance of the traditional mat water gilding
GA - good matt appearance, but poor adhesion of gold leaf
GB - good matt appearance but brush strokes slightly apparent/or surface uneven
GO - good matt, but oil gilding appearance remains
GS - good although surface slightly shiny
GSB - good although surface slightly shiny and brush strokes slightly apparent
RB - reasonable matt, but brush strokes apparent/or surface uneven
RR - reasonable matt, but surface rough
ROR - reasonable matt, but oil gilding appearance remains and surface is rough
RS - reasonable, but surface evidently shiny
RSB - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
PB - poor, brush strokes very apparent
PS - poor, surface to shiny
PSB - poor, surface to shiny and brush strokes apparent
PA - poor, gold leaf does not adhere
POA - poor, gold leaf does not adhere properly and oil gilding appearance remains
PR - poor, surface very rough
Stage II: Paraloid® B-72

Photo 33 - Stage II: Paraloid® B-72; all samples prior to gilding

Photo 34 - Stage II: samples with B-72 in xylene after gilding and an application of protective coating
**Performance of B-72 in 1-methoxypropan-2-ol.**

(See photographs: 35 to 37)

Each sample was coated with one layer of B-72 in 1-methoxypropan-2-ol, with varied success. Samples grouped as A had a number of matte patches, B samples had a rather uniform semi-gloss surface with relatively few small matte areas, and samples labelled C had an even semi-gloss surface. Although the application of B-72 solutions to A and B samples did not present any difficulties, the formation of a thin layer of resin on C samples required particular care, due to the high viscosity of the 20% solution.

The first attempt at application of gold leaf using a mixture containing 25% propanol gave unsatisfactory results. All samples had patches of missing gold leaf. Although their numbers gradually decreased on samples with films formed with higher solid resin concentration solutions, nevertheless, even sample Cs had several small areas with missing gold leaf. As with films formed using B-72 in xylene, it was necessary to apply a second layer of resin solution. Gold leaf was removed from the gilded samples with ethanol, and then the surface of each sample was coated with a second layer of a solution of B-72 in relevant concentrations. Great care was taken to apply all solutions in very thin layers, particularly at the 20% solid resin concentration, in order to reduce to a minimum the thickness of the formed film, which could otherwise make the line joining both types of gilding, traditional and non-traditional, apparent.

After the second coating, samples using methods B and C achieved a much improved gloss appearance of the surface, whereas samples using regime A still retained a uniform but semi-gloss surface shine. After the application of the first layer of gold leaf, gaps in the gold coating were apparent, although in the case of samples using method C they were rather small or else caused by imperfections in the gold leaf. As in the tests of B-72 in xylene, a significant negative correlation was noted between the smoothness of the surface and increases in propanol.
concentration within the film re-activating mixture. The smoothest texture
was achieved on surfaces re-activated with a solvent mixture consisting of 25%
propanol.

Samples coated using methods B and C were completely covered following
application of the second layer of gold leaf, whereas samples using A, which were
activated with mixtures containing subsequently 25% and 35 % of propanol, still
had small missing patches of gold. The surface of samples using A that were
activated with a mixture of solvents containing 50% propanol, showed good
adhesion of gold leaf. Nevertheless the surface was rather rough due to wrinkles
in the initially applied gold that proved impossible to remove. The best gilded
surface textures overall were achieved with method A activated with a mixture
containing 25% propanol.

Two coats of ormolu were applied over the surface of each sample, gilded onto a
foundation formed of both B-72 in xylene and 1-methoxypropan-2-ol. Although
in all cases it helped to form a more uniform surface, the uneven texture of the
gilded surface on samples with wrinkles (activated with greater than 25%
concentration of propanol) was still apparent.
Table 16: Performance of B-72 in 1-methoxypropan-2-ol activated with mixture of 25 % propan-2-ol with Shellsol®A/Shellsol®T (1:4).

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B-72 in xylene L2. Watercolours L3. 15% B-72 in 1-methoxypropan-2-ol</td>
<td>No apparent problems</td>
<td>GS with mat patches</td>
<td>PA GA</td>
<td>GA</td>
</tr>
<tr>
<td>B. L1. 10% B-72 in xylene L2. Watercolours L3. 17.5% B-72 in 1-methoxypropan-2-ol</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GA, GO</td>
<td>GO</td>
</tr>
<tr>
<td>C. L1. 10% B-72 in xylene L2. Watercolours L3. 20% B-72 in 1-methoxypropan-2-ol</td>
<td>No apparent problems, although care must be taken during application due to great viscosity of solution</td>
<td>GS</td>
<td>GA, GB</td>
<td>GO</td>
</tr>
</tbody>
</table>

Table 17: Performance of B-72 in 1-methoxypropan-2-ol activated with mixture of 35 % propan-2-ol with Shellsol®A/Shellsol®T (1:4).

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B-72 in xylene L2. Watercolours L3. 15% B-72 in 1-methoxypropan-2-ol</td>
<td>No apparent problems</td>
<td>GS with matte patches</td>
<td>POA GA, GO</td>
<td>GA, GO</td>
</tr>
<tr>
<td>B. L1. 10% B-72 in xylene L2. Watercolours L3. 17.5% B-72 in 1-methoxypropan-2-ol</td>
<td>No apparent problems</td>
<td>GS</td>
<td>POA ROR</td>
<td>ROR</td>
</tr>
<tr>
<td>C. L1. 10% B-72 in xylene L2. Watercolours L3. 20% B-72 in 1-methoxypropan-2-ol</td>
<td>No apparent problems, although care must be taken during application due to great viscosity of solution</td>
<td>GS</td>
<td>POA 2. ROR</td>
<td>ROR</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>GS with mat patches</td>
<td>POA</td>
<td>GO, GB</td>
</tr>
<tr>
<td>L2. Watercolours</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L3. 15% B-72 in 1-methoxypropan-2-ol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. L1. 10% B-72 in xylene</td>
<td>No apparent problems</td>
<td>GS</td>
<td>POA</td>
<td>ROR</td>
</tr>
<tr>
<td>L2. Watercolours</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>L3. 17.5% B-72 in 1-methoxypropan-2-ol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. L1. 10% B-72 in xylene</td>
<td>No apparent problems although care must be taken during application due to great viscosity of solution</td>
<td>GS</td>
<td>POA</td>
<td>ROR</td>
</tr>
<tr>
<td>L2. Watercolours</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>L3. 20% B-72 in 1-methoxypropan-2-ol</td>
<td></td>
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</tbody>
</table>

Legend for all:

- **E** - excellent, identical with an appearance of the traditional mat water gilding
- **GA** - good matt appearance, but poor adhesion of gold leaf
- **GB** - good matt appearance but brush strokes slightly apparent/or surface uneven
- **GO** - good matt, but oil gilding appearance remains
- **GS** - good although surface slightly shiny
- **GBS** - good although surface slightly shiny and brush strokes slightly apparent
- **RB** - reasonable matt, but brush strokes apparent/or surface uneven
- **RR** - reasonable matt, but surface rough
- **ROR** - reasonable matt, but oil gilding appearance remains and surface is rough
- **RS** - reasonable, but surface evidently shiny
- **RSB** - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
- **PB** - poor, brush strokes very apparent
- **PS** - poor, surface to shiny
- **PSB** - poor, surface to shiny and brush strokes apparent
- **PA** - poor, gold leaf does not adhere
- **POA** - poor, gold leaf does not adhere properly and oil gilding appearance remains
- **PR** - poor, surface very rough
Stage II: Paraloid® B-72 - continuing

Photo 35 - Stage II: samples with B-72 in 1-methoxypropan-2-ol after gilding

Photo 36 - Stage II: samples with B-72 in 1-methoxypropan-2-ol after gilding and an application of protective coating

Photo 37 - Stage II: sample C with B-72 in 1-methoxypropan-2-ol activated with Shellsol® A/Shellsol® T with 25% of propan-2-ol
4.1.1.3. Discussion

Experiments conducted with B-72 solutions showed that the re-activation of dry films creates problems at all concentrations of this resin. This observation accords with empirical evidence contained in the conservation literature in which it has been noted that re-activation of the B-72 adhesive is difficult (Phenix, 1984). Tests involving the application of this resin for lining the paintings have shown that excessive solvent spray results in the adhesive becoming fluid and consequently migrating away. The most uniform activation was achieved by spraying the applied film not with a solvent but with a thin solution of the resin itself (Phenix, 1984).

In the current work it was shown that even a mixture of solvents chosen for reactivation of this resin, is insufficiently powerful to re-activate the dried film. Both solvents selected for dissolution of B-72 copolymer have relatively low evaporation rates. Consequently, the levelling of the formed film was easy to achieve. Nevertheless, the mobility of the surface created with gold leaf was high and migration of the resin during drying was difficult to prevent. Therefore, even with an isolation layer of B-72 in xylene, one coat of a solution of high resin concentration was insufficient to provide a proper foundation for gilding. More than two layers of a solution with a higher concentration of B-72 were required for good adhesion of gold leaf. Tests with B-72 showed that the concentration of resin in both solvents must be at least 15% and more than one layer of solution is required in order to achieve an even uniform semi-gloss appearance of B-72 film. Furthermore, matte patches on the surface prior to gilding will result in patches in the gilded surface covered with gold leaf. 15% solutions of B-72 in 1-methoxypropan-2-ol have a slightly lower viscosity than a similar concentration solution of this resin in xylene, allowing better brush application.
20% solutions of B-72 in 1-methoxypropan-2-ol (w/v) were particularly viscous, requiring special care during application in order to form a thin film on the surface. These solutions were only slightly less viscous than 20% solutions of B-72 in toluene, which were included in the first set of tests (see: chapter 3). Nevertheless, the surface achieved with 20% B-72 in glycol solvent was free of the brush strokes that had impaired previous tests involving 20% B-72 in toluene. These improved results were achieved due to several factors. Firstly, 1-methoxypropan-2-ol proved a better solvent for B-72, producing a less viscous solution that was easier to apply using a brush. Secondly, the evaporation rate of glycol ether solvent is much lower (0.75) (Phenix, 1993) than toluene (2.3) (Horie, 1987), and this allowed a longer time for levelling of the film formed.

In comparison to previous tests, no difference has been noted with regards to changes made in the wetting mixture. Using propanol instead of ethanol did not improve the adhesion of B72 films. Neither did a slight increase in the aromatic content in the Shellsol®T/ Shellsol®A mixture show any effect.

Activation mixtures with lower propanol contents formed solutions with lower evaporation rates, allowing longer drying time and the formation of a better gilded surface texture. An increase in propanol content levels in the activation mixture significantly altered its evaporation rate and also improved the surface tension of the applied mixture and the activation of dry film. As a consequence, instead of relaxing over the surface, although applied gold leaf adhered better to the surface it also showed a ‘sinking’ effect, causing the formation of wrinkles and a rough texture.

In both sets of tests, optimum results in terms of texture were achieved with an activation mixture consisting of 25% propanol. This indicated that the drying time and initial attraction of gold leaf must be moderate in order to achieve a smooth surface. The drying time could potentially be extended in order to achieve improved results, if required. Although higher proportions of propanol in the activation mixture resulted in better adhesion, they also resulted in a greater
‘sinking’ effect, greater amounts of surface wrinkles and contributed to a worse appearance of the line joining traditional and non-traditional gilded areas. Additional tests with an activation mixture of lower propanol content than 25% might provide more satisfactory results in terms of smoother surfaces; due to the longer drying time, which would allow gold leaf to relax and spread evenly over the surface.

### 4.1.2. Practical Application


Fig. 1. The frame for the drawing *Wet Evening, George Street, Sydney*, 1889, by A.H.Fullwood (1863-1930).

Dimensions: 1415 x 1125 x 25 mm, (See photographs: 38 to 45)
The frame was restored for the ‘Australian Watercolours’ exhibition in 2005.

This 19th century frame consisted of outer plain oak moulding, which surrounded a broad (120mm wide) inner slip with a textured finish and a narrower (40mm wide) plain moulding at the sight edge (Fig.1). The slip was painted over with a bright white, probably acrylic base. Initial tests showed the paint reacted positively to acetone, revealing a cream white colour underneath in the textured part of the frame and bare wood at the plain moulding. Examination of the verso of the frame indicated that this plain moulding was a later addition to the frame, which earlier must have accommodated the same drawing with larger mounts. This plain moulding was permanently fixed to the part with a textured finish and presently formed an integral part of the frame, aesthetically and physically necessary to accommodate the drawing. However, its wooden finish creates an unpleasant aspect for the image of the painting and therefore, after discussion with curators, the decision was made that after removal of white overpaintings, this section of the frame would be regilded.

White paint was removed with acetone and a new gesso foundation was applied to the plain wood. After levelling, a white gesso foundation was sealed with one layer of 10% B-72 in xylene (w/v), followed by two coats of 15% B-72 in 1-methoxypropan-2-ol (w/v). The dried film of acrylic resin was reactivated just prior to the application of gold leaf using a mixture containing 20% propanol in Shellsol®A/ Shellsol®T (1:4). After drying, the surface was gilded again, wetting the surface with the same activation mixture of solvents. The dry gilded surface was coated with two layers of traditional ormolu varnish (5% w/v rabbit skin glue with an addition of up to 10% of diluted shellac) in order to form a deeper matte finish. The gilding was then additionally covered with one coat of acrylic varnish Soluvar® Matte to protect it against abrasions and other potential damage caused during handling.
Stage II: Paraloid® B-72: Practical test

Case study: the frame for the drawing ‘Wet Evening, George Street, Sydney’, 1889, by A.H.Fullwood (1863-1930)

Photo 38 - Stage II: B-72 - case study; inner slip of the frame during removal of overpaintings

Photo 39 - Stage II: B-72 - case study; detail of the inner slip during removal of overpaintings

Photo 40 - Stage II: B-72 - case study; detail of the inner slip prepared for gilding and in-painting

Photo 41 - Stage II: B-72 - case study; detail of the inner slip after the first gold leaf layer
Stage II: Paraloid® B-72: Practical test – continuing

Photo 42 - Stage II: B-72 - case study; detail of the inner slip after the first gold leaf layer

Photo 43 - Stage II: B-72 - case study; detail of the inner slip after the second gold leaf layer and protective coating
Stage II: Paraloid® B-72: Practical test - continuing

Photo 44 - Stage II: B-72 - case study; inner slip after the second gold leaf layer and protective coating

Photo 45 - Stage II: B-72 - case study; inner slip after the second gold leaf layer and protective coating
4.1.2.2. Results and discussion

After sealing the gesso with 10% (w/v) B-72 in xylene and the application of two coats of 15% (w/v) B-72 in 1-methoxy-propan-2-ol, the surface achieved a semi gloss appearance. Nevertheless, the presence of some matte patches indicated uneven distribution of the resin. After the first application of gold leaf, the surface had many uncovered areas. The results of tests conducted earlier (see above) indicated that this patchy surface was not only the result of imperfections in the applied gold leaf but instead demonstrated that the applied gold leaf did not adhere to the surface properly. This lack of adhesion occurred mostly – but was not limited to - areas where the saturation of resin into deeper gesso layers was greatest. These areas were noticeable as matt patches, even prior to the application of gold leaf. Although following the application of a second layer of gold leaf many of these patches were covered, the surface still required a selective application of small pieces of gold for a third time in order to provide a satisfactory finish.

This trial confirmed that even distributions of B-72 based films are difficult to achieve and that the resin also has the tendency to migrate unevenly underneath the surface when rewetted with solvents. Despite the relative success of empirical trials based on this polymer, the appearance of the gilded surface formed with this resin in situ on gilded artefacts was less satisfactory. Tests demonstrated that this copolymer material is more suitable for compensation of losses in small areas than on large surfaces that required regilding.
4.2. Gilding with Polyvinyl Acetate

Resin: AYAF.

4.2.1. Investigation into the performance of
AYAF depending on varied resin
concentrations in solutions, solvents
selected for this resin, and methods of
reactivation of dried films.

Previous tests (see chapter 3) indicated that the performance of AYAF resin films could be greatly improved if the polymer were applied at high resin concentrations in solvents with lower evaporation rates.

It has been stated in conservation literature that PVAc resins are soluble in a range of solvents including aromatic hydrocarbons, alcohols containing some water (5%), ketones, esters, glycols, and chlorinated hydrocarbons, but are insoluble in aliphatic hydrocarbons (Schniewind, Kronkright, 1984, Feller, R., L., Stolow, N., Jones, E.H., 1985, Berger, G. A., 1990, Hansen, Lowinger, Sadoff, 1993, Hansen, Volent, 1994, Down, JL, MacDonald, A, Tetreault, J, Williams, RS, 1996, Pocobene, 1998). They are also known to swell in contact with water (Pocobene, 1998). Depending on the application method, several solvents are recommended for AYAF resin to form an appropriate varnish in painting conservation. For sprayed applications, AYAF is usually diluted in ethyl alcohol, or a mixture of solvents including ethyl alcohol, cellosolve acetate and diacetone alcohol, forming solutions of around 10% solid resin concentration. A mixture of toluene, ethyl alcohol, ethylene dichloride, cellosolve and cellosolve acetate can be used for spray and brush application in a concentrations between 10-20 % AYAF (Pocobene, 1998).
Pocobene (1998) noticed that when applied using a brush, PVAc resin should be dissolved in slower evaporating solvents to increase working time. He did not however, recommend applying PVAc in an ethanol-based solution. Feller (1985) observed that for a solvent-type varnish, which is formed from resins of high viscosity grades, the formulation of the solvent is critical to the success of the varnish coating. Feller also noticed that in order to achieve good levelling with a varnish of a high molecular weight, the rate of evaporation of the selected solvent should be slowed down. For comparison, Feller noted, for example, that AYAF dissolved in a mixture of ethyl alcohol, cellosolve acetate and diacetone alcohol, forms a film of a rough texture, whereas a solution of this resin involving only ethyl alcohol and diacetone alcohol, which would have a slower evaporation rate than the previous mixture, produces a smooth surface.

In object conservation, 5% w/v concentrations AYAF have been used for the consolidation of matte paint in solutions of ethanol (Hansen, Lowinger, Sadoff, 1993, Hansen, Volent, 1994) and methanol (Schniewind, Kronkright, 1984). This high molecular weight resin, diluted in such volatile solvents is known to produce a non-glossy surface of a rather rough texture. The matte effect results from the rapid drying of the polymer, preventing levelling (Feller, 1985).

An AYAF film foundation, formed for matte water-gilding, provides a well levelled but semi-matte appearance. High gloss films could produce a gilded surface with a higher level of gloss than those produced using the traditional techniques. The utility of AYAF as a surface for matte water-gilding is therefore controlled by its evaporation rate. Although a slower rate of drying will result in a better levelled surface for the applied film, the formed surface will also attain a higher gloss.

In view of the above results, an investigation of the performance of AYAF in ethanol/ diacetone alcohol (2:1) solution was undertaken. The proportion of ethanol/diacetone alcohol approximates to that selected by Feller (1985) as optimum for a well-levelled film. In the current test, the adhesive properties
of the polymer at varied concentrations were investigated, notwithstanding the propensity of this material to form undesirably gloss surfaces. This set of tests provides the basis for further investigation into the appropriate proportions of ethanol/diacetone alcohol in relation to the level of gloss required for a matte water-gilded surface.

The sensitivity of AYAF films to reactivation mixtures was also investigated in the light of Pocobene’s (1998) observation that this polymer was particularly sensitive to water. Three solutions of water/ethanol were selected: 1:2, 1:1, 2:1. The evaporation rate of the reactivation mixture increases as a function of ethanol concentration. Increasing the evaporation rate and therefore the ethanol concentration could, in principle, decrease the potential glossy appearance of the reactivated AYAF film. Although ethanol is a good solvent for AYAF and a solution with higher alcohol contents could provide better adhesion for gold leaf, greater ethanol concentrations will also decrease the surface tension of the activation mixture causing that AYAF film to attract gold leaf rapidly, forming undesired wrinkles and roughness of the gilded surface. The addition of ethanol does not allow sufficient time for gold leaf to relax evenly over the surface, as occurs in traditional gilding techniques performed with gilders water containing excess alcohol. Nevertheless, the results of this test are sufficiently encouraging to suggest they could provide be developed further in the future.

### 4.2.1.1. Preparation of the samples

Samples were prepared in a similar manner as for previous tests, with the foundation consisting of gesso sealed with 10% B-72 in xylene, and gouache paints imitating bole. Three solutions of AYAF in ethanol/diethyl ether were prepared in concentrations (%w/v):

- Sample A - 10%,
4.2.1.2. Testing results

(See photographs: 46-47)

Brushed applications of 10% and 15% solutions of AYAF were successful, whereas solutions of 20% w/v resin concentration were too viscous and set too rapidly requiring particular care during brushing in order to achieve a thin coating. Following drying, samples using method A had a rather matte surface appearance with small, slightly shinier patches; samples from method B had a gloss surface with small matte patches; and samples prepared using method C had an entirely gloss surface.

In all cases, gold leaf adhered reasonably well with a single application of resin. It was, however, notable that small areas missing gold leaf were apparent on all samples, caused mostly by imperfections in the gold leaf. Optimum results in terms of texture were attained either by reactivation with a water/ethanol mixture 2:1, or else with a mixture of an equimolar proportions of both solvents. Limited success was achieved using method B reactivated with a 2:1 mixture of
water and ethanol. A rather rough texture was achieved, with all other methods producing characteristic wrinkles in gold leaf.

In all samples the level of gloss was judged low, being only slightly higher than the surface achievable using traditional techniques.

Samples judged acceptable following the application of a first layer of gold (A, B, C, reactivated with water/ethanol 2:1, and A, reactivated with a 1:1 water/ethanol mixture) were gilded again.

A slight problem was encountered following the application of reactivation mixtures during the second gilding. The gilded surface showed high levels of sensitivity to the water/ethanol solution, with the attendant risk that repeated brush strokes would remove the first coating of gold leaf. Although the adhesion of gold leaf was generally good, not all areas with missing gold leaf were covered using method A. All samples achieved what was deemed an acceptable texture and gloss level. Optimum results following repeated gold leaf application were achieved using method C, with film foundation reactivated with water/ethanol (2:1). Despite the otherwise satisfactory results, the boundary between both traditional and non-traditional types of gilding was apparent due to the slightly greater roughness on the surface and the significant thickness of the non-traditional film.

Additional problems were noted during the application of the protective layer. The surface again showed great sensitivity to water and repeated brush strokes could damage the gilding layer.

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B-72 in xylene L2. Watercolours L3. 10% AYAF in ethanol/diacetone alcohol (2:1)</td>
<td>No apparent problems</td>
<td>GB</td>
<td>GA, GB</td>
<td>GA, GB</td>
</tr>
<tr>
<td>B. L1. 10% B-72 in xylene L2. Watercolours L3. 15% AYAF in ethanol/diacetone alcohol (2:1)</td>
<td>No apparent problems</td>
<td>GB GS</td>
<td>1. GA GB 2. GB</td>
<td>GB</td>
</tr>
<tr>
<td>C. L1. 10% B-72 in xylene L2. Watercolours L3. 20% AYAF in ethanol/diacetone alcohol (2:1)</td>
<td>High viscosity liquid Caution required during brush application</td>
<td>GS</td>
<td>GA, GB GB</td>
<td>GB</td>
</tr>
</tbody>
</table>

Table 20: Performance of AYAF in ethanol/diacetone alcohol, activated with water/ethanol 1:1.

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B-72 in xylene L2. Watercolours L3. 10% AYAF in ethanol/diacetone alcohol (2:1)</td>
<td>No apparent problems</td>
<td>GB</td>
<td>GA, GB GA, GB</td>
<td>GA GB</td>
</tr>
<tr>
<td>B. L1. 10% B-72 in xylene L2. Watercolours L3. 15% AYAF in ethanol/diacetone alcohol (2:1)</td>
<td>No apparent problems</td>
<td>GB GS</td>
<td>ROR</td>
<td>ROR</td>
</tr>
<tr>
<td>C. L1. 10% B-72 in xylene L2. Watercolours L3. 20% AYAF in ethanol/diacetone alcohol (2:1)</td>
<td>High viscosity liquid Caution required during brush application</td>
<td>GS</td>
<td>PR</td>
<td>PR</td>
</tr>
</tbody>
</table>
Table 21: Performance of AYAF in ethanol/diacetone alcohol, activated with water/ethanol 1:2.

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B-72 in xylene L2. Watercolours L3. 10% AYAF in ethanol/diacetone alcohol (2:1)</td>
<td>No apparent problems</td>
<td>GB</td>
<td>ROR</td>
<td>ROR</td>
</tr>
<tr>
<td>B. L1. 10% B-72 in xylene L2. Watercolours L3. 15% AYAF in ethanol/diacetone alcohol (2:1)</td>
<td>No apparent problems</td>
<td>GB</td>
<td>GS</td>
<td>PR</td>
</tr>
<tr>
<td>C. L1. 10% B-72 in xylene L2. Watercolours L3. 20% AYAF in ethanol/diacetone alcohol (2:1)</td>
<td>High viscosity liquid Caution required during brush application</td>
<td>GS</td>
<td>PR</td>
<td>PR</td>
</tr>
</tbody>
</table>

Legend for all:

- **E** - excellent, identical with an appearance of the traditional mat water gilding
- **GA** - good matt appearance, but poor adhesion of gold leaf
- **GB** - good matt appearance but brush strokes slightly apparent/or surface uneven
- **GO** - good matt, but oil gilding appearance remains
- **GS** - good although surface slightly shiny
- **GSB** - good although surface slightly shiny and brush strokes slightly apparent
- **RB** - reasonable matt, but brush strokes apparent/or surface uneven
- **RR** - reasonable matt, but surface rough
- **ROR** - reasonable matt, but oil gilding appearance remains and surface is rough
- **RS** - reasonable, but surface evidently shiny
- **RSB** - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
- **PB** - poor, brush strokes very apparent
- **PS** - poor, surface to shiny
- **PSB** - poor, surface to shiny and brush strokes apparent
- **PA** - poor, gold leaf does not adhere
- **POA** - poor, gold leaf does not adhere properly and oil gilding appearance remains
- **PR** - poor, surface very rough
Stage II: Polyvinyl Acetate Resin AYAF

Photo 46 - Stage II: PVAC AYAF; all samples prior to gilding

Photo 47 - Stage II: PVAC AYAF; all samples after gilding and an application of protective coating
4.2.1.3. **Discussion**

Gilding onto a polyvinyl acetate resin AYAF foundation produced mixed results. Reactivation mixtures of water/ethanol (2:1) provided sufficient adhesion for gold leaf. A higher proportion of ethanol in the activation mixture did not, however, provide enough time for the gold leaf to relax and spread evenly over the surface. As a consequence wrinkles formed and resulted in a rough surface texture. The quality of the surface with regard to its texture was inversely correlated to both the resin concentration and also the ethanol contents of the reactivation mixtures. Optimum surface quality was achieved in samples based on method C, showing that even a 20% solid resin concentration solution can form well-levelled films provided that slow evaporation solvents are selected. Nevertheless, exceptional care is required during brush-based application of the AYAF solutions of such high concentrations since due to its high molecular weight this polymer has a tendency to form films of significant thickness. An additional drawback of this material is its sensitivity to water solutions, which appears to be greater than previously described in the literature.

Further testing is still required to eliminate the appearance of lines between old and new gilded materials and the elimination of microscopic wrinkling, which became apparent on the gilded surfaces of several samples. However, the slight distortion of joins between AYAF-based surfaces and those formed as a result of traditional gilding are more noticeable under a magnifying glass or stereo microscope than with the naked eye. Wrinkling is detectable on samples with foundations formed with all three solution concentrations and its occurrence was independent of the concentration of propanol in the wetting mixture used during gilding. It proved impossible to determine whether wrinkling was caused by the imperfect (thick) application of resin solution (manual failure), the presence of an isolation layer of B-72, or an indeterminate interaction between the wetting mixture and the polymer film. Since the phenomenon occurs in areas that are susceptible to the accumulation of a solution during brush application, wrinkling could possibly relate to accumulation of B-72 copolymer on the surface during the...
application of an isolation layer. In the gilding process, areas of accumulated resin expand during the application of any wetting mixture containing ethanol. It is likely, therefore, that stretching of the polymer film is irreversible and subsequent contraction during drying could therefore result in wrinkling of surfaces in these areas.

4.2.2. Practical application

4.2.2.1. Case study: Conservation of the frame for the drawing Reflections, 1898, by A.H. Fullwood (1863-1930)

Figure 2. The frame for the drawing, 'Reflections', 1898, by A.H. Fullwood (1863-1930).

Agenda: Layers apparent on the subsequent sections of the frame:
A: wood; gesso; bronze paint; grey-white gesso; shellac; oil-gilding; greenish-grey paint
B: wood; gesso; red bole; gold leaf; oil-gilding; greenish-grey paint
C: wood; gesso; light pink coating; bronze paint; oil-gilding; greenish-grey paint

Dimensions: 1230 x 9250 x 20 mm. (See photographs: 48 to 55.)
Treatment was carried out prior to the preparation of this drawing for the Australian Watercolours exhibition in 2005.

The frame consisted of plain moulding with cavetto and triple reeding at the outer edge and broad flat moulding enriched with raised reeded moulding that divided it into broad frieze and flat with bevel at the inner edge (fig 2). The original finish of the frame was completely hidden under layers of oil-regilding and greenish-grey paint.

Small sections of the frame at the right upper corner were selected for examination using a stratigraphic window under a magnified glass (x6). Subsequent layers were successively removed with a scalpel, revealing that flat parts of the moulding were painted originally with bronze paint over the sealed gesso foundation, whereas the inner reeded moulding had been gilded with gold leaf over a red bole foundation. This finish was then altered by the application of gesso on the inner frieze and regilding of the entire frame using gold leaf and oil gilding technique. Later this finish was partly repainted with grey paint, probably in order to cover greater losses in the gilded finish, which had started to separate from the paint underneath forming dark unpleasant concave patches on the surface. The outermost reeded moulding was probably added at the same time as the grey paint. This part of the moulding was made of a new wood and was finished with bronze paint and painted grey with the rest of the frame. It is possible that the inner original part of the frame formed an extended slip for the major frame that was later lost.

In the course of treatment the outer reeded moulding was removed from the frame. It was decided that it would be replaced with a replica of the plain oak moulding that formed the main part of the original frame in the other work of A. H. Fullwood, Wet Evening, also in the collection of the Art Gallery of New South Wales (see 6.1.2.1). This type of moulding would also be more suitable and accurate to the period of the artwork.
The inner part of the frame (broad flat moulding enriched with raised reeded moulding) was restored. The regilded layers and greenish-grey paint had a tendency to flake and, except in the reeded moulding where acetone compresses were more efficient, could be separated reasonably easily from the other layers with a scalpel. After removal of the regilding layers, it became obvious that the original bronze paint layers were in poor condition and aesthetically unpleasant. Therefore the decision was made that the entire surface would be regilded to create an appearance closer to that originally intended. The regilded surface would also provide a more sympathetic framing for the work of art.

The flat surfaces were coated with new gesso layers, which were levelled and then isolated with 10% B-72 in xylene (w/v), followed by gouache paints imitating bole. The buffed surface was then coated with two layers of 15% AYAF (w/v) in ethanol/diethyl ether (2:1, v/v). The dry film was reactivated with water with 20% ethanol just prior to the application of gold leaf.
Stage II: Polyvinyl Acetate Resin AYAF: practical test

Case study: the frame for the drawing *Reflections, 1898*, by A.H. Fullwood (1863-1930)

Photo 48 - Stage II: PVAC AYAF – case study; during removal of overpaintings

Photo 49 - Stage II: PVAC AYAF – case study; LUC prior to removal of overpaintings

Photo 50 - Stage II: PVAC AYAF – case study; LLC during removal of overpaintings

Photo 51 - Stage II: PVAC AYAF – case study; RUC during removal of overpaintings, showing revealed damages
Stage II: Polyvinyl Acetate Resin AYAF: practical test - continuing

Photo 52 - Stage II: PVAC AYAF - case study; detail of the frame during removal of overpaintings.

Photo 53 - Stage II: PVAC AYAF – case study; RUC during preparation for gilding

Photo 54 - Stage II: PVAC AYAF – case study; LLC prior to gilding

Photo 55 - Stage II: PVAC AYAF – case study; RUC after gilding, prior to an application of ormolu
4.2.2.2. Results and discussion

After application of the first coat of gold leaf the surface had small ‘spot-like’ areas of missing gold coating. In addition, the gold leaf had the unpleasant appearance of unrelaxed leaf. The entire surface was gilded again with much better results. The surface was completely covered, and the appearance of a matte water-gilded surface, was improved further following the application of two coats of traditional ormolu varnish (rabbit skin glue with an addition of up to 10% of diluted shellac). Application of the first coat of this varnish had to be performed very carefully as repeated brush movement could remove gold leaf. In contrast, the second coat was much easier to apply.

This test confirmed that AYAF is a material that could be used for losses compensation on matte water-gilded surfaces. Despite some of limitations, such as sensitivity to water, the consequent possibility of gold leaf removal with a second application of gold leaf or ormolu as well as its toxicity during application due to the solvent used, this material can be employed in all conservation treatments. It appears results obtained using AYAF are more reliable than those using B-72 solutions.
4.3. **Gilding with Acrylic Dispersion:**

*Plextol®B500.*

**4.3.1. Investigation into the performance of Plextol®B500 depending on varied solution concentrations and methods of activation of dried films.**

In previous tests Plextol®B500 performed very well when diluted in the proportion 1:1 with water/ethanol (4:1) mixed with gouache paints. The only noticeable drawback of this material was the appearance of joining lines between gold leaves, which were similar to joining lines typical of the oil gilding method. In order to overcome this problem it was decided to include a film reactivation method in the current experiments that would involve wetting the surface in a manner analogous to traditional water-gilding techniques.

It has been noted in the conservation literature that acrylic emulsion paint films are readily soluble in xylene, toluene, and acetone and in certain circumstances they also show sensitivity to aliphatic hydrocarbons and water (Stringari and Pratt, 1993). Plextol®B500 thickened with toluene is used as an adhesive in painting conservation for cold lining, where dry films are activated or softened by spraying with toluene (Duffy, 1989, Phenix, Hedley, 1984) or propan-2-ol (Mehra, 1981, Phenix, Hedley, 1984). Previous tests also demonstrate that for the purpose of attracting gold leaf, a dry film of Plextol®B500 can be successfully activated with moisture (exhalation).

The sensitivity of Plextol®B500 to water and propan-2-ol are features that could be beneficial for the purpose of this research in regards to the reactivation of dry films prior to the application of gold leaf. There are two reasons why the presence of propan-2-ol in the reactivation mixture may provide better adhesion of
gold leaf. It has been shown that this solvent can reactivate a dry film of Plextol®B500, providing better adhesion for gold leaf. Secondly, it can also work as a surfactant, breaking the surface tension of water. Mixtures of water and propan-2-ol were therefore included in the current program.

There has been no methodical research published regarding the behaviour of Plextol®B500 in water solutions. Nevertheless, it has been observed empirically that solutions consisting only 20% (v/v) of the stock solution of Plextol®B500 provide an adequate bond for the consolidation of flaking paint in oil paintings on glass, whereas lower concentrations of this acrylic emulsion did not provide sufficient adhesion between the glass and the paint layer (Dudek, M., 1996).

In the current research, Plextol®B500 was prepared in three solutions of different concentrations in order to investigate the behaviour of this material and its adhesive properties. Prior to the application of gold leaf, dry films were reactivated using four methods; exhalation, and using three solutions of water/propan-2-ol mixtures of varying proportions.

### 4.3.1.1. Preparation of samples

All samples were prepared in a similar manner to samples using method E in previous experiments: the gesso foundation in each sample was sealed with 10% B-72 in xylene, followed by two coats of a polymer/ gouache paint mixture, simulating bole. The second coat was slightly abraded with fine emery paper prior to the application of the final layer of polymer/ gouache paint solution.

As in previous tests, in order to overcome an opalescence phenomenon Plextol®B500 was first diluted with water/ethanol (4:1) to the required concentration and then a minute amount of appropriate gouache colours was added in order to achieve a suitable tone.
Three concentrations of a Plextol®B500 solution were prepared in the manner described below:

- Samples A - 2 parts of Plextol®B500 : 1 part of a water/ethanol mixture (4:1); (v/v)
- Samples B - 1 part of Plextol®B500 : 1 part of a water/ethanol mixture (4:1); (v/v)
- Samples C - 1 part of Plextol®B500 : 2 parts of a water/ethanol mixture (4:1); (v/v)

Two coats of a particular solution were applied onto four samples and the dried film of each of them was subsequently reactivated with one of the following methods:

- exhalation
- water with 10% propan-2-ol
- water with 25% propan-2-ol
- 1:1 mixture of water and propan-2-ol.

### 4.3.1.2. Testing results

(See photographs: 56 to 58).

No problems were encountered with the brush-based application of any of the selected Plextol®B500 solutions. After the application of two coats, the surface achieved a semi-gloss appearance, slightly shinier than the original bole foundation.
All samples provided very good gold leaf adhesion with the first application. In fact, adhesion was so good on all samples, regardless of the concentration of polymer in the solutions applied, that a second gold leaf layer was unnecessary. Optimum gold leaf behaviour was observed during gilding using a mixture of water with 10% propan-2-ol. The wetting mixture provided sufficient attraction for the gold leaf without breaking or causing the ‘sinking down’ effect observed during tests with B-72.

The gilded surface of all samples had a smooth texture, which to the expert panel convened to judge the results was adjudged similar to traditional matte water-gilding. In the samples reactivated with a water/propanol mixture, joining lines between gold leaves produced characteristic marks of overlapping edges, enhancing the resemblance to water-gilding. Nevertheless, in all of these samples layers gilded on polymer had a greater level of gloss than surfaces gilded on traditional bole foundations. A slight distortion of the surface was noted at lines joining areas of new and traditional gilding.

After the application of a protective coating of ormolu, the surface of samples reactivated with a mixture of water and propanol were slightly transparent: a distinctive feature of distressed or aged water-gilding. This appearance was likely caused by imperfections in the gold leaf, which had many detectable microscopic holes made during the manufacturing process. Such imperfections in gold leaf are, of course, the reason for double gilding when using traditional gilding techniques. Additional imperfections in gold leaf, ignored during all test assessments, were beating marks, which were rather obvious and formed unpleasant marks on the gilded surface after application. Such beating marks indicate rather poor craftsmanship and are characteristic for gold leaf from the particular manufacturer. However, these imperfections in gold leaf do not have any influence on the result of the evaluations since the same gold leaf was used for both traditional control samples and those non-traditional gilded.
<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1. 10% B72 in xylene(w/v) 2. watercolours L3 Plextol® B 500 in water/ethanol (4:1), 2:1, plus watercolour paint (two layers)</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>GS</td>
</tr>
<tr>
<td>L1. 10% B72 in xylene(w/v) L2. Watercolours L3. Plextol® B 500 in water/ethanol (4:1), 1:1, plus watercolour paint (two layers)</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>GS</td>
</tr>
<tr>
<td>L1. 10% B72 in xylene(w/v) L2. Watercolours L3. Plextol® B 500 in water/ethanol (4:1), 1:2, plus watercolour paint (two layers)</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>GS</td>
</tr>
</tbody>
</table>

Table 23: Performance of Plextol® B 500 - activated with water with 25% of propan-2-ol

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B72 in xylene(w/v) L2 watercolours L3. Plextol® B 500 in water/ethanol (4:1), 2:1, plus watercolour paint</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>GS/E</td>
</tr>
<tr>
<td>B. L1. 10% B72 in xylene(w/v) L2. watercolours L3. Plextol® B 500 in water/ethanol (4:1), 1:1, plus watercolour paint</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>GS/E</td>
</tr>
<tr>
<td>C. L1. 10% B72 in xylene(w/v) L2. watercolours L3. Plextol® B 500 in water/ethanol (4:1), 1:2, plus watercolour paint</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>GS/E</td>
</tr>
</tbody>
</table>
Table 24: Performance of Plextol® B 500 - activated with water with 25% of propan-2-ol

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B72 in xylene(w/v) L2. watercolours L3. Plextol® B 500 in water/ethanol (4:1), 2:1, plus watercolour paint</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>GS/E</td>
</tr>
<tr>
<td>B. L1. 10% B72 in xylene(w/v) L2. watercolours L3. Plextol® B 500 in water/ethanol (4:1), 1:1, plus watercolour paint</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>GS/E</td>
</tr>
<tr>
<td>C. L1. 10% B72 in xylene(w/v) L2. watercolours L3. Plextol® B 500 in water/ethanol (4:1), 1:2, plus watercolour paint</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS</td>
<td>GS/E</td>
</tr>
</tbody>
</table>
Table 25: Performance of Plextol® B 500 - activated with water with 50% of propan-2-ol

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. L1. 10% B72 in xylene (w/v) L2. watercolours L3. Plextol® B 500 in water/ethanol (4:1), 2:1, plus watercolour paint</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS GB</td>
<td>GS GB</td>
</tr>
<tr>
<td>B. L1. 10% B72 in xylene (w/v) L2. watercolours L3. Plextol® B 500 in water/ethanol (4:1), 1:1, plus watercolour paint</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS GB</td>
<td>GS GB</td>
</tr>
<tr>
<td>C. L1. 10% B72 in xylene (w/v) L2. watercolours L3. Plextol® B 500 in water/ethanol (4:1), 1:2, plus watercolour paint</td>
<td>No apparent problems</td>
<td>GS</td>
<td>GS GB</td>
<td>GS GB</td>
</tr>
</tbody>
</table>

Legend:
- **E** - excellent, identical with an appearance of the traditional mat water gilding
- **GA** - good matt appearance, but poor adhesion of gold leaf
- **GB** - good matt appearance but brush strokes slightly apparent/or surface uneven
- **GS** - good matt, but oil gilding appearance remains
- **GSB** - good although surface slightly shiny
- **GO** - good although surface slightly shiny and brush strokes slightly apparent
- **RB** - reasonable matt, but brush strokes apparent/or surface uneven
- **RR** - reasonable matt, but surface rough
- **ROR** - reasonable matt, but oil gilding appearance remains and surface is rough
- **RS** - reasonable, but surface evidently shiny
- **RSB** - reasonable, but surface evidently shiny and brush strokes apparent/or surface rough
- **PB** - poor, brush strokes very apparent
- **PS** - poor, surface to shiny
- **PSB** - poor, surface to shiny and brush strokes apparent
- **PA** - poor, gold leaf does not adhere
- **POA** - poor, gold leaf does not adhere properly and oil gilding appearance remains
- **PR** - poor, surface very rough
Stage II: Plextol® B500

Photo 56 - Stage II: Plextol® B500; test 1 - all samples prior to gilding

Photo 57 - Stage II: Plextol® B500; test 1 - all samples after gilding and an application of protective coating
4.3.1.3. Additional tests

The results of all tests with Plextol®B500 were judged satisfactory and demonstrated the broad flexibility of this material in terms of the concentrations of acrylic emulsion and the possibilities regarding film reactivation methods. Nevertheless two additional tests were included with a view to further improving the appearance of gilded surfaces by reducing both the level of gloss and distressed appearance of the gilded surface:

- Tests 2: Gilding on a foundation prepared with B-72 isolation film, gouache paints imitating bole, and only one coat of a Plextol®B500/ water/ ethanol/ gouache paints mixture in varied concentrations, reactivated with a mixture of 25% propanol in water. Subsequent second gilding followed evaluation of the surface quality of the first layer of gold leaf. Although gilding performed with a reactivation mixture containing 10% propanol yields the best texture of any material tested, a mixture with a greater content of propanol was selected due to concerns that one layer of Plextol®B500 film would require greater adhesion for gold leaf.

- Tests 3: Double gilding of a surface prepared with B-72 film, gouache paints, and only one coat of a Plextol®B500/ water/ ethanol/ gouache paints mixture and a variety of methods of reactivation of the dried film.

In conducting these tests it was assumed that one coat of Plextol®B500 film with added gouache paints, could produce a surface with a lower gloss than foundations consisting of two layers of this material. It was further assumed that double gilding would also cover all missing spots caused by imperfections in the gold leaf and should thereby provide a solid opaque appearance on the surface, as it does for surfaces gilded with the traditional method.
**Preparation of the samples for the additional tests**

Three samples, **A1, B1, C1**, were prepared for the second tests. The gesso foundation was coated with one layer of 10% B-72 in xylene (w/v), followed by two layers of gouache paints simulating bole, and one layer of Plextol®B500 : water/ethanol mixture (with gouache paints added), in the subsequent concentrations

- 2:1 (A1),
- 1:1 (B1),
- 1:2 (C1).

The dry films were reactivated with a mixture of water with 25% propan-2-ol just prior to the application of gold leaf. After drying, gold leaf was smoothed with a cotton ball and gilded again following wetting the surface with the same solution.

For the third test, three samples, **A2, A3, A4** were prepared with a gesso foundation isolated with one layer of 10% B-72 in xylene (w/v), followed by 2 layers of gouache paints and one layer of a 2:1 mixture of Plextol®B500: water/ethanol mixed with gouache paints. Samples were then gilded in the following manner:

- **Sample A2** was firstly gilded with gold leaf, reactivating the dry film of Plextol®B500 using exhalation. The gilded surface was then smoothed with a cotton ball and gilded again, reactivating the film 1° with exhalation, and after an unsuccessful attempt (see: below) 2° with a mixture consisting of 25% propan-2-ol just prior to application of gold leaf.

- **Sample A3** was double gilded, wetting the surface with a mixture of 25%
propan-2-ol content for both gold leaf layers.

- **Sample A4** was double gilded, applying gold leaf on the surface wetted firstly with a mixture of water with 25% propan-2-ol, and secondly with a mixture of water with 10% propan-2-ol.
Stage II: Plextol® B500 - continuing

Photo 58 - Stage II: Plextol® B500; test 1 - sample C activated with water/propan-2-ol (1:1)

Photo 59 - Stage II: Plextol® B500; additional tests 2 and 3
Stage II: Plextol® B500 - continuing

Photo 60 - Stage II: Plextol® B500; additional tests 2 and 3

Photo 61 - Stage II: Plextol® B500; test 2 - sample C1

Photo 62 - Stage II: Plextol® B500; test 3 - samples A2, A3, A4
Stage II: Plextol® B500 – continuing

Photo 63 - Stage II: Plextol® B500; test 3 - sample A2.

Photo 64 - All samples with Plextol® B500 included in testing in the Stage I and II
Results of the additional tests

(See photographs: 59 to 64).
In all cases, foundations prepared for gilding were characterised with a lower gloss than those achieved in previous tests. An excellent, semi-matte appearance similar to a background made of traditional bole was achieved.

In all cases adhesion of gold leaf was satisfactory, even following only the first application. Results were similar to the findings of the first tests, with several small spots on the gilded surface left uncovered due to imperfections in gold leaf (such an outcome is common during gilding performed with traditional matte water-gilding methods, and therefore double gilding is usually required in order to achieve a surface fully covered with gold leaf).

The samples A1, B1, and C1 as well as A3, and A4 were gilded again with excellent results obtained. A second layer of gold leaf adhered well to the surface. However, an attempt at gilding the surface of sample A2 again by reactivating it with exhalation was unsuccessful. Gold leaf did not adhere even to small spots left exposed during the first gilding. All residues of loose gold leaf were then removed and gold leaf was applied again on the surface wetted with a mixture of water with 25% propan-2-ol. Gold leaf adhered very well to the surface, also covering small dot-size areas missed during the first gilding.

In all samples used in these additional experiments, areas gilded using acrylic emulsion showed acceptable levels of gloss and provided textures to the surface. Furthermore, no distinction could be made between the appearance of the gilded surfaces of particular samples in either test 2 and 3. Although the joining line between traditional and non-traditional forms of gilding was noticeable they were not very significant and would, in all probability, be deemed acceptable in conservation practice.
Table 26: Test 2 - additional test of performance of Plextol® B 500; one coating activated with water with 25% of propan-2-ol

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1. L1. 10% B72 in xylene (w/v) L2 watercolours L3. One coat of Plextol® B 500 in water/ethanol (4:1), 2:1, plus watercolour paint</td>
<td>No apparent problems</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>B1. L1. 10% B72 in xylene (w/v) L2. watercolours L3. One coat of Plextol® B 500 in water/ethanol (4:1), 1:1, plus watercolour paint</td>
<td>No apparent problems</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>C1. L1. 10% B72 in xylene (w/v) L2. watercolours L3. One coat of Plextol® B 500 in water/ethanol (4:1), 1:2, plus watercolour paint</td>
<td>No apparent problems</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
</tbody>
</table>
Table 27: Test 3 - Additional test of performance of Plextol® B 500; film activated with mixed methods

<table>
<thead>
<tr>
<th>Type of foundation</th>
<th>Evaluation of performance during application</th>
<th>Surface appearance prior to application of gold leaf</th>
<th>Surface appearance after application of gold leaf</th>
<th>Surface appearance after application of protective layer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2. L1. 10% B72 in xylene(w/v) L2. watercolours L3. one coat of Plextol® B 500 in water/ethanol (4:1), 2:1, plus watercolour paint - foundation for first gold leaf layer activated with exhalation - second coat of gold leaf applied with 1° exhalation, 2° water/propanol (25%)</td>
<td>No apparent problems</td>
<td>E</td>
<td>G After second layer: 1° PA 2° E</td>
<td>E</td>
</tr>
<tr>
<td>A3. L1. 10% B72 in xylene(w/v) L2. watercolours L3. One coat of Plextol® B 500 in water/ethanol (4:1), 2:1, plus watercolour paint - double gilding, foundation activated with water with 25% of propan-2-ol</td>
<td>No apparent problems</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
<tr>
<td>A4. L1. 10% B72 in xylene(w/v) L2. watercolours L3. One coat of Plextol® B 500 in water/ethanol (4:1), 2:1, plus watercolour paint - first coat activated with water/propanol (25%) - second activated with water with 10% of propan-2-ol</td>
<td>No apparent problems</td>
<td>E</td>
<td>E</td>
<td>E</td>
</tr>
</tbody>
</table>

Legend:

- E - excellent, identical with an appearance of the traditional mat water gilding
- GA - good matt appearance, but poor adhesion of gold leaf
- GB - good matt appearance but brush strokes slightly apparent or surface uneven
- GO - good matt, but oil gilding appearance remains
- GS - good although surface slightly shiny
- GSB - good although surface slightly shiny and brush strokes slightly apparent
- RB - reasonable matt, but brush strokes apparent or surface uneven
- RR - reasonable matt, but surface rough
- ROR - reasonable matt, but oil gilding appearance remains and surface is rough
- RS - reasonable, but surface evidently shiny
- RSB - reasonable, but surface evidently shiny and brush strokes apparent or surface rough
- PB - poor, brush strokes very apparent
- PS - poor, surface to shiny
- PSB - poor, surface to shiny and brush strokes apparent
- PA - poor, gold leaf does not adhere
- POA - poor, gold leaf does not adhere properly and oil gilding appearance remains
- PR - poor, surface very rough
4.3.1.4. Discussion

Experiments with Plextol®B500 furnished excellent results. Tests with a foundation of two layers of Plextol®B500 acrylic emulsion produced acceptable adhesion of gold and suitable texture of the formed surfaces, particularly with a film reactivated with a mixture containing 10% propanol. Nevertheless, all surfaces showed a greater level of gloss than parts gilded with the traditional method. In experiments conducted in the STAGE 1 (see chapter 3), the level of gloss of the gilded surface was judged excellent, despite being formed of three layers of Plextol®B500 solution. Differences in appearance of the surface result from variations in the reactivation methods used on the dried films. Exhalation moisture causes briefly a blooming and matting effect on dry Plextol® foundations. Gold leaf slightly pressed to such surfaces retains its matte appearance as the surface gains only a little moisture and dries rather quickly. In the second method of application, dry films of acrylic foundation are wetted significantly with a water/propanol solution, which has a rather low evaporation rate and takes a longer time to dry out allowing the formation of a gloss surface again. It is important to note that films with one coat of Plextol®B500 produced an excellent low sheen foundation layer, and the gilded surface retained such an appearance after drying.

No difference was noted in the adhesion of gold leaf and the appearance of the gilded surface between samples with films formed using either low or high concentrations of Plextol®B500. Even the most dilute solutions provided sufficient attraction for gold leaf, particularly if gilding was performed using a water/propanol mixture for film activation. The stock solution of Plextol®B500 has around 50% solid resin concentration, which is greater than other acrylic emulsions (De Witte, E., Florquin, S., Goessens-Landrie, M., 1984). Greater w/v resin concentration of Plextol®B500 emulsion could be responsible for the maintenance of adhesion even in diluted solutions of this material. Indeed, the results of the tests conducted indicate that this material offers great flexibility in working properties in terms of solution concentrations, application methods, and
gilding techniques. It is for example, noteworthy that the surface can be
gilded on the film reactivated first with exhalation and then with water/ alcohol
mixture for a second coating of gold leaf.

Optimum results in terms of surface appearance were obtained by building with a
reactivation mixture consisting of 10% propan-2-ol. Acceptable results were also
achieved with a wetting mixture containing 25% propanol for first gilding and
10% for the second layer of gold leaf as well as with a solution of 25% propanol
content for both gildings. Solutions with propanol contents greater than 25%
produced rougher surfaces with the characteristic wrinkles of unrelaxed gold leaf.
These results suggest that the addition of propan-2-ol in a wetting mixture is more
effective at breaking the surface tension of water than the reactivation of a dry
film of Plextol®B500.

The distinctive appearance of joining lines between traditionally and non-
traditionally gilded areas was almost the only drawback of gilding on a
Plextol®B500 foundation. The effect, visible in all samples, was most likely
caused by the presence of an isolation layer of B-72 that accumulated on the edges
of a surface gilded with the traditional technique. This forms a thin line of shiny
film and consequently provided additional adhesion for gold leaf and a more shiny
appearance for gilding performed on such a polymer foundation. Special care is
required to apply both B-72 and Plextol®B500 in very thin coats, particularly at
the border lines, in order to eliminate these joining marks.

**4.3.2. Practical Implications**

Field testing of Plextol®B500 was carried out on a number of gilded objects.
During the years 2000-2005 several gilded frames with various problems
requiring conservation have been selected and treated using acrylic dispersion
Plextol® B500 as a substitute for traditional matte water-gilding and a mixture of acrylic dispersion Plextol® B500/ Plextol® D360\textsuperscript{29} as a substitute for traditional oil-gilding materials. The following accounts are brief reports from the treatments carried out.

4.3.2.1. **Case study 1: Conservation of the frame for the painting Madame De La Porte, 1754, by Jean-Marc Nattier (1685-1766)**

Louis XV style frame; Dimensions: 111.0 x 94.5 x 10.0 cm. (See photographs: 65 to 67).

This treatment was performed in the year 2001 and it was the first involving Plextol® B500 as a substitute for traditional gilding materials.

This rococo style frame, which is most likely the original for the painting, was carved and originally gilded using matte and burnished water-gilding techniques over red bole foundation. The finish of the surface prior to treatment was a mix of original gilding, bronze overpaintings (in fact brass particles in resinous medium) and in-gilding undertaken with traditional gilding techniques during previous restorations. The original gilding was abraded on the extremes of the moulding and covered with dirt and dust. Regilded areas were slightly lighter and more yellow than original parts due to the different colour of gold leaf used. Although abrasions of the surface were also apparent, their condition was sound.

\textsuperscript{29} In the course of tests that were conducted on the site of major subject if this research I have discovered that a mixture of acrylic dispersions Plextol® B500 and Plextol® D360 can successfully replicate traditional gold size. Acrylic dispersion Plextol® D360 is a copolymer of methyl methacrylate (MMA), butyl methacrylate (BMA), and ethyl methacrylate (EMA). It is a stable conservation material used successfully as an adhesive in conservation of paintings, textiles, and mural paintings. It settles preserving permanent tack.
The frame had many losses to its carved ornaments many of which had been painted with bronze paint in an attempt to disguise the damage. The numerous losses along the apophyge moulding, cleavages and lifting in the gesso foundation, indicated a loss of adhesion in all sections of the frame. Areas with bronze overpainting were dark due to the oxidation of metal particles and this detracted from the general appearance of the frame.

In 1999 the frame was restored, concentrating on stabilisation of the surface, removal of bronze paint, replacement of missing parts of ornaments, and selective in-gilding of areas with greater losses.

Lifted and fragile areas of the surface were consolidated with a 5% (w/v) gelatine solution. Bronze overpaints were removed with acetone, while the gilded surface was selectively cleaned with 5% (w/v) tri-ammonium citrate (TAC) solution in distilled water, followed by saliva and white spirit to remove residual TAC. Previous in-gildings were left untouched.

The gilding surrounding the losses was coated with 10% (w/v) B-72 in xylene to protect the gilding during the infilling process. Areas with losses were isolated with the same resin solution and then in-filled with several layers of gesso based on calcium carbonate (and 5% w/v rabbit-skin glue). After levelling, B72 film around all in-filled areas was removed. In-filled areas were then coated with 10% (w/v) B-72 in xylene and watercolours matching the colour of bole.

Coloured infillings were coated with two layers of 20% (w/v) B-72 in xylene. After drying, the B-72 film was activated prior to gold leaf application using white spirit with the addition of 25% (v/v) ethanol. Areas that required burnishing were burnished with agates, while other in-gildings on the matte surface were left unburnished. Small areas with losses were in-painted with non-corrosive iridescent mica powders mixed with gelatine binder. The extremities of the moulding (which were burnished), were covered with 23% (w/v) solution of hydrogenated hydrocarbon resin Regalrez®1094 in white spirit for
protection and to enhance their glossy appearance. Matte areas were coated with ormolu (5% w/v rabbit-skin glue solution with 10% v/v of diluted shellac).

In 2001 this restored frame was damaged during transit. Part of the carved moulding was broken and lost. The replacement segment was made from traditional composition material coated with gesso and after levelling it was painted with Plextol® B500 diluted 2:1 (v/v) with water/propanol (4:1, v/v) and mixed with gouache paints imitating the colour of bole. After drying, the surface was activated by exhalation immediately prior to the application of gold leaf. The dried surface was then burnished with agate, slightly distressed, protected with Regalrez® 1094 varnish and patinated to match the original surface.
Stage II: Plextol® B500: Practical tests

Case study 1: the frame for the painting *Madame De La Porte, 1754, by Jean-Marc Nattier* (1685-1766)

Photo 65 - Stage II: Plextol® B500 - case study 1; a fragment of the corner prior to in-gilding

Photo 66 - Stage II: Plextol® B500 - case study 1; a fragment of the corner after treatment

Photo 67 - Stage II: Plextol® B500 - case study 1; the corner of the frame after treatment
4.3.2.2. Case study 2: Conservation of the frame for the painting *Art Students, 1895*, by *E. Phillips Fox* (1865–1915).

Dimensions prior to alterations: 2610 x 1478 x 125 mm. Dimensions after alterations: 2192 x 1470 x 170 mm. (See photographs: 68 to 79)

This frame was restored in 2002.

The original frame for the *Art Students, 1895*, was vanished in unknown circumstances many years ago. Since this time the painting has been encased in a contemporary - Whistlerian style - reeded frame, which was historically and aesthetically unsuitable for the painting. Over the years many curators and...
conservators have deliberated over the creation of an appropriate reproduction frame. The Parallel Visions exhibition, which was intended to open at the Art Gallery of New South Wales in 2002, provided opportune circumstances to undertake this project.

In searching for an appropriate design for the frame for Art Students, another painting by Phillips Fox, Lady in Black, 1900 was found. It was slightly larger than Art Students, but was sympathetic in the presentation of the subject and was painted only five years later. The natural aging process of the unstable materials used by Phillips Fox to paint Lady in Black caused the image of the painting to be destroyed beyond possibility of restoration (Painting Conservation Report, 2001). Due to its poor condition, the painting would never again be exhibited. The original frame that surrounded Lady in Black was in a better state of preservation than the painting. Although it was in a fragile condition, it still retained its original gilded surface and could be conserved.

The frame represents a traditional European eclectic style, typical of frames from the second half of the 19th century. It consists of three sections (Fig.3); main outer moulding with plain torus at the top moulding and composition acanthus leaf on the ogee profile, inner section with small taenia, and inner slip. The corners of the frame are enriched with small cartouches with cabochons in the centre, and scrolls. The frame was gilded on calcium carbonate-based gesso and a brownish red bole foundation, using both oil and water-gilding techniques. Traces of original burnished gilding were detectable on the inner taenia moulding, whereas the matte water-gilding technique was used for the top torus, plain ogee at the inner slip, and inner slip.

The gilded surface of the frame was extremely dirty, and partly painted over with bronze paint (in fact, brass particles in an unidentified medium, which responded well to acetone during solvent tests), and semi-transparent brown washes, particularly on the top torus. The gilding was worn and abraded in many areas, with a thick layer of dirt and dust accumulated in the cavities of the
ornamented moulding. Flaking and lifting in the gilded finish were extensive on the top torus, indicative of a weak gesso foundation. Many losses had occurred, exposing the white background and bare wood. Losses in ornaments were most severe at the corners. Minor losses were also visible at the inner bead astragal of the upper member of the frame and at the outer astragal of the back edges of the lower member of the frame.

After modification to accommodate the *Art Students* painting, the frame required major restoration aimed at preserving the remains of the original gilded surface. The treatment focused on stabilisation of the fragile gesso foundation, gentle surface cleaning, removal of bronze overpaintings, replacement of losses of ornaments and in-gilding missing areas of the gilded surface.

Layers of black dirt and dust, which accumulated during years in storage, were slowly removed with cotton swabs saturated with a 5% (w/v) tri-ammonium citrate solution, revealing well-preserved original gilding. Residues of tri-ammonium citrate were removed with saliva and then with white spirit. Overpaintings of bronze paint and semi-brown washes, which were apparent in several areas on the frame, were removed using cotton swabs saturated with acetone. For the stubborn areas of overpaintings, poultices saturated with acetone were applied as a first step to soften the paint layers. Fragile parts of ornaments and gesso foundation were consolidated with diluted Plextol® B500 (2:1 with water / ethanol 4:1). This process was preceded with the application of ethanol in order to ensure deep penetration of the consolidant. Original ornaments were reattached using undiluted Plextol® B500. Losses of ornaments were replaced using traditional compo consisting of calcium carbonate, rosin, linseed oil, hide glue, rabbit skin glue, and glycerol, with the addition of x-ray dense barium sulphate for easy identification in the future. Losses in the foundation were replaced with several layers of gesso, based on calcium carbonate (English whiting), and levelled using dry and wet techniques. Gilding around losses was protected with 25% (w/v) Regalrez® 1094 in white spirit, in order to prevent damage during levelling. A new slip was coated with rabbit skin glue.
solution and several layers of gesso (as above) and then prepared for gilding in a similar manner as to other parts.

After levelling, the temporary Regalrez® 1094 varnish was removed with Shelsoll® A/Shellsol® T (1:4). Parts containing new gesso layers, including the inner slip, were sealed with one layer of 10% Paraloid® B-72 (w/v) in xylene, and then painted with watercolours simulating bole. For water-gilded passages two coats of diluted Plextol® B500 (2:1, with water/ethanol 4:1) were applied over areas coated previously with watercolours, and left to dry. The surface was then activated with exhalation just prior to the application of gold leaf. since it was considered that a gilding method involving wetting with a gilder’s water could weaken the already fragile and brittle gesso foundation, exhalation was also used for the second layer of gold leaf. The new inner slip was gilded in a similar technique.

Losses in ornaments were in-gilded by laying gold leaf on a film formed with a mixture of Plextol® B500/Plextol® D360 1:1, which simulated traditional gold size. Prior to application, this mixture was diluted in the proportion 2:1 with a water/ethanol mixture 4:1 in order to reduce its viscosity.

Two coats of proteinaceous ormolu (rabbit skin glue + 10% addition of weak shellac solution) were then applied over the entire frame. The top torus and outer mouldings of the frame were additionally covered with acrylic varnish Soluvar® Matte in order to provide protection for gilding during handling of the frame. Additional in-painting of minute losses in the gilded surface was carried out using iridescent mica powders mixed with ormolu or diluted Plextol® B500.
Stage II: Plextol® B500: Practical tests – continuing

Case study 2: the frame for the painting *Art Students, 1895, by E.Phillips Fox*

Photo 68 - Stage II: Plextol® B500 - case study 2; *Lady in Black, 1900, by E.Phillips Fox*, in an original frame

Photo 69 - Stage II: Plextol® B500 - case study 2; *Art Students, 1895, by E.Phillips Fox*, in previous frame

Photo 70 - Stage II: Plextol® B500 - case study 2; the new frame for *Art Students, 1895, by E.Phillips Fox*, prior to treatment

Photo 71 - Stage II: Plextol® B500 - case study 2; the new frame for *Art Students, 1895, by E.Phillips Fox*, prior to treatment
Case study 2: the frame for the painting *Art Students, 1895*, by E. Phillips Fox - continuing

Photo 72 - Stage II: Plextol® B500 - case study 2; surface cleaning and removal of overpaintings

Photo 73 - Stage II: Plextol® B500 - case study 2; detail prior to treatment

Photo 74 - Stage II: Plextol® B500 - case study 2; consolidation of detached and fragile areas

Photo 75 - Stage II: Plextol® B500 - case study 2; application of new gesso layers

Photo 76 - Stage II: Plextol® B500 - case study 2; prior to in-gilding

Photo 77 - Stage II: Plextol® B500 - case study 2; distressing of new gold leaf
Case study 2: the frame for the painting *Art Students, 1895*, by E. Phillips Fox - continuing

Photo 78 - Stage II: Plextol® B500 - case study 2; after treatment

Photo 79 - Stage II: Plextol® B500 - case study 2; detail after treatment
4.3.2.3. Case study 3: Conservation of the frame for the painting ‘The apotheosis of a pope and martyr’, by Giovanni Domenico Tiepolo (1727-1804)

Fig. 4. The frame for the painting *The apotheosis of a pope and martyr*, by Giovanni Domenico Tiepolo, 1727 – 1804

Dimensions: 99.5 x 61.3 x 5.5 cm. (See photographs: 80 to 98).
This treatment was carried out in the year 2003.

A ‘Canaletto-type’ frame with burnished ‘mirrors’ and corners, carved in a low relief with undulating stems and flowers on a punched background, was originally gilded using matte and burnished water-gilding techniques. The gilded surface was badly damaged on the uppermost parts of the moulding. The gesso foundation was very fragile and had the tendency for delamination and separation from the wooden background. Many losses exposing bare wood or white gesso were apparent at the top edges of the ogee moulding in the mirror sections or at the punched background. Some damaged parts were painted over with bronze paint and yellow ochre gouache paints.
Solvent tests conducted during the restoration process confirmed that the bronze paint responded best to acetone, whereas yellow ochre could be removed with saliva. The entire gilded surface was gently cleaned with a 5% tri-ammonium citrate solution in distilled water (w/v) followed by saliva, and white spirit. Fragile and detached areas were consolidated with Plextol®B500 diluted 2:1 with water/ethanol 4:1. Areas with losses were also isolated with diluted Plextol®B500, whereas the gilding around losses was protected with Regalrez®1094 varnish, prior to application of several layers of gesso based on calcium carbonate (English whiting). The replaced gesso layers were prepared for in-gilding using a wet levelling method and Regalrez®1094 varnish was then removed with white spirit. The smooth gesso surface was isolated with 10% Paraloid®B72 in xylene (w/v) and coated with yellow gouache paints imitating bole. Areas in mirror sections were additionally coated with red gouache paints imitating red bole.

In-gilding was carried out using 23-karat gold leaf (Stagg Brand®) applied over a foundation of Plextol®B500 (diluted 2:1 with water/ethanol 4:1). Since it was considered probable that the wet activation method might weaken the already fragile gesso layers, the dried film of Plextol® was activated by exhalation shortly prior to application of gold leaf. Whilst the surfaces in mirror parts of the moulding were then burnished with agate, the other parts were left in matte. New gilding was then slightly distressed to match the original worn gilding.

The matte gilded surface was covered with two layers of a traditional ormulu protective coating consisting of rabbit skin glue with up to a 10% addition of shellac. Additional protection against handling was provided with two layers of acrylic varnish Soulvar® Matte, which was applied over outer parts of the moulding (the running ornament at the outer edge, outer scotia and the uppermost parts of ogee moulding). Burnished mirror parts of the moulding were protected with Regalrez®1094 varnish. Additional in-painting was carried out using iridescent mica pigments with Plextol®B500 as a binder. Toning down of in-
gilded sections in order to match the original surface was carried out using gouache paints.
Stage II: Plextol® B500: Practical tests – continuing

Case study 3: the frame for the painting ‘The apotheosis of a pope and martyr’, by Giovanni Domenico Tiepolo (1727-1804)

Photo 80 - Stage II: Plextol® B500 - case study 3; the corner prior to treatment

Photo 81 - Stage II: Plextol® B500 - case study 3; detail of the frame prior to treatment

Photo 82 - Stage II: Plextol® B500 - case study 3; detail of the frame prior to treatment

Photo 83 - Stage II: Plextol® B500 - case study 3; detail of the frame prior to treatment

Photo 84 - Stage II: Plextol® B500 - case study 3; detail of the frame prior to treatment

Photo 85 - Stage II: Plextol® B500 - case study 3; detail of the frame during surface cleaning
Case study 3: the frame for the painting ‘The apotheosis of a pope and martyr’, by Giovanni Domenico Tiepolo (1727-1804) - continuing

Photo 86 - Stage II: Plextol® B500 - case study 3; detail of the frame during surface cleaning and removal of overpaintings

Photo 87 - Stage II: Plextol® B500 - case study 3; detail of the frame during surface cleaning and removal of overpaintings
Case study 3: the frame for the painting 'The apotheosis of a pope and martyr', by Giovanni Domenico Tiepolo (1727-1804) - continuing

Photo 88 - Stage II: Plextol® B500 - case study 3; detail of the frame after surface cleaning and losses replacements

Photo 89 - Stage II: Plextol® B500 - case study 3; detail of the frame prior to in-gilding
Case study 3: the frame for the painting *The apotheosis of a pope and martyr*, by Giovanni Domenico Tiepolo (1727-1804) - continuing

Photo 90 - Stage II: Plextol® B500 - case study 3; application of the Plextol® B500 foundation

Photo 91 - Stage II: Plextol® B500 - case study 3; activation of the dry film with exhalation

Photo 92 - Stage II: Plextol® B500 - case study 3; application of a gold leaf

Photo 93 - Stage II: Plextol® B500 - case study 3; gold leaf that adhered to the Plextol® B500 foundation

Photo 94 - Stage II: Plextol® B500 - case study 3; a fragment of the frame after gilding - a ‘mirror’ section was burnished with agate

Photo 95 - Stage II: Plextol® B500 - case study 3; a fragment of the frame after gilding - a ‘mirror’ section was burnished with agate
Case study 3: the frame for the painting *The apotheosis of a pope and martyr*, by Giovanni Domenico Tiepolo (1727-1804) - continuing
4.3.2.4. Case study 4: Conservation of the frame for the painting Classical Landscape, c.1820, by John Glover (1767-1849)

Fig. 5. The frame for the painting Classical Landscape, c. 1820; by John Glover (1767-1849)

Dimensions: 183.5 x 276.7 x 9.0 cm. (See photographs: 99 to 113).
The frame was fully restored for the John Glover retrospective exhibition in 2003.

This eclectic style ogee profile frame was enriched with running ornaments of floral scrolls with acanthus leaf at the corners. The main moulding of the frame was originally gilded using oil-gilding technique. The original water-gilding of the slip was applied using a glair medium, confirmed by FTIR examination of the samples.
The painting pre-dates Glover’s migration to Australia (Tasmania) in 1831. Based upon the style, minimal structural modifications and successive restoration treatments, it is believed that the frame is most likely contemporary to the painting. The preference for matte oil gilding across the entire frame surface, as used here, was employed by some artists in England around the early 19th century seeking to achieve the effect of dull matte gilding close up to the picture. It was also presumed to be more durable and easier to clean (Gregory 1996, Museum Management and Curatorship Vol.15 No.4).

The frame suffered water damage in the past and was restored several times prior to purchase by the Art Gallery of New South Wales in 1975. Prior to the present restoration, oxidised bronze paint covered the entire gilded surface of the frame. Examination of cross-sections showed distinctive orange fluorescence in the top paint layer under UV light, indicating a shellac medium. Surprisingly, the surface structure of the slip was the most complex of all those tested, consisting of at least three gilding layers in addition to the bronze overpainting.

The ornaments at the corners are not original. They showed no underlying preparatory foundation or gilding layers beneath the heavy application of bronze paint. Contemporary frames, similar in style at the National Portrait Gallery, London, incorporate rocaille corners with volutes around a central cabochon.

Water damage at the top left corner had resulted in mould growth and extensive losses to the original foundation and gilding layers. Cracking and embrittlement of the compo had made it vulnerable to damage, resulting in severe losses along the corners and uppermost ornamentation. Previous repairs to these losses have been made with yellow coloured synthetic foam adhesive and applied over a poorly-restored foundation and surface layers. They were deformed in shape and visually distracting.

Methylated spirits proved to be the most effective solvent for removal of the uppermost bronze paint layer, confirming that the medium used for this
paint layer was shellac. Further treatment with an acetone compress was required in scattered areas across the frame (mainly around areas of restorations). This process removed most of the underlying bronze paint based on the natural resin. It also exposed areas of ungilded replacement ornaments, a patchy surface of both original and previously restored gilding and demarcated modifications made to the original running pattern of the ogee moulding at each of the corners. Unsatisfactory previous repairs were removed in order to facilitate cleaning.

After removal of the bronze paint, darkened deposits of proteinaceous coating were revealed on the surface, which were subsequently removed with a 10% tri-ammonium citrate solution, followed by saliva and white spirit. A 10% tri-ammonium citrate solution was also used to remove the protein glue-based restored water-gilding on the inner slip without disturbing the underlying original glair-based water-gilding.

Overall it was found that the original oil-gilding remained well adhered with little flaking evident primarily across the uppermost parts of the ogee moulding. Consolidation was carried out in conjunction with surface cleaning where necessary, using Plextol®B500 diluted 2:1 with water: ethanol mixture 4:1.

The Plextol®B500 mixture used for consolidation was also used as an isolation layer as it creates a flexible acrylic film, which prior to drying is slightly water sensitive and provides a good base for new gesso layers or compo insuring proper adhesion. It forms a new unified layer with gesso that can easily be removed if required.

In order to recreate missing parts of ornaments, a mould using dental silicone rubber and Sculpey® was taken from the corresponding details, and a compo cast made and cut to size. Barium sulphate was added to the traditional compo material to ease X-ray identification in the future. Dents, scratches and losses in the flat surface were in-filled with putty made of a mixture of rabbit skin glue, rosin, glycerol, whiting, as well as barium sulphate.
A new gesso foundation was applied over replaced areas of moulding, and levelled using the wet levelling system. An isolation layer of 10% B72 was then applied over the surface followed by a raw umber watercolour coating, which imitated yellow bole and formed a proper foundation for gold leaf.

Replaced areas of moulding and areas with severe gold leaf losses were coated with a mixture of Plextol®B500/ Plextol®D360 1:1, diluted 2:1 with water: ethanol 4:1. This mixture dries out whilst preserving a tack similar to traditional gold size. Gilding was carried out using 23-karat gold leaf (Stagg Brand®).

After removal of all bronze overpainting, the inner slip presented a very patchy surface due to many damaged areas in-filled and coloured with raw umber. It was therefore decided that in order to provide an even uniform surface next to the image of the painting, the whole slip should be regilded. Gilding was carried out using Plextol®B500 diluted 2:1 with water: ethanol 4:1, which was activated with exhalation for the first gold leaf layer, and water with 10% ethanol for the second coat of gold leaf.

The whole gilded surface on the frame was protected with two layers of ormolu consisting of 5% rabbit skin glue with an addition of 10% diluted shellac. The new gilding was then toned down with gouache paints. The outer parts of the frame and extremes of moulding were additionally protected with two layers of acrylic varnish Soluvar® Matte in order to prevent any potential abrasions caused by future handling. The surface was then slightly brushed with rotten stone powder mixed with dry earth pigments.
Stage II: Plextol® B500: Practical tests – continuing

Case study 4: the frame for the painting Classical Landscape, c.1820, by John Glover (1767-1849)

Photo 99 - Stage II: Plextol® B500 - case study 4; the corner of the frame during removal of overpaintings

Photo 100 - Stage II: Plextol® B500 - case study 4; detail of the frame during removal of overpaintings

Photo 101 - Stage II: Plextol® B500 - case study 4; the corner of the frame prior to treatment
Case study 4: the frame for the painting *Classical Landscape, c.1820, by John Glover (1767-1849)* - continuing

Photo 102 - Stage II: Plextol® B500 - case study 4; the corner after replacement of losses

Photo 103 - Stage II: Plextol® B500 - case study 4; detail of the frame after replacement of losses
Case study 4: the frame for the painting *Classical Landscape*, c.1820, by John Glover (1767-1849) - continuing

Photo 104 - Stage II: Plextol® B500 - case study 4; detail after replacement of losses

Photo 105 - Stage II: Plextol® B500 - case study 4; entire frame after replacement of losses
Case study 4: the frame for the painting *Classical Landscape, c.1820, by John Glover (1767-1849)* - continuing

Photo 106 - Stage II: Plextol® B500 - case study 4; after replacement of losses

Photo 107 - Stage II: Plextol® B500 - case study 4; after replacement of losses

Photo 108 - Stage II: Plextol® B500 - case study 4; after replacement of losses
Case study 4: the frame for the painting *Classical Landscape, c.1820, by John Glover (1767-1849)*

Photo 109 - Stage II: Plextol® B500 - case study 4; the LUC after treatment

Photo 110 - Stage II: Plextol® B500 - case study 4; a fragment of the frame after in-gilding

Photo 111 - Stage II: Plextol® B500 - case study 4; the painting in its frame after treatment
4.3.2.5. **Case study 5: Conservation of the frame for the painting ‘Port-Goulphar, Belle-Île’, 1887, by Claude Monet, 1840-1926**

Fig. 6. The frame for the painting *Port-Goulphar, Belle-Île*, 1887, by Claude Monet, 1840-1926.

Dimensions: 982 x 820 x 78. (See photographs: 114 to 128).

The frame was restored in 2004.

In 1949, the Art Gallery of New South Wales purchased Claude Monet’s *Port-Goulphar, Belle-Île* framed in a Carlo Maratta style frame (Mitchell, 1996), which was stylistically related to Louis XVI frames, and was also favoured by the collector Durand-Ruel, who owned the painting until 1944. This frame consisted of plain moulding enriched with carved twisted ribbon-and-stick moulding, attached at the top edge of the inner scotia, and a carved running ornament of narrow palmette leaf attached next to the cavetto at the inner edge. The upper layers of gilded finish are likely to have been added shortly prior to the sale of the painting to the Art Gallery of New South Wales. Incisions at the top ovolo
moulding were intended to imitate age cracks, and a layer of artificially-applied dusty patina.

Early in the 1980s, Monet’s painting was reframed in a Louis XIV reproduction frame with a distressed dark finish, in accordance with the mistaken perception of the time that such elaborate broad mouldings were typical of Impressionist frames favoured by Monet. As later research has shown, it was the type of frame preferred by dealers and collectors rather than Monet himself, who in fact favoured narrower frames; Louis XIII or Louis XVI types, as well as classical styles (Stuchey, 1995).

The original Maratta frame for *Port-Goulphar, Belle Île*, 1887 was restored prior to lending the painting for the exhibition Impressionists held at the National Gallery of Victoria, Melbourne, Australia, in 2005. The condition of the frame was very poor. The gesso foundation was fragile, with a tendency to separate and delaminate subsequent gesso layers from the wooden background, which created losses particularly at the uppermost parts of the ovolo moulding, the outer scotia and the outer edges. Flaking was particularly severe around the damaged areas of the moulding. Brittle ornaments had been severely damaged in the past, and had been re-gilded and heavily patinated to cover imperfections. Several palmette leaves were incomplete or chipped. Due to the fragile nature of the surface layers it was very difficult to take cross-sections, and microscopic examination did not provide entirely reliable information. A stratigraphical examination followed, with removal of each subsequent layer in several designated areas on the frame.

1. Originally the ovolo, inner scotia and outer scotia were water-gilded on red-brownish bole and burnished or left matt (eighteenth-century finish).

2. A two-structured gesso layer was applied, followed by the application of gold leaf using a matt water-gilding technique, for the inner and outer scotia. The ovolo
was water-gilded over black bole, and burnished.

3. The inner and outer scotia were oil-gilded using imitation gold leaf, which was covered with a dark semi-transparent patina.

4. Finally, the inner and outer scotia were regilded using matt water-gilding and the ovolo was re-gilded using a burnished water-gilding technique with yellow gold leaf applied over red bole. The gilding surface was then incised across the ovolo moulding, imitating cracks on an aged gilded surface, and covered with a grey semi-transparent patina imitating dust.

Current treatment focused on the removal of all layers above scheme 3 that had presumably been created during the adoption of the frame for the Monet painting. The grey artificial patina, top varnish and upper layers of gilding were removed with a variety of methods involving solvents as well as the use of a scalpel. The powdering and delaminating gesso layers were consolidated with the acrylic dispersion Plextol® B500, diluted 2:1 with water and ethanol mixed 4:1. A layer of the same material also isolated the original substance from the new calcium carbonate-based gesso and infillings for small losses and damaged areas on flat surfaces. All replaced areas of the gesso foundation were then isolated with 10% Paraloid® B-72 in xylene prior to the application of red and black watercolours to simulate traditional bole.

In-gilding was carried out by laying gold leaf on a foundation of Plextol® B500 diluted 2:1 with water and ethanol mixed 4:1 and activating it with exhalation. This method of in-gilding was considered the safest for the fragile original gesso layers, which otherwise could easily have been damaged if a traditional water-gilding method had been implemented. The gold leaf on the ovolo moulding and the twisted ribbon ornaments was burnished with agate to simulate traditional burnished gilding. The entire surface of the inner and outer scotia moulding was covered with a layer of acrylic varnish mixed 1:1 from Soluvar® Gloss and
Soluvar® Matte. The burnished sections were protected with two layers of Soluvar® Gloss varnish.
Case study 5: the frame for the painting ‘Port-Goulphar, Belle-Île’, 1887, by Claude Monet, 1840-1926

Photo 112 - Stage II: Plextol® B500 - case study 5; prior to treatment

Photo 113 - Stage II: Plextol® B500 - case study 5; upper member prior to treatment
Case study 5: the frame for the painting *Port-Goulphar, Belle-Île*, 1887, by Claude Monet, 1840-1926 - continuing

Photo 114 - Stage II: Plextol® B500 - case study 5; LUC prior to treatment.

Photo 115 - Stage II: Plextol® B500 - case study 5; RLC prior to treatment
Case study 5: the frame for the painting ‘Port-Goulphar, Belle-Île’, 1887, by Claude Monet, 1840-1926 - continuing

Photo 116 - Stage II: Plextol® B500 - case study 5; LUC during removal of regilding

Photo 117 - Stage II: Plextol® B500 - case study 5; left member during removal of regilding

Photo 118 - Stage II: Plextol® B500 - case study 5; RLC during removal of regilding layers
Case study 5: the frame for the painting ‘Port-Goulphar, Belle-Île’, 1887, by Claude Monet, 1840-1926 - continuing

Photo 119 - Stage II: Plextol® B500 - case study 5; after replacement of losses

Photo 120 - Stage II: Plextol® B500 - case study 5; LUC after replacement of losses

Photo 121 - Stage II: Plextol® B500 - case study 5; outer moulding after replacement of losses

Photo 122 - Stage II: Plextol® B500 - case study 5; LLC after replacement of losses
Case study 5: the frame for the painting ‘Port-Goulphar, Belle-Île’, 1887, by Claude Monet, 1840-1926 - continuing

Photo 123 - Stage II: Plextol® B500 - case study 5; LLC prior to in-gilding

Photo 124 - Stage II: Plextol® B500 - case study 5; RUC prior to in-gilding

Photo 125 - Stage II: Plextol® B500 - case study 5; right upper corner after treatment
Case study 5: the frame for the painting ‘Port-Goulphar, Belle-Île’, 1887, by Claude Monet, 1840-1926

Photo 126 - Stage II: Plextol® B500 - case study 5; after treatment
4.3.2.6. Results and Discussion

All tests carried out have proved that acrylic dispersion Plextol® B500 is a very useful and appropriate material for the compensation of losses on matte water-gilded surfaces. Of all materials tested, Plextol® B500 demonstrates the greatest ability to recreate matte water-gilded surfaces. It is relatively easy to handle, prepare and use. In comparison with other tested polymers, it shows the greatest flexibility. Experiments have shown that this material is very versatile due to its ability to retain adhesion even in low concentrations, and the variety of activation methods that may be applied to the dried film depending on the condition of the object. Plextol® B500 can be diluted in varied proportions with water/ethanol mixture or with water/ethanol mixture mixed with watercolours/gouache paints, whilst still preserving its adhesive properties. If the substrate is sound, the dried film can be activated with exhalation for fragile and brittle gesso foundations or gilder’s water. Plextol® B500 is also a material used widely in other stages of gilded objects conservation such as consolidation and retouching, which assures its compatibility with other materials.

An additional benefit of gilding on a Plextol® B500 foundation is that the surface can be burnished if required. Tests of agate burnishing of surfaces produced using Plextol® B500 were exceptional. The resultant surface had a level of shine comparable with a slightly aged surface produced using traditional water-gilding technique.

In addition, it was empirically determined that Plextol® B500 combined with Plextol® D360 forms a mixture that simulates traditional oil gold size. A mixture of Plextol® B500 and Plextol® D360 can thus be prepared in various proportions according to desired tack strength. This mixture can also be diluted to a great degree with water with an addition of ethanol in order to prepare fluids easily applied by brush.
4.4. Conclusions

The test conducted in the stage II proved that with varied degrees of success, all three materials, B-72, PVAC AYAF and Plextol B500 are suitable to use for loss replacements in gilded objects conservation. The final phase for testing sought to examine the behaviour and effects of gilding using these synthetic backgrounds over time. Little is currently known of the time dependent deterioration of the non-traditional gilding materials' properties. If non-traditional materials are to be accepted within a profession with such exacting standards of reversibility and durability and stringent aesthetic demands, it is vital to determine what distinctions in terms of appearance, if any, occur between gilded surfaces created with traditional and non-traditional materials over time. These considerations form the basis of the next chapter.
5.0 STAGE III: TESTING AGING BEHAVIOUR OF SURFACES GILDED USING SELECTED SYNTHETIC POLYMERS

The final experimental chapter of this thesis covers the tests undertaken to examine the long-term stability and reversibility of the synthetic materials compared to surfaces gilded using traditional methods. All three materials that formed the focus of the previous chapter have proven to be durable in accelerated aging tests conducted on these polymers in other areas of conservation practice (Magin, 2002, Down, MacDonald, Tetreault, Williams, 1996, Whitmore, Colaluca, Val, 1995, Horton-James, Walston, Zounis, 1991, Duffy, 1989, Howells, Burnstock, Hedley, Hackney, 1984). Nevertheless, gilded surfaces are mixed media and subject to quite complex stress forces and unless subjected to exhaustive accelerated aging tests, any differences in behaviour between the aged properties of non-traditional and traditional materials over time may have a serious visual impact on a work of art.

5.1. Accelerated aging vs. natural aging

Accelerated aging is an attempt to simulate, over a short time period, the effects of long periods of natural aging. Within modern conservation practice its purpose is to evaluate the stability of materials, or the effects of treatments on the permanence of conservation materials. Accelerating aging tests vary depending on requirements. It can, for instance, consist of exposure to any combination of potentially damaging environmental factors including heat, humidity, light, oxygen, and pollutants. The underlying assumption of most accelerated aging experiments is that the test replicates the effect of natural aging in all respects
other than the rate at which the degradation occurs. Physico-chemical testing is conducted before and after commencement of the test to determine whether any measurable changes have occurred during the aging process. Many of the standard tests used in conservation practice are adopted from industrial testing methods. This is not totally satisfactory for the evaluation of the materials in the museum, as many aspects of industrial durability are not relevant to museum objects and the signs of failure are quite different. The preservation of objects entails not only the retention of functional properties, but also the preservation of the cultural information inherent in the object. Such information could be visual, physical, optical, structural, or chemical in nature. Therefore, considerable research has been undertaken to develop conservation-specific tests that measure changes in properties that are more relevant to conservation (Erhardt, Mecklenburg, 1995, Shashoua, 1993). As noted earlier, it is particularly important, for instance, that varnishes and other polymer coatings used in conservation be evaluated for their solubility and degree of yellowing. Nevertheless, it is recognised within the profession that yellowing of coatings is symptomatic of other more fundamentally important aspects of film degradation affecting the polymer’s mechanical behaviour and reversibility and consequently other tests have been developed to better measures of their degradation (Erhardt, Mecklenburg, 1995).

In a practical sense, there are few restrictions on the forms of tests that may be employed for accelerated aging. Indeed, any test that provides information that provides a direct measure of the effects of aging may provide useful data. If, however, inter-laboratory data comparisons are to be useful it is important that the aging conditions themselves meet certain requirements. The most basic requirement is that accelerated aging conditions must replicate those of long term naturally occurring processes. If the accelerated conditions do not accurately simulate natural aging, then any test conducted on the aged samples can be considered unreliable in predicting the effects of natural aging (Erhardt, Mecklenburg, 1995).
As Erhardt and Mecklenburg (1995) stated, different accelerated aging conditions can produce quite different results and therefore a means of standardisation is an imperative. Natural aging can cover a wide range of conditions and produce a wide range of results. Whilst a specific set of accelerated aging conditions may produce degradation, this does not a priori mean that the changes that occur are the same as those that would have occurred during natural aging, as the activation energies in accelerated aging are considerably higher. Pushed beyond the limits of reasonable inference, the aging process becomes so different from that which occurs under normal conditions that the results are irrelevant to any understanding of natural aging. It is vital, therefore, to determine the range of conditions that reasonably simulate the natural aging of each type of materials under consideration.

In 1994 Feller noticed that conservators’ and conservation scientists’ understanding of deterioration mechanisms and techniques for their prevention were at a rudimentary stage. He noted that in addition to a greater comprehension of the chemical mechanism of deterioration processes, additional attention must also be given to research the pattern or ‘pathogenesis of their deterioration’ in specific materials and conservation problems. Feller (1994) also stressed that continuing research is needed into methods of monitoring changes that occur in the materials of aging artefacts and noted that further problems in accelerated aging can be encountered when the results of tests conducted under continuous exposure are compared to those of diurnal alterations of light and darkness, and seasonal differences in temperature and humidity. He suggested that it may be possible to develop a few relatively simple procedures and controls that will enable those less well endowed with training, equipment and funding to scan and rank the numerous proprietary materials and systems that the conservators so frequently need to evaluate.

Feller (1994) reiterated, after Kamal (1970), that although temperature is important as a controlling parameter in many of the aging processes such as oxidation and hydrolysis, polymer degradation by pure thermal energy is not
a critical factor in material weatherability studies. He suggested that thermal aging tests focus, instead, on thermal-oxidative deterioration i.e. reactions induced by thermal energy in the presence of and with the participation of oxygen but in the absence of visible and near-ultraviolet radiation.

Based on his thermo-oxidative class Feller (1994) classifies conservable materials into broad categories and provides a rough estimate of required testing times for the durability of objects at elevated temperatures. For example class C materials (unstable; lifetime below 20 years) requires 2.4 days of testing at 100°C; whereas Class A1 (excellent, 500 year minimum) needs 60 days of testing at the same temperature.

As noted above, accelerated thermal-aging tests commonly involve higher than normal temperatures in order to speed up reactions. The Arrhenius equation\textsuperscript{30} is widely employed in order to explore the measured rates of deterioration and thereby estimate the rate of moderate temperatures in ordinary usage. There are, however, a number of difficulties inherent in such an approach when it is used to predict aging rates at regular (low) temperatures. Erhardt and Mecklenburg (1995) noticed for example, that there are numerous situations in which the physical states of the substance, or the modes of failure of a system, differ as a function of temperature. They suggested that more sophisticated methods of studying thermal effects such as the equalized-aging process and residual thermal stability testing, furnished better data regarding the stability of conservation materials. Whist they admitted that the employment of high temperatures poses many problems, they recognised that materials can withstand a wide range of

\textsuperscript{30}The Arrhenius equation is a simple, but remarkably accurate, formula for the temperature dependence of a chemical reaction rate, more correctly, of a rate coefficient, as this coefficient includes all magnitudes that affect reaction rate except for concentration. In short, the Arrhenius equation is an expression that shows the dependence of the rate constant $k$ of chemical reactions on the temperature $T$ (in Kelvin) and activation energy $E_a$, as shown below:

$$k = Ae^{-E_a/RT}$$

where $A$ is the pre-exponential factor or simply the *pre-factor* and $R$ is the gas constant. (http://en.wikipedia.org/wiki/Arrhenius_equation)
temperatures and that there are situations arise in which high temperature accelerated aging is both practical and appropriate (Erhard, Meckelneburg, 1995).

Nevertheless, towards the end of the last century increasing numbers of articles in conservation literature have criticised thermal aging tests, noticing that the results fail to reproduce the effects of natural aging over time. It has been admitted for instance, that whilst thermal aging tests may be useful indicators of relative stability when compared with other samples under the same conditions, evidence of discolouration produced at elevated temperatures does not imply that the same discoloration will ever occur at ambient temperatures (Hamm, Gavett, Golden, Hayes, Kelly, Messinger, Contopoulos, Suffield, 1993).

In a discussion of various aspects of adhesive research and thermo-chemical accelerating aging, Down (1996) reported that Arrhenius-based accelerated aging tests did not work for epoxy resin adhesives, poly(vinyl acetate) adhesives and animal glues. He suggested various reasons for this failure such as the composite nature of many artefacts, variations in the chemical composition of many adhesives within each class, a relative humidity effect (dry oven used), a film thickness effect in relation to oxygen penetration, an effect relating to Tg, or an effect caused by examining an overall rate rather than an initial rate.

Michalski (2002), who plotted temperature- and RH-dependent material degradation data, stated that accelerated aging using temperature alone based on Arrhenius law “is at best a euphemism and at worst a delusion, for what common sense tells us is simply baking”. He stated that the chemistry of degradation is invariably complex and extrapolation will be faulty if the rate-determining step in a chain of reactions were to change with temperature or RH. “Attempts by industry to use Arrhenius to rank commercial products in a very rapid test are doomed” (Michalski, 2002). He suggested an empirically derived power law relation was much more relevant or close to natural conditions for RH data between 0-20%.
Begin and Kaminska (2002) noted that most of their own studies were based on an assumption that elevated aging temperatures only accelerate the reactions responsible for natural aging, without significantly altering their nature. They further noted that based on theoretical elevated temperature models some researchers could predict the natural aging pattern of materials for other materials elevated temperatures would be meaningless due to substantial errors associated with this approach in comparison to natural aging. They acknowledged, however, that natural aging tests were impractical and that artificial aging tests, despite all their inherent problems, appear to be indispensable to estimate the life expectancy of materials.

Analysing the aging process of cellulose (60-90°C, 30-80% RH), Erhardt and Mecklenburg (1995) concluded RH is the factor that determines the pathways for chemical degradation and that changing the temperature whilst keeping the RH constant accelerated the aging process without fundamentally altering it. In their judgement, therefore, at constant RH equivalent states of aging can be reached simply by aging for appropriate lengths of time. In contrast, changing RH alters both the relative rates of degradation reactions and the distribution of reaction products. Using such methods, comparable states of aging cannot be reached. They concluded that accelerated aging should be conducted at the same relative humidity as the prevailing ambient conditions in the museum environment. They also noted that the very low values of relative humidity produced during dry oven aging do not reflect natural aging conditions.

Bansa (2002) remarked that doubts regarding the usefulness of the Arrhenius relationship for accelerated aging of paper were explainable, since as paper is, in fact, a composite of various substances of various activation energies. In his opinion neither the old nor the new tests (Baranski, 2002) imitate natural aging and ‘the differences between the reactions in all these methods of accelerating aging are negligible in comparison to the difference between these reactions under artificial aging and what actually happens during natural aging’ (Bansa, 2002). He concluded that the particular methods of accelerated aging do not
matter, and it is more important to ensure that the tests are standardised and to make the correct use of their outcomes. In his view, accelerated aging tests should never be used to duplicate absolute reaction rates or determine theoretical lifetimes. They should instead provide only relative information regarding the benefits of particular conservation treatments (Bansa, 2002).

According to Feller (1994), scientists should begin to analyse problems in deterioration and preservation of organic materials in museums by distinguishing those aspects that are associated with the initiation steps (the effect of light and catalysts) from those associated with the propagation steps (the effect of the chemical structure of compounds and the effect of the concentration of oxygen). He noticed that measures of changes in physical properties occurring during deterioration – changes in brittleness, tensile strength, and colour – show a lag phase in which little seems to be taking place, followed by one in which marked changes occur rapidly. Such periods of relative stability may be considered as an induction time with respect to a given physical property of a chemical reaction.

5.2. Factors determining degradation of gilded surfaces

The rate of deterioration of gilded wooden objects is governed by environmental conditions in which these objects are displayed, stored or transported. Fluctuations in relative humidity and temperature are known to be the major factors influencing chemical, physical, and mechanical degradation of materials in unstable environments.

Wood, a hygroscopic material, responds dramatically to the fluctuation of relative humidity, absorbing moisture and swelling in high humidity and shrinking in a drier atmosphere. Variations in relative humidity cause movement of the wood
and may lead to twisting, splitting, cracking, shrinking, and swelling.

Most studies regarding the degradation of gilded objects stress fluctuations of the substrate as the primary cause of delamination and crack formation.

Fluctuations in ambient relative humidity change the dimensions of components and alter their mechanical properties. Mecklenburg, Tumosa and Erhardt (1998), for instance, noted that there are three major components to RH induced alterations on painted wood.

1. Built-in restraint due to construction, which prevents joined wood from naturally swelling and shrinking across its grain in response to RH fluctuations. The common damage caused by the repeating changes of humidity is dislocation and separation of wood pieces originally joined, such as the corners of the frame.

2. Restraint of foundation and gilding layers caused by movement of the wooden substrate in a direction parallel to the wood grain (the longitudinal direction). Stresses induced in the ground and gilded layers due to changes in RH oppose the stresses parallel to the grain (Mecklenburg, Tumosa, Erhardt, 1998) and as a result gesso foundations, gilding and polychromy crack perpendicularly to the direction of stress forces (Mecklenburg, 1991). Cracks across the grains are very common in gilded picture frames or gilded objects of significant length such as furniture, particularly on matte gilded surfaces.

3. RH response of foundation and gilding layers in a direction perpendicular to the grain of an unrestrained substrate. Differences in the rate of response of various materials to fluctuations of RH are of a particular concern as they can lead to the separation from their support resulting in formation of cleavages, lifting, flaking and consequently loss of the gilded surface.
Wood responds to fluctuations in relative humidity in its three principal axes; longitudinal (parallel to the grain), radial, and tangential. Most responses to moisture are in a tangential direction where wood swells 80 times as much as in a longitudinal direction. In the radial direction it swells half as much as it does tangentially (Mecklenburg, Tumosa, Erhardt, 1998). Mecklenburg, Tumosa, and Wyplosz (1995) studied the cross-grained mechanical behaviour of various wood samples and its response to changes in relative humidity, noting that wood has a tendency to undergo brittle fracture if restrained and desiccated to very low humidity levels. It was significant that the loss of ductility or elongation to break at lower humidity was distinctive in all tested samples and independent of wood species.

Mecklenburg, Tumosa, Erhardt (1998) conducted a number of tests to determine the elastic limits of painted wood (wood, glue, gesso, oil paints) responding to fluctuation in relative humidity. The results indicated that no significant damage is caused to most wood types when RH fluctuations are restrained between 35% and 60%. If, however, wood is fixed in position at 50% RH and then the relative humidity is increased to 85% RH, the wood will undergo plastic deformation through compression (Mecklenburg, Tumosa, Erhardt, 1998). Upon desiccation from 85% to 50% RH the wood would be susceptible to cracking. Data collected by Mecklenburg et al. (1995) provides minimum allowable RH fluctuations for many species of wood. Determining the magnitude of the related RH or temperature change can be extremely useful in the determination of permissible limits for fluctuations of RH within museum environments.

Mecklenburg, Tumosa, and Wyplosz (1995) noted that certain species of denser woods have considerable swelling tolerance. Although partial penetration of moisture into wood creates one of the more severe stress conditions, they noticed that three days were required for wood samples used in their test program to come to equilibrium with the environment under conditions of changing relative humidity. It is suggested therefore, that loose or poorly fitting joints and existing

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cracks in objects allow some dimensional responses of all materials, regardless of the orientation of the object.

Humidity and temperature fluctuations in wood and gesso layers impact on other materials. Cracks apparent in compo ornaments are a frequently a result of alterations in the frame’s oil and resin components. Similar changes will occur in an oil-gilded surface, which due to oil degradation will result in craquelure patches. Animal glue, used in the protective coatings, may become brittle over time. Due to the formation of microscopic cracks on the surface layer animal glue will lose its adhesion and consequently will separate from the surface and the underlying gold leaf.

Prolonged exposure to light can cause fading of any colorants (stains, dyes etc.) in varnishes covering gilding. In general terms, since the energy of light is proportional to its frequency ultraviolet light is particularly dangerous for polymer-based coatings and should be eliminated. Longer wavelengths of infrared light are responsible for molecular vibrations that heat and dry the object thereby causing embrittlement.

Discolouration of gilded surfaces, caused by sulphur-rich components of air, does not usually occur in coatings gilded with gold leaf above 18-carats. Gold leaf below 18 carats tarnishes with time; tarnishing vulnerability increases with decreased carats and increased sulphur impurities in the air (Lins, 1991). Silver or copper-rich metal leaf is more susceptible to corrosion, particularly in a moisture- and pollutant-rich environment. Grey-brown film of silver sulphide, which is sometimes apparent on surfaces gilded with silver leaf, is a product of the reaction between silver and hydrogen sulphide-contaminated air (Scott, 1983, Cession, 1990). High relative humidity promotes significant corrosion of both silver leaf and copper alloys. The corrosion processes of copper alloys are dominated by the corrosion behaviour of copper. Metal leaf can turn malachite green due to the formation of basic copper carbonate (Cu_2(OH)_3CO_3) or jet black stains of formed cupric oxide (CuO). Although varnish layers act as a barrier to fluid
diffusion and can significantly slow down the process of corrosion, brass leaf, particularly in powder form, can oxidise despite the protective coating. Copper in brass leaf can react with acetic acid and ammonia produced during wood decomposition creating copper acetate, which reacts with resins and oils in the gold size forming resinate or oleate of copper. In consequence, both the gold size and gilded surfaces take on an emerald hue.

### 5.2.1. Wood - Gesso composite

The ratio of inert solids in gesso mixtures (gypsum or ground chalk, sometimes with the addition of zinc white or/and kaolin) used to hide glue has a considerable impact on the mechanical and dimensional properties of gesso attached to wooden surfaces (Mecklenburg, Tumosa, Erhardt, 1998). According to these scholars, higher concentrations of inert filler (higher pigment volume concentration PVC) form a weaker and stiffer gesso that is less dimensionally responsive to fluctuations of humidity. Mecklenburg et al. (1998) tested two gesso mixtures, with PVC=58.3 and PVC = 81.6. They noticed that higher PVC gesso reached its yield and failure point at dramatically lower strains than gesso with lower PVC value. However, Michalski (1991) stated that in such circumstances permanent damage will only occur if the gesso is applied during glue’s so-called ‘glassy phase’. According to his model, strain in gesso is highest across the grain at high relative humidity. Despite this, strain in gesso does not have a great impact on subsequent crack formation, as the so-called ‘glassy response’ lasts less than a day at high RH. In contrast, the glassy behaviour of glue at low humidity lasts for many months. At low relative humidity, the gesso layer is under tension only along the grain and therefore it cracks across the grain. Michalski (1991) suggested that cracks formed in gilded objects, which are distinctively straight and in even intervals, may result from fatigue caused by small cyclic fluctuations in size.
Michalski (1991) also conducted tests with gesso of various PVC values on aluminium supports, exposed to humidity fluctuations of 5% (during daylight hours) and 90% (at night). According to Michalski, his experiments showed that at 50% RH when ‘soft gesso’ (99-90% PVC) is applied, delamination does not occur even when the gesso is poorly adhered to the surface. In the case of harder gesso (lower PVC values), decreasing the humidity to 5% RH causes formation of significant stress and if adhesion was poor and gesso layers had low thickness, the gesso tends to delaminate. His experiments have also revealed that high humidity shrinkage dramatically widens cracks in detached gesso, whereas RH fluctuations exert little influence on gesso that is well attached to the substrate.

Michalski (1991) noted that gold leaf creates a vapour barrier and that wood gilded all over its surface should therefore be resistant to seasonal humidity changes, whereas wood gilded only on one side (for example, picture frames) is not and will respond within a week. Michalski (1991) also suggested that since gold leaf is a barrier to water vapour diffusion, gesso layers are unlikely to respond to external environmental RH fluctuations and will therefore stay in equilibrium with the underlying wood. In these circumstances, he believed moisture gradients could not be the cause of cracks developing or cupping in gilding. In his opinion, partly gilded pieces such as frames, seats, and tabletops suffer humidity fluctuation only because the back is not covered with gold.

Mecklenburg (1991) tested samples of gesso of various glue concentrations in extremes of RH ranging from 95% to 8% and noted many instances of dramatic swelling at high relative humidity particularly at high PVC values. If subjected to four RH cycles, Mecklenburg noted all specimens exhibited an initial permanent shrinkage after the second exposure to 95% RH. He observed that materials experienced dramatic and permanent changes when they were exposed to very high RH conditions and subsequently desiccated, concluding that any substrate to which gesso is applied provides at least partial protection to gesso layers, given
that the substrate wood layer does not expand and contract in response to RH.

Mecklenburg, Tumosa and Erhardt (1998) noticed that at 50% RH, fully restrained gesso of PVC value 58.3% reaches its yield point under tension and compression at RH values of 26% and 76% respectively. Their experiments with cottonwood have shown almost the same rates in shrinking and swelling of gesso in the humidity range between 40-60%, but that significant deviation from these mid-range values has dramatic effects on the deterioration of gilded surfaces. The wood-gesso composite is much less tolerant to extremes of RH fluctuation in the tangential direction. Thus desiccation will cause severe strains in gesso layers leading to cleavage and buckling. Humidification from 50% to 80% will cause the gesso layer to crack.

Mecklenburg, Tumosa and Erhardt (1998) showed that moisture represents one of the most important factors in delamination of gesso layers from gilded surfaces. High moisture contents of wood will break the adhesion bond and subsequent desiccation will cause the materials to separate.

The experiments of Mecklenburg, Tumosa and Erhardt (1998) also demonstrated possible causes for the characteristic damage found on wood-gesso composites. Severe increases in RH, it was suggested, cause cracking parallel to the grain of the substrate (longitudinally), whereas cracking caused by desiccation will run perpendicular to the grain of the substrate (across the grain). Severe desiccation is also responsible for compression cleavages and ridging in gesso layers, with ridges running parallel to the grains of the substrate. The tests also indicated that if a painted panel is equilibrated at an extremely high or low humidity, it cannot be returned to moderate RH levels without sustaining damage.
Degradation mechanisms for polymers are divided into three classes: chemical, physical and mechanical (McClinchey, 1993). Chemical aging refers to an irreversible change in the polymer chain/network through a mechanism such as cross linking or chain scissions resulting from changes in the covalent bond structure of the polymer (McClinchey, 1993). Chemical degradation mechanisms include thermo-oxidative, thermal and hydrophilic aging (Gates and Grayson, 1998). Physical aging results in changes of molecular weight changes, molecular weight distribution and the branching of polymers. It is dependant upon changes in secondary bond forces (McClinchey, 1993). Physical aging will occur when a polymer is cooled below its Tg and the material reaches stable equilibrium. This process is characterised by changes in the free volume, enthalpy, and entropy of the polymer and will produce measurable changes in their mechanical properties (Gates and Grayson, 1998). The physical degradation of a polymer can be reversed in-situ, whereas changes caused by chemical degradation cannot (McClinchey, 1993). McClinchey (1993) provided an example of yellowing of organic materials caused by the chemical formation of chromophores. As he stated, however, macroscopic changes such as greying, embrittlement and decrease in solubility are all caused by underlying changes in the physico-chemical properties of the given material. Modified physical properties caused by chemical degradation cannot be reversed and they therefore become the new physical properties of the particular system.

Mechanical degradation is also an irreversible process that is observable on a macroscopic scale. The mechanical results of degradation mechanisms include matrix cracking, delamination, interface degradation, fibre breaks and inelastic deformation. These degradation processes have a direct effect on physical properties such as bulk stiffness and strength (Gates and Grayson, 1998). Deterioration or damage such as accretions, blooming, cracking, crazing, discoloration, embrittlement, oozing, softening, etc. are on the other hand, related
to changes in or loss of additives.

Feller (1994) noted that most of the accelerated aging tests of polymers have been conducted only at either above or below the Tg and that the results are therefore not readily applicable. Papers by Bakova and Lazar (1969), for instance, indicate that in acrylics the rate of decay of radicals within acrylic-based polymers became much faster as temperatures approached Tg. It has been suggested that increased molecular mobility at temperatures above Tg may induce cross-linking to predominate over chain-breaking (Theberge and Cloud 1978, Chodak and Zimanyova 1984). This may be the reason why cross-linking predominates when poly(isobutyl methacrylate) is tested in the usually employed ‘xenon-arc-Fadeometer’, in which the sample temperature may reach a temperature as high as 62°C. In contrast, significant chain-breaking occurs when the temperature of the sample is kept at 32°C (Feller, Curran, Bailie, 1981). Feller noted that the tests conducted at different temperatures are not directly comparable particularly if the polymer systems contain inhibitors. Citing Scott (1969), he noted that stabilizers effective at low temperatures are not necessarily effective at high temperatures and *vice versa*.

Second order glass transition temperatures (Tg) are a critical factor in determining the properties of acrylic emulsions and their ability to form a continuous film. Materials with low glass transition temperatures are susceptible to cold flow that can take place or else the materials may remain tacky at ambient temperatures. In warm conditions these flexible surfaces can also attract particular dust and dirt and deform readily. Furthermore acrylic resins become glassy or brittle within a narrow range below room temperature. Acrylic polymers can become glassy at temperatures as low as 5°C and mechanical cracking can result if stress is applied at these temperatures (Stringari, Pratt, 1993).

In view of the foregoing discussion, it was therefore decided to test sample frames at both a controlled constant temperature and by allowing the temperature to follow diurnal fluctuations, in order to determine whether the elevated
temperatures during the day cause any deformation of gilded surfaces on the synthetic polymer backgrounds.

Contraction of wood can play a major role in the deterioration and changing appearance of gilded surfaces. It has been noted, for instance, that the durability of a reasonably tough coating such as a 50/50 copolymer of isobutyl methacrylate is much higher than that of dammar varnish. During continuous exposure in a carbon-arc Fade-ometer, the dammar varnish would remain plastic and therefore cracks that might form would tend to remain refused under the heat of the arc lamp. If samples were removed after several hundred hours of continuous exposure in the Fade-ometer, the acrylic and the dammar might still appear rather glossy and since micro cracks in the dammar might pass unnoticed, the marked increase in the brittleness of this resin would not be discerned. On the other hand if the two coatings were evaluated along side one another, under the glass in the outdoor environment, then, in contrast to the acrylic, the dammar would soon become opaque due to extensive fracturing (Feller, 1994)

In an article by Howells et al. (1984), six acrylic dispersions were subjected to accelerated aging using sunlight, florescent light, and elevated temperatures. The dispersions were then tested for changes in weight, colour, solubility, mechanical properties, softening to heat, submersion in water, and pH. Only one resin copolymer of vinyl acetate (50) and ethylene (50) Vinamul®3252, showed no significant changes in these parameters over the duration of the test period. The most commonly noted change in physical properties was yellowing, a characteristic that did not seem to impact any of the other physical properties of the dispersion, including removability.

In the 1980-‘s and 1990’s the Canadian Conservation Institute conducted aging experiments on 27 polyvinyl acetate resins and dispersions as well as 25 acrylic based adhesives in regards to changes in pH, flexibility, emission of harmful volatiles, strength and yellowing upon dark aging at room temperature and fluorescence light aging( Down, MacDonald, Tetreault, Williams, 1996).
The results indicated that light aging tended to decrease the pH of both types of resins and that both PVAc coatings retained more strength and less flexibility than the acrylics. It was noted however, that PVAc-based adhesives exposed to UV light yellowed approximately twice as quickly as the acrylic adhesives and that initially acidic PVAc resin coatings (AYAA, AYAC, AYAF, AYAT) but the pH rose upon dark aging. Tests indicate that all three materials will become less flexible over time.

Although accelerated aging tests involving RH fluctuation are rare in conservation research compared to tests involving thermal-oxidative factors, they are becoming more common. Bansa (2002) reported controlled variation of relative humidity has been used in accelerated aging of paper by Kassberger (80°C, 30/60/30% RH, 1h cycle), as well as in research on fighting corrosive ink (90°C, 35/80/35% RH, 3h cycle) conducted by the Netherlands Institute for Culture Heritage in Amsterdam.

As Feller (1994) stated, after Kamal and Saxon (1967), water can have at least three effects that are important in the degradation of polymers.

1. Chemical: hydrolysis of the ester or amide bonds.

2. Physical: loss of the bond between the vehicle and a substrate or pigment.

3. Photochemical: generation of hydroxy radicals or other radical species.

Feller noted a fourth possibility as the facilitation of ionization and the mobility of ionic entities, which he classified as an important aspect of corrosion chemistry. Nevertheless, as he remarked, a polymer formation by condensation reactions can be reversed with loss of water.
Calvini (1987) noted differences in behaviour between substrates involving both absorbed water vapour and water in the condensed (liquid) phase. In the latter case, contact with water causes leaching and cracking effects that are different results to those occurring in the presence of only water vapour (Abeysinghe, 1982).

As mentioned above, the elevated temperatures traditionally employed in thermal aging tests tend to reduce the moisture content of samples to levels far less than those of normal aging (Feller, 1994). Feller (1994) stated that the desire to test objects under the two extremes, 0% and 100% RH, can pose certain practical problems that are often neither controlled nor defined unambiguously. He observed that the behaviour of various polymers tested for photochemical degradation may be considered as occurring under moderated conditions in the region from 20 to 80% RH. Empirical evidence collected as part of the current study shows the increase in absorption and the rates of many photochemical processes is nearly proportional to RH.

In aging by hydrolytic degradation, the degree of plasticity in a polymer will increase due to long term exposure to moisture. In terms of its effect on gilded surfaces, moisture exposure has two important components; 1) diffusion of water into the sample, and 2) plasticization of the matrix (McClinchey, 1993).

Feller (1994) indicated instances where the hydrolysis of bonds, thought to be the principal process of degradation in a polymer, did not occur in the absence of oxygen. The diversity of these possible models of action has led conservators to note that the role of water in weathering remains far from being understood. The actions of moisture in deterioration, though difficult to predict in advance, must be verified in each specific situation.
5.4. Aims of the Tests

Surfaces gilded using the materials and methods featured in the previous chapter were placed under cyclic loads through variations in RH. A surface gilded using traditional matte water-gilding method was exposed to the same extreme conditions, as a control.

Data on the climate in Australia obtained from the Bureau of Meteorology shows that, subject to locality and season, the greatest fluctuations in relative humidity occur between 9.00 am and 3.00 pm. Although relative humidity can be lower than 20% or exceed 80%, the fluctuations between morning and afternoon values are usually not greater than 30% for a given day of the year (See graphs: 1 to 3).
Graph 1: Average daily relative humidity – January to December
Sydney

Australian Bureau of Meteorology
Based on the 30-year period 1961-90.

Graph 2: Average daily relative humidity – January to December
Alice Springs

Australian Bureau of Meteorology
Based on the 30-year period 1961-90.
Average daily relative humidity - January to December

Darwin

Australian Bureau of Meteorology

Based on the 30-year period 1961-90.

Melbourne

Australian Bureau of Meteorology

Based on the 30-year period 1961-90.
Average daily relative humidity - January to December
Mount Isa

Average daily relative humidity - January to December
Perth Regional Office

Australian Bureau of Meteorology
Based on the 30-year period 1961-90.
Nevertheless, the meteorological data does not take into account changes in humidity caused by other sources such as direct sunlight, air-conditioning or winter heaters. Although more severe RH and temperature fluctuation conditions are unlikely to exist in large museums, they are common place in private collections or small regional museums. In addition, empirical evidence suggests that dramatic changes in environmental conditions frequently affect artworks if inappropriately handled in transit or when transferred to another collection.

Reports in the conservation literature provide recount instances of damage occasioned by the movement of gilded objects. Miura and Ogawa (1999), for example, reported that a gilded urushi coating in the 12th century Golden Hall of Chusonji temple, Hiraizumi, Iwate Prefecture, Japan, developed a 1 mm crack when moved and that despite a glass showcase being constructed for its protection in the 1990s the crack width increased by 0.2mm per year!

Thus far, relatively little attention has been given in conservation science to the effects of physical stress in materials as a factor that can speed up deterioration of gilded objects (Feller, 1994).

Although from the preceding discussion it is recognised that accelerated aging tests do not replicate natural aging conditions (see above), they are useful to provide indications of the relative behaviours of non-traditional and traditional gilding methods. In the experiments conducted as part of the current study the appearance of gilded surfaces under stress was closely monitored over time. These tests were intended to analyse changes in visual appearance of gilded surfaces caused by extreme humidity fluctuations or humidity/temperature changes due to day/night cycles. It was not necessary to conduct separate accelerated aging tests of polymer films formed of these three synthetic materials, as tests of this type have been conducted and reported elsewhere (Magin, 2002, Down, MacDonald, Tetreault, Williams, 1996, Whitmore, Colaluca, Val, 1995, Horton-James, Walston, Zounis, 1991, Duffy, 1989, Howells, Burnstock, Hedley,
5.5. **Description of test**

5.5.1. **Preparation of two frame samples:**

(See photographs: 127-130)

Two plain-wood flat moulding frames of external dimensions 500 x 500 mm were constructed of Pine Radiata (Pinus radiata) wood with mitre joint corners supported by synthetic dovetail biscuits hereinafter referred to as Frame No 1 and Frame No 2. The verso of each frame was left uncoated whereas the wooden surface of the front and sides moulding of each of the frames were coated with one layer of 12% RSG (1 part of coarse powdered RSG : 6 parts of water), followed by two layers of calcium carbonate-gesso based on 7% RSG solution (1 part of coarse powdered RSG: 12.5 parts of water) and eight layers of calcium carbonate-gesso based on 5% RSG solution (1 part of coarse powdered RSG : 13.5 parts of water). The gesso foundation was then levelled using wet-and-dry until the required silky smooth appearance was achieved. Following smoothing, one side of each frame was gilded using traditional matte water-gilding, and the three other sides were sealed with two layers of 10% B-72 in xylene, followed by two coats of watercolours imitating red bole. These three sides were then gilded using 15% B72 in 1-methoxypropan-2-ol, 15% AYAF resin in ethanol/diacetone alcohol (2:1), and Plextol®B500 diluted 2:1 with water ethanol (4:1), as described below.

**B-72**

Two coats of 15% B-72 in 1-methoxypropan-2-ol were applied over the watercolour surface and left to dry. The surface was then double gilded and
the dried film surface activated with a mixture of Shellsol®A: Shellsoll®T 1:4 with the addition of 15% ethanol.

- **Notes on the performance during gold leaf application:**

Initially, gold leaf had a tendency to sink in during the gilding process and stains of solvent became apparent on the surface of the gold leaf. It was found that by waiting several seconds between the application of an activating mixture and the application of gold leaf the problem was partially eliminated. It is suggested that the problem could be optimised via solvent selection.

**AYAF**

Two coats of 15% AYAF in ethanol/ diacetone alcohol (2:1) were applied over the watercolour surface, which was then double gilded activating the dry film with water with 20% addition of ethanol, just prior to gold leaf application.

- **Notes on the performance during gold leaf application:**

Due to the high molecular weight of AYAF resin, even 15% solution produced a liquid of a significant viscosity. Its application therefore required special care. Nevertheless, the levelling of a drying mixture was satisfactory, due to the slow evaporation rate of chosen solvents. Gold leaf adhesion was good and the entire surface was successfully covered at the first attempt.

**Plextol B500**

One layer of Plextol®B-500 diluted 2:1 with water ethanol (4:1) was applied over the watercolour surface. The surface was then double gilded activating the dry film with exhalation for the first layer of gold leaf, and water with 25% addition
of ethanol for the second layer of gold leaf.

- **Notes on the performance during gold leaf application:**

  One layer of diluted Plextol®B500, applied over the watercolour foundation on Frame No 1, resulted in a surface with a patchy, semi-matte appearance, not covered entirely by gold leaf at first attempt. Although Frame No 1 was covered completely during application of the second layer of gold leaf, nevertheless, in order to provide better adhesion of gold leaf, Frame No 2 was coated with a second layer of diluted Plextol®B500 prior to gilding. Gold leaf adhered to the surface firmly covering it almost completely with the first layer, and the second gilding was required only to cover imperfections of the material (pinholes made during gold leaf manufacture).

  It is clear from these experiments that the surface preparation procedures prior to film application are critical to achieving satisfactory gold leaf adhesion. The watercolours should be first buffed or slightly burnished in order to achieve semi-matte appearance of the surface, thereby preventing saturation of the Plextol®B500 solution. Although a second coat of this acrylic dispersion could provide sufficient adhesion of gold leaf, it could also create a surface with greater gloss than that desired. If this material is selected for conservation of matte water-gilding particular care is required during application of Plextol®B500 in order to achieve a surface with appropriate gloss in each particular instance.

  The gilded surfaces of both frames were coated with two layers of traditional ormolu protective coating (5% w/v RSG with the addition of up to 10% of diluted seedlac).

  Gilding created using synthetic materials simulated traditional matte-water gilding and blended well with gilding performed using traditional method.
Stage III: Aging tendency tests – Preparation of two frames

Photo 127 - Stage III - Frame No 1 prepared for gilding using synthetic materials

Photo 128 - Stage III - Frame No 1 (clockwise): upper site - traditional technique; RHS – Plextol® B500; bottom site – AYAF; LHS – B-72

Photo 129 - Stage III - Frame No 2 prepared for gilding using synthetic materials

Photo 130 - Stage III - Frame No 2 (clockwise): upper site - traditional technique; RHS – Plextol® B500; bottom site – AYAF; LHS – B-72
5.5.2. **Test Conditions:**

5.5.2.1. **Frame No 1**

(See photographs 131-135)

Frame No 1, was placed in a Plexiglass chamber of dimensions 1020 x 800 x 700 mm situated on a table in an air conditioned room with reasonably stable ambient temperature (photo 131). The frame was positioned on four small polyester blocks in a manner allowing most parts of the bare-wood verso of the frame to be left uncovered and exposed to the environment. The frame was then exposed to extreme cyclic humidity fluctuations created by cuvettes containing conditioned silica gel ArtSorb® (Fuji-Davidson Chemicals Ltd) ranging from 100% to desiccated (approximately 2.7% RH) (photos 132-135).

Conditions within the chamber were monitored constantly using ACR SmartReader® Data Logger model 2, marked Data Logger 2, (range: 1 to 100%, accuracy: +/- 4%, RH from 10 to 90%), placed in the frame in an elevated position on a small polyester block (photos 132-133).

The amount of silica gel required for desiccation was calculated according to the ArtSorb® manufacturer’s advice that 50 g of dry silica is required to stabilise the condition of a 2 cubic feet chamber.

According to the above calculation, 500g of dry silica gel was required to stabilise the conditions in the Plexiglas chamber. In order to speed up the process of changing from wet to dry conditions, however, double the amount of silica gel (1000g) was used in the test and placed on in cuvettes in order to maximise the vapour absorption area.
The time required to settle the conditions from wet to dry (and opposite) were established empirically by running a test in the chamber without the sample. It is shown that 12 hours were required to change conditions from constant 95% RH to constant 25% RH by changing a cuvette with water immersed silica to a cuvette with silica desiccated to 11.4% RH.

Based on this assessment, it was decided to change cuvettes every second or every third day, thereby allowing the tested frame at least 24 hours to fully adjust to the dry or wet conditions in the chamber. All changes within the chamber were logged and desiccated silica gel was tested with the ACR® remote RH and temperature sensing Probe, model EH-020A, prior to placing it in the chamber. The average relative humidity for desiccated silica was 2.7% RH (although the lowest recorded was 0.5%). The test was conducted for 12 months (365 days). Recorded RH fluctuations ranged from 14.2%, to 100.0%. Slight temperature changes were noted during the test, probably due to temperatures of water in the cuvettes. Nevertheless, the temperature of the test materials remained within an 8.5°C range at all times (17.4°C - 25.9°C).

Using this procedure the test materials were exposed to sudden dramatic, diurnal, changes in RH from above 90% to below 20%.

The position of the frame was rotated every few days ensuring that the environmental conditions affected each sample evenly.
Stage III: Aging tendency tests – Frame No 1: test conditions

Photo 131 - Stage III - Frame No 1 in the chamber with a cuvette containing silica gel immersed in water; outside the chamber a cuvette with conditioned silica gel used to create dry conditions.

Photo 132 - Stage III – Frame No 1 with a cuvette containing silica gel conditioned to approximately 2.7% RH.

Photo 133 - Stage III – Frame No 1 with a cuvette containing silica gel immersed in water; ACR SmartReader® Data Logger in the middle of the frame for monitoring RH and temperature.

Photo 134 - Stage III – Frame No 1 with a cuvette containing silica gel immersed in water; just after changing of cuvettes.

Photo 135 - Stage III – Frame No 1 with a cuvette containing silica gel immersed in water; a few hours after changing of cuvettes.
Graph 4: Frame No1 – Fluctuation of humidity in the chamber; October 2004 – April 2005
Graph 5: Frame No1 – Fluctuation of humidity in the chamber; September – October 2004
Graph 6: Frame No1 – Fluctuation of humidity in the chamber; March – April 2005
5.5.2.2. **Frame No 2**

(See photographs 136-140)

The second frame was placed on a wall in a sunroom and exposed to direct sunlight, testing the behaviour of gilded surfaces under the stress of natural changes in RH and temperature due to day-night cycles. The conditions were also monitored with the temperature and relative humidity info ACR® SmartReader Data Logger model 2 (named Data Logger 3), which was placed on the wall within the frame. The test was monitored for 2 years. The lowest temperature recorded was 17.1°C, and the highest was 39.4°C. Commonly the temperature of the test piece rose by almost 20°C per day, during sunny days. The lowest recorded relative humidity was 6.98% RH and the highest was 74.61% RH. The RH commonly changed by more than 40% per day.
Stage III: Aging tendency tests – Frame No 2: test conditions

Photo 136 - Stage III – Frame No 2 in a sunroom exposed to direct sunlight

Photo 137 - Stage III – Frame No 2; ACR® SmartReader Data Logger in the middle of the frame for monitoring fluctuations of RH and temperature

Photo 138 - Stage III – Frame No 2; conditions in rainy days

Photo 139 - Stage III – Frame No 2; conditions in sunny days

Photo 140 - Stage III – Frame No 2; conditions in sunny days
Graph 7: Frame No2 – Daily fluctuation of humidity in the sunroom; July 2005 – January 2006
Graph 8: Frame No2 – Daily fluctuation of humidity in the sunroom; November - December 2004
Graph 9: Frame No2 – Daily fluctuation of humidity in the sunroom; July - August 2005
5.5.3. **Testing Criteria**

The surfaces gilded with synthetic polymers were compared with those surfaces gilded using traditional method. Particular attention was paid to recognised signs of damage such as gloss/matte appearance, surface texture, colour, cracks formation and other physical changes.

As noted earlier, changes in colour, surface texture, and crack density are known indicators of thermo-oxidative degradation. Physical changes such as an increase in cracks density, matrix cracking, delamination, fibre breaks, and inelastic deformation, on the other hand, could indicate of hydrothermal instability. High temperatures are said to sometimes generate micro-cracks and could occur in the test with frame No 2. Increases in environmental stress factors such as temperature and moisture may decrease fibre strength as well as modify the matrix response to these externally applied loads.

Inelastic deformation could occur in a polymeric matrix composite due to loss of plasticity, creep (the slow continuous deformation of a material under constant stress) and stress relaxation. According to McGlinchey (1993), these mechanisms can be accelerated by exposure to higher stresses and higher temperatures.

If the stress placed on a material is too high, the elastic limit may be exceeded and the material deforms plastically. As McGlinchey (1993) noted, the damage caused by this type of deformation is time dependent.

5.5.4. **Examination procedures**

The tested samples were subject to comparative visual inspections with the naked eye during tests in progress, as well as instrumental analysis of the gilded
surfaces, before and after tests.

The appearance of all gilded surfaces on Frame No 1 was inspected with the naked eye each time the cuvette was changed. The gilded surfaces of Frame No 2 were inspected on a weekly basis. The data loggers were read several times during both tests in order to monitor the conditions and monitor the fluctuations in humidity or humidity/temperature occurring.

The appearance of both frames was also inspected with a Leica® stereomicroscope and recorded with digital photographs prior to and after the tests. In addition, samples from each of the gilded surfaces were tested using a polarised microscope with UV attachment and a confocal microscope with laser scanning facilities connected to a Raman spectrometer prior to and after completion of the tests.
Stage III: Aging tendency tests – surfaces prior to testing

Photo 141 - Stage III: Traditional gilding.  
Photo 142 - Stage III: Plextol® B500.  
Photo 143 - Stage III: Paraloid® B-72.  
Photo 144 - Stage III: PVAc AYAF.
5.6. Results

5.6.1. Testing Results in the Dry-Wet Chamber - Frame No 1

(See photographs 145-167)

No visible changes were observed during the 12 months of testing (365 days) on the sections of the frame gilded with either Plextol®B500 and AYAF. Due to the lack of airflow and high RH, as anticipated, spots of mould were found on all gilded surfaces (photo 145). This affected only the protein-based traditional film coatings. Following removal, no staining of the gilded surface was observed (photo 146-148).

After 200 days and 85 cycles, cracks developed at the mitred corners.

It was noted however that hairline craquelure developed on surfaces gilded over B-72 (photos 152-156). No visual differences were observed between either the Plextol®B500, AYAF-based gildings and those formed using the traditional gilding method (photos 157, 158, and 162). Clearly, synthetic gilded surfaces can withstand and respond to frequent dramatic fluctuations of humidity in manner that is at least as good as that of traditional gilding.

Although no cracks were apparent to the naked eye on the surface gilded on the AYAF foundation, parallel hair-line cracks were found across the grain of the wooden background. Furthermore craquelure was seen in the gilded film even under low magnification of magnified glass or the Leica® stereo microscope (6.5x) (photo 159).
Parallel cracks across the grain of wooden backgrounds could also be observed in the Plextol B500 gilded sections when inspected with magnified glass or stereo microscope. These cracks were, however, less distinct than those formed using the other types of gilding on synthetic foundation (photo 164), indicating greater elasticity of Plextol. A small crack running longitudinally (parallel to the grain) from a mitre of the corner (photo 163) that appeared on the surface, follows a crack in the wood. This shows damage that is typical in a wood-gesso composite caused by severe increases in RH (Mecklenburg, Tumosa and Erhardt, 1998).

No changes to the traditionally gilded surfaces of the frame were detected with the naked eye. Nevertheless craquelure similar to that obtained with Plextol®B500, was apparent under higher magnifications.

From a visual perspective following 365 days of testing, the appearance of all the gilded surfaces after 365 days had changed little. The degradation of polymer did not induce distinctive deformations of the gilded surface. Gilding created with Plextol®B500 remained close to and comparable with that achieved using traditional methods and materials.
Stage III: Aging tendency tests – Results: Frame No 1

Photo 145 - Stage III: The Frame No 1 after testing – prior to removal of protective coating.

Photo 146 - Stage III: The Frame No 1 after testing - after removal of protective coating.

Photo 147 - Stage III: The Frame No 1 after testing - after removal of protective coating.

Photo 148 - Stage III: The Frame No 1 after testing - after removal of protective coating.
Stage III: Aging tendency tests – Results: Frame No 1 – B-72

Photo 149 - Stage III: The Frame No 1– B-72; prior to testing

Photo 150 - Stage III: The Frame No 1– B-72; after testing

Photo 151 - Stage III: The Frame No 1– B-72; after testing

Photo 152 - Stage III: The Frame No 1– B-72; after testing
Stage III: Aging tendency tests – Results: Frame No 1 – B-72 - continuing

Photo 153 - Stage III: The Frame No 1 - B-72 – LUC, after testing

Photo 154 - Stage III: The Frame No 1 - B-72 ; stereomicroscope, 6.5x; after testing
Stage III: Aging tendency tests – Results: Frame No 1 – B-72 - continuing

Photo 155 - Stage III: The Frame No 1 - B-72 ; stereomicroscopy, 6.5x; after testing

Photo 156 - Stage III: The Frame No 1 - B-72; confocal microscopy, 100x; after testing showing craquelure formation in the gilded surface
Stage III: Aging tendency tests – Results: Frame No 1 – PVAc AYAF

Photo 157 - Stage III: The Frame No 1 – PVAc AYAF; RLC after testing

Photo 158 - Stage III: The Frame No 1 – PVAc AYAF; RLC after testing
Stage III: Aging tendency tests – Results: Frame No 1 – PVAc AYAF

Photo 159 - Stage III: The Frame No 1 – PVAc AYAF; after testing

Photo 160 - Stage III: The Frame No 1 – PVAc AYAF; confocal microscopy; 100x; before testing

Photo 161 - Stage III: The Frame No 1 – PVAc AYAF; confocal microscopy, 100x; after testing
Stage III: Aging tendency tests – Results: Frame No 1 – Plextol® B500

Photo 162 - Stage III: The Frame No 1 – Plextol® B500; RUC after testing

Photo 163 - Stage III: The Frame No 1 – Plextol® B500; RLC after testing

Photo 164 - Stage III: The Frame No 1 – Plextol® B500; after testing
Stage III: Aging tendency tests – Results: Frame No 1 – Plextol® B500 - continuing

Photo 165 - Stage III: the Frame No 1 – Plextol® B500; stereomicroscopy, 6.5x, after testing

Photo 166 - Stage III: the Frame No 1 – Plextol® B500; confocal microscopy, 100x, prior to testing

Photo 167 - Stage III: the Frame No 1 – Plextol® B500; confocal microscopy, 100x, after testing
5.6.2. Testing Results in the Sunroom - Frame No 2

The surface gilded with B-72 copolymer started to show a craquelure pattern after approximately 8 months of exposure (photos 168-171). As the test progressed, this craquelure development became obvious even to the untrained eye. The cracks were similar in form to those of oil degradation occurring with traditional materials and the surface began to resemble that of aged oil-gilding. The surface of this section became hazier than the others and this whitish bloom remained on the surface even after removal of the protective glue layer (photo 170).

No distinctive changes could be detected in the gilding performed with AYAF if examined with the naked eye after 24 months of exposure to dramatic humidity and temperature fluctuations due to the day/night cycles. However, stereomicroscopy, even at low magnification, showed distinctive parallel cracks as well as craquelure formation (photo 176).

Similarly, although visual inspection without magnification did not detect any changes in the gilded surface performed with Plextol®B500, hairline cracks could be observed when inspected with the stereomicroscope under higher levels of magnification (photo 182).

Similar results were obtained from the section gilded using the traditional method.
Stage III: Aging tendency tests – Results: Frame No 2

Photo 168 - Stage III: the Frame No 2 – after 2 years of testing

Sections of gilding after removal of the protective layer
Stage III: Aging tendency tests – Results: Frame No 2 – B-72

Photo 169 - Stage III: the Frame No 2 – B-72; LUC after testing

Blooming around the cracks stays even after removal of a glue layer

Photo 170 - Stage III: the Frame No 2 – B-72; close-up of the LUC after testing

Photo 171 - Stage III: the Frame No 2 – B-72; LUC, after testing
Stage III: Aging tendency tests – Results: Frame No 2 – B-72 - continuing

Photo 172 - Stage III: the Frame No 2 – B-72; confocal microscopy, 100x, prior to testing

Photo 173 - Stage III: the Frame No 2 – B-72; confocal microscopy, 100x, after testing
Stage III: Aging tendency tests – Results: Frame No 2 – PVAc AYAF

Selected areas, which were monitored under the stereomicroscope prior to and after test

Photo 174 - Stage III: the Frame No 2 – PVAc AYAF; LLC after testing

Photo 175 - Stage III: the Frame No 2 – PVAc AYAF; RLC after testing
Stage III: Aging tendency tests – Results: Frame No 2 – PVAc AYAF – continuing

Photo 176 - Stage III: the Frame No 2 – PVAc AYAF; after testing

Photo 177 - Stage III: the Frame No 2 – PVAc AYAF; confocal microscopy, 100x, prior to testing

Photo 178 - Stage III: the Frame No 2 – PVAc AYAF; confocal microscopy, 100x, after testing
Stage III: Aging tendency tests – Results: Frame No 2 – Plextol® B500

Photo 179 - Stage III: the Frame No 2 – Plextol® B500; RUC after testing

Photo 180 - Stage III: the Frame No 2 – Plextol® B500; RLC after testing

Photo 181 - Stage III: the Frame No 2 – Plextol® B500; after testing

Photo 182 - Stage III: the Frame No 2 – Plextol® B500; after testing
Stage III: Aging tendency tests – Results: Frame No 2 – Plextol® B500 - continuing

Photo 183 - Stage III - Plextol® B500; confocal microscopy, 100x, prior to testing

Photo 184 - Stage III - Plextol® B500; confocal microscopy, 100x, after testing
5.7. Discussion

It has been widely noted in conservation literature that B-72 is a stable thermoplastic resin characterised by good resistance to oxidation, light, hydrolysis and moderate heat that forms strong and durable films without being brittle (Koob, 1986). Films of this material are said to be sufficiently flexible to withstand being bent around a mandrel less than 1/10-inch in diameter without cracking (Feller, 1985). Feller (1985) described it as the most stable known thermoplastic resin, expected to suffer a loss of no more than 20% of its mechanical properties in 100 years under exposure to normal museum conditions.

In contrast to these views, the experiments conducted here have shown that B-72 is the least stable of the materials tested and that it has a tendency to develop cracks when exposed to large fluctuations in relative humidity. Furthermore, it appears that dramatic temperature/humidity fluctuations can cause significant stress in this material and results in damage visible to the naked eye. It seems that B-72 films develop greater brittleness with age than either polyvinyl acetate resin or acrylic dispersion films, which presumably preserve more flexibility thereby allowing them to resistance stresses induced by fluctuations in environmental conditions.

The deterioration of materials exposed to direct sunlight is primarily determined by the ultraviolet radiation portion of sunlight, which is the driving force for photo-chemically induced bond cleavage and free radical formation. Although heat, loss of moisture, and oxygen availability are all factors that promote deterioration, their influence is recognised as of secondary importance (Searle, 1994). Gold leaf represents a significant barrier to the deleterious effects against significant UV exposure. Heat generated by direct sunlight exposure is therefore more likely to be responsible for significant degradation of the polymer matrix than photo-chemically induction scission. Searle (1994) noticed that when polymer materials used in conservation are exposed to direct sunlight, cracking
and crazing are likely to occur. Micro-cracking will subsequently affect the rate of moisture absorption/desorption during repeated hydro-thermal cycles and this accelerating deteriorative process is likely to be responsible for the bloom affecting cracks on the B-72 gilding in Frame No 2.

Surfaces gilded on the AYAF and Plextol foundations were also likely to develop micro-cracks over time. Nevertheless, it is notable that humidity and temperature fluctuation experiments of much greater duration than those in the current tests are required before these changes have any significant impact on the appearance of gilded surfaces.

Changes in humidity, temperature and UV absorption caused re-crystallization of the protective adhesive coatings and were responsible for the increased opacification or greyness of this layer on all tests. In Frame No 2, in particular, the glue layer became partially opaque and grey. In frames gilded using Plextol®B500 and AYAF the damage caused by this re-crystallisation was confined to the uppermost layers, whereas for gilding on B-72 the hazy greyish surface extended far more deeply beneath and the grey effect was apparent even after removal of the layer.

Compression shrinkage is likely to be responsible for cracks developing in the mitre corners. It is remarkable that cracks at the corners only developed in Frame No 1 where the bare-wood verso was unattached and where the frame was best able absorb/ release humidity freely. This indicates that the changes in relative humidity and temperature of sunlight exposed samples were sufficient to buffer the materials of the frame and that where damage occurred it was the result of changes affecting the upper layers of the surface (gold and polymers) rather than the underlying wood, which remained protected and undamaged.

None of the surfaces developed the cracks running across the wood grains distinctive of aged water-gilded surfaces. Clearly accelerated aging tests are insufficient to induce the forms of fatigue caused by the small growth of
stress in the longitudinal direction in each wet/dry cycle, confirming Michalski’s (1991) theory regarding the effectiveness of gold leaf as a barrier to moisture diffusion through wood. In line with results achieved elsewhere (Mecklenburg, Tumosa, and Wyplosz, 1995), three days were required for wood samples to reach equilibrium with the new environmental conditions following changes to relative humidity. In contrast to the tests performed by Mecklenburg, Tumosa and Erhardt (1998), despite the fact that RH was often at extreme values, in the current tests no cracks developed in tangential directions on wood-gesso composites. Furthermore, there were no signs of the delamination that is known to occur with gilded surfaces due to scission of the adhesive bond between layers, caused by high moisture content in the wood followed by subsequent desiccation.

Radiata pinewood, which was used as a base for all samples, is not particularly resistant to the absorption of moisture\textsuperscript{31}. The lack of cracks in the wood-gesso composite in all tests could be caused by a combination of several other factors, such as:

- The presence of gold leaf and subsequent foundation layers on three sides of the frame, which formed a partial barrier, limiting the access of moisture and protecting the wood against the influence of extreme conditions.

- Insufficient time to achieve equilibrium with the environment between the desiccation/re-wetting periods. In the case of Frame no 1, three-day breaks were often allowed between the changing of conditions due to weekends and holiday periods. Cracks in the mitered corners developed after six and half months. In the case of Frame No 2, the diurnal cycle is known to be too short to affect levels deeper than just surface layers. In consequence, the gilding layers were more affected by the direct heat from sunlight than by movement of wood.

\textsuperscript{31} Radiata Pine is classed as a medium-density softwood; density 460 - 560 kg/m\textsuperscript{3}, prone to shrinkage and distortion, shrinkage in tangential direction 4.7\%, in radial 2.2\%, resistant to decay.
6.0 CONCLUSIONS

The results presented here indicate conclusively that losses in matte water-gilded surfaces can be successfully compensated using stable synthetic polymers. As the tests have demonstrated, with adjustments to application techniques, three materials, B-72, AYAF and Plextol®B500, can be used effectively to replicate matte water-gilding in the conservation of gilded surfaces. The material most suitable for a particular conservation treatment must however, be determined based upon the particular circumstances and the conservation treatment required.

Although all three materials performed well in practical trials, the acrylic resin copolymer B-72 proved to be more useful for in-gilding of losses in small surface areas. The case study confirmed problems with obtaining an evenly distributed film of B-72 and that the film has a tendency to migrate unevenly beneath the surface layer when rewetted with solvents. Despite its success in terms of the appearance of gilded surfaces formed, this material would not be suitable for replacement of large surfaces requiring regilding. Nevertheless, B-72 should be considered as an alternative material for in-gilding in the treatment of gilded objects, particularly in circumstances where usage of water-soluble materials and techniques could endanger the condition of the object.

The result of trials with poly(vinylacetate) resin AYAF confirmed that this material can be successfully employed in conservation treatments to compensate even large losses of gilded surfaces. Nevertheless, the tests also revealed some limitations. AYAF is particularly sensitive to water. Consequently, the application of second layers of gold and/ or ormolu may cause the removal of previously applied gold leaf. Exposure of the conservator to noxious solvent vapour is a significant problem when dealing with large frames or large areas of loss replacement in gilding. Nevertheless, as the results have shown, in terms of
its performance as a background for gold leaf, AYAF appears to be more reliable than the B-72 solutions.

All materials exhibited a tendency to form cracks following exposure to the extreme stresses generated by humidity and temperature fluctuations. Results of experiments conducted as part of this study showed that the appearance of the gilded surfaces subjected to RH changes alone, changed little when inspected with the naked eye, indicating that all three materials exhibit reasonable resistance to stress. Physical degradation of the synthetic polymers was detectable using low magnification microscopy. It did not, however, cause the forms of distinctive deformation of the gilded surfaces known from museum artefacts. Visual examination with the naked eye of Frame No 2 revealed a distinctive craquelure formation in the surface gilded with B-72, whereas gildings created with either Plextol®B500 and AYAF showed little change, indicating greater flexibility and stability of these materials under gold leaf.

In view of the availability of B72 in conservation laboratories and the knowledge-based of its performance in conservation, the aging performance of the copolymer was slightly disappointing, demonstrating that it is not the material of choice for the treatment of areas exposed to environmental stresses.

The foundations formed using all three materials can be burnished if required. Although the burnishing possibilities of B-72 have been known for some time (Thornton, 1991), tests of the gilded surfaces formed with AYAF and Plextol®B-500 confirmed that these too may be burnished using agates. In all instances, the surfaces produced have a level of gloss comparable with a slightly aged surface formed using traditional water gilding technique.

In all experiments, acrylic dispersion Plextol®B500 provided the best results of all synthetic polymers tested. Unfortunately, Plextol®B500 is also known to discolor over time. This drawback, though significant in other areas of
conservation, is shown here to be unimportant in the conservation of gilded surfaces, since the adhesive is protected from photo-chemically induced deterioration by the gold leaf layer.

The tests conducted here show Plextol®B500 is very versatile for gilded surface conservation, due to:

- its ability to retain adhesion despite low concentration in solutions, and;
- the possibility of using various activation methods for dried film.

Applied as a very thin layer over a matte surface, double gilded, and activated using a combination of exhalation and a low-alcohol water mixture, Plextol®B500 can facilitate a perfect replication of an original matte water-gilded surface.

Used alongside traditional gilding techniques and materials, Plextol®B500 offers:

- **Successful replication of traditional water-gilding surfaces**
- **Reversibility of treatment**
- **Flexibility of working time**
  
  The area intended for gilding can be left at any time and work can be resumed in a few hours or the next day.
- **Flexibility and full control over viscosity and working properties**
  
  Plextol®B500 can be diluted to the desired viscosity without losing adhesion. The viscosity of this acrylic dispersion, as provided by the manufacturer, is too great to create properly leveled film. Therefore, in order to form a low viscosity solution that can easily be applied over the
gesso surface by brush and form a thin evenly distributed film layer, Plextol®B500 should be diluted with distilled water. Ethanol can be added to improve the wetting properties of the applied mixture.

- **Diverse application methods due to its compatibility with other materials**

Plextol®B500 can be applied alone over a watercolours/ gouache foundation or mixed with watercolours/ gouache paints to imitate bole. Yet, one should keep in mind that tampering polymer system by adding extra pigment and binders leads to potentially serious alterations in its properties and stability.

- **Diverse film activation methods depending on the condition of gilded objects**

Dry films of Plextol®B500 can be activated with exhalation for fragile foundation layers, thereby avoiding the application of water, which is known to cause additional weakening of the original gesso. If the gesso structure is sound and overlapping effect of gold leaf is required, the dried film may also be activated with gilder’s water.

- **Acceleration of treatment**

Minimal preparation and drying time accelerate the restoration process without compromising its quality.

- **Safe working environment**

No solvents other than water involved. As a water-based dispersion, the polymer does not generate the significant health risks associated with organic solvents.

There are few disadvantages of this material and the methods for its application. Over the course of this research program it has, however, been noticed that gilded surfaces formed with acrylic dispersions may be slightly more sensitive to
abrasive damage than those formed over traditional methods, and so should be protected with varnishes. In addition, burnished gilded surface formed with acrylic dispersion Plextol®B500 has a lower gloss than new gilding formed with traditional water-gilding technique. Therefore this material would be more suitable for restoration purposes, rather than for new gilding, where a higher-gloss surface is often required.

It has been shown here that stable synthetic polymers can be used to expand treatment options for gilded objects, thereby bringing gilding materials into line with the ethical standards regarding delectability and reversibility reached in other fields of conservation.
7.0 APPENDIX 1

FRAME NO 1 : Test in the wet-dry chamber - changing cycles data

RH of the desiccated silica gel was tested with the ACR® Remote RH and Temperature Sensing Probe, model EH-020A (Range: 1 to 100%; accuracy: +/-4% RH from 10 to 90% at -20 to 40° C)

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8.0 **REFERENCES:**


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9.0 GLOSSARY OF TERMS

**Acanthus leaf**  
Stylised leaf and stem ornament based on the acanthus plant. It has been used since classical times, the most recognizable stylized form on the top of columns, also used as architectural moldings and as a decorative form on furniture, frames or other decorative art objects. Acanthus was a common corner decoration of 19th century frames. Also used as ogee ornament of acanthus foliage alternating with shield shapes called a leaf-and-shield (shield-and-leaf). A variation of leaf-and shield is leaf-and-tongue. Acanthus foliage alternating with dart is called leaf-and-dart or acanthus-and-dart.

**Anthemion**  
See: Palmette

**Appliqué Relief Brocade application**  
A raised decorative pattern applied to carved wood or stone surfaces in order to imitate very fine and beautiful textiles embroidered with the gold thread; usually gilded and polychromed; technique popular particular on sculptures, altarpieces and panel paintings from the beginning of the 14th c (around 1420) until about 1560.

**Astragal**  
2/3 convex circle moulding. May be enriched with applied ornament such as ‘beads’, bead-and-reel. When left blank it is termed ‘un-worked’ or ‘plain’.

**Bar-and-bead**  
An astragal moulding carved to resemble elliptical bars separated by beads, also called ‘sausage-and-berry’. When the bead is alternated with shapes resembling stacked disks it is called bead-and-reel.

**Bead-and-reel**  
See: bar-and-bead.
Bead astragal  An astragal or torus moulding resembling a string of beads; sometimes called a pearl course.

Bronze paint  Bronze powder mixed with varied mediums

Bronze powder  In general use term for metallic bronze coloured paints. The term is technically incorrect however as ‘bronze powders’ are usually alloys of copper & zinc; ‘brass powders’. Metal powders are only reflective if they are in the form of flat, shiny flakes, and prior to the nineteenth century this was accomplished by beating the metal into leaf and then grinding it into a powder with the aid of an organic medium such as honey or gum that prevented the particles from sticking to each other. This laborious process continued to be the only one employed until the early 19th century, but it made bronze powders too expensive apart from their use on objects of the highest quality, such as japanned furniture. In about 1840, Henry Bessemer began the manufacture and marketing of bronze powders according to his own secret recipes, which were strictly guarded against industrial spies. The price of his bronze powders undercut traditional metallic powders, and the use of Bessemer’s ‘gold powders’ became popular. Bronze powder finishes on frames were used as a cheap alternative to gilding from the end of the 19th century. In the 20th century bronze powders mixed with varied mediums were also used for painting over worn or damaged gilding. Bronze powder if not protected oxidizes very quickly. The rate of oxidation depends on the condition and medium used. In some cases the thin layer of partially reflective film of interference colours can develop on the surface, creating an effect similar to oil on water.

Burnished ‘mirrors’  Convex reposes on frames, often water-gilded and highly burnished to imitate mirrors; distinctive decoration in the Canaletto and Lely styles of frames

Cabochons  A convex round or oval ornament used in corner or in the centre of
a repeating ornament.

‘Canaletto’-style frame Dates from the first quarter of the 18th c.; developed from the same ogee section as the ‘Longhi’ type frame with gadrooning running ornament at the back edge and corner and centre sections carved in the low relief with undulating stems and flowers on the punched background.

‘Carlo Maratta’ style frame Known also as Salvator Rosa frame; popular in Italy from the 17th c., in England common from the second half of the 18th c. to frame paintings acquired at the Grand Tour; it consist of the inner scotia surrounded by three-quarter round or deep ogee profile; plain mouldings are often enriched with running ornaments of ribbon-and-stick, leaf-and-tongue, gadrooning or ‘egg moulding’.

Cartouches A framed panel often elaborately decorated based on the shape of scroll; it may be concave or convex, with a plain or decorated centre. Cartouches are usually found at corners and in the middle of the frame members.

Cavetto ¼ - circle concave moulding. See also: scotia and cove.

Composition A material used to create pressed ornaments on picture frames, often called ‘compo’. Warm composition material can be pressed into rigid moulds, and it hardens in stages due to cooling and gelation, loss of water, and ‘drying’ (oxidation) of the oil components. Composition ornaments became common from the late 18th century, replacing the technique of carving directly into wood. Composition became the dominant ornament material in the production of the 19th century picture frames.

Cove Moulding similar to cavetto. Term used for a concave moulding of greater size, or greater concavity than quarter-circle.
**Dammar** Also spelled ‘Damar’, or ‘Dammer’; copal resin obtained from coniferous trees (Dipterocarpaceae family of trees) characteristic of Southeast and East Asia, including Shorea species Balanocarpus, or Hopea; most is produced by tapping trees, however some is collected in fossilized form from the ground. The gum varies in colour from clear to pale yellow, while the fossilized form is grey-brown; Dammar was first introduced as a picture varnish in 1826 and is commonly referred to as Dammar varnish.

**Distinctness-of-image gloss** An indication of how clearly or sharply specularly reflected images can be seen, indicating slight variations of the mirror image around the angle of reflection (Samet, 1996).

**Gadrooning** A decorative motif consisting of convex curves in a series. In furniture and other interior accessories, the term applies to an ornamental carved band of tapered, curving and alternating concave and convex sections, usually diverging obliquely either side of a central point, often with rounded ends vaguely reminiscent of flower petals. It was widely used during the Italian Renaissance.

**Gilding** Term describing techniques and finish achieved using gold leaf or gold leaf imitation. Gilding methods are determined by the foundation materials, which lie underneath the gold leaf. Traditional gilding requires a substrate of gesso, which is sanded until it achieves a smooth silk-like surface. For oil-gilding a gesso prepared surface is coated with a sealer (usually shellac) and gold size. The gold leaf is applied on slightly tacky, almost dry, gold size. Water-gilding requires a substrate of bole. A smooth gesso is coated with a weak solution of gelatine, glue, or glair (egg white), or with a weak solution of yellow bole mixed with binder. Then several layers of bole of cream consistency are applied in order to build up a smooth opaque foundation. Dried bole foundation is wet with the 'gilders water' in order to activate the proteinaceous binder, and gold leaf is laid down immediately on its wet surface. Gold leaf laid down on gesso and bole foundation can be burnished with agate to achieve a brilliant shiny surface (burnished water-gilding), or left matte. Matte water-gilding usually requires double gilding;
when the first layer of gold leaf is dry the second leaf is applied in a similar manner. When the surface is dry it is often protected with a layer of ‘ormolu’, a weak solution of animal glue with the addition of up to 10% of diluted seedlac or shellac, which assists the achievement of the distinctive deep matte appearance of the gilded surface.

**Gilders water** Water solution used by gilders to wet a bole foundation prior to application of gold leaf in water-gilding technique. Addition of ethanol into the ‘gilders water’ reduces surface tension of the water and allows gold leaf to be ‘sucked down’ on the surface. A small amount of weak gelatine solution in the ‘gilders water’ helps with adhesion of gold leaf to the substrate in matte water-gilding technique.

**Gold leaf** Alloys of gold beaten into extremely thin leaves (0.3 – 0.8 micrometers) so bare hands cannot handle them but instead the leaves have to be manipulated by special wide brush called gilder’s tip. The colour of gold leaf is determined by the content of copper and silver, and varies from white, 12-carat (50% of gold, 50% of silver, by weight) through greenish and reddish alloys (more copper content) up to natural 24-carat pure gold leaf.

**Glair** A medium for gold leaf application in water-gilding technique; is made of a bitten egg white mixed with water.

**Gold size or oil size** A substrate for oil-gilding consisting of copal resin, linseed oil and the addition of a siccative.

**Leaf-and-shield** See: *acanthus*.

**Leaf-and-tongue** See: *acanthus*. 
**Leaf-and-dart**  See: *acanthus*.

**Louis XIV frame**  A frame design developed during the reign of Louis XIV; the characteristic feature was the emphasized corners and/or centres; one of the example of this style had the raised corners carved with flowers often including the symbolic Louis XIV sunflower with an artificial triple leaf in the form of a foliated fanned lambrequin; the most regular type, which became the synonymous with the Baroque style of Louis XIV, was the corner-and-centre frame with a typical cartouche decoration containing shell, acanthus leaves, anthemia or fleurs-de-lis; it became dominant style for portraits.

**Louis XVI frame**  Neo-classical style frames consisting of the architrave or entablature type moulding often with frieze to which a scotia or ogee profile was added; plain mouldings were often enriched with pearl astragals or running ornaments of egg-and-dart, guilloche, fluting, laurel leaf, acanthus leaf, or cabling.

**Metal leaf**  Imitation of gold leaf consisting of copper and zinc alloys; also called brass leaf, bronze leaf (incorrectly, as bronze is composed of copper and tin), Dutch metal and Schlagmetal. These leaves are much larger and thicker than genuine gold leaf, and require a coat of varnish to protect against rapid tarnishing.

**Mitre**  Corner joints in which the line of junction between two members forming the right angle is set at an angle of 45°.

**Mastic**  (*Pistacia lentiscus*) is an evergreen shrub or small tree growing to 3–4 m tall, mainly cultivated for its aromatic soft resin on the Greek island of Chios. It is native throughout the Mediterranean region, from Morocco and Iberia at the east through southern France and Turkey to Syria and Israel in the west; it is also native on the Canary Islands. It has an application in the food industry. In art Mastic Varnish is clearer than Dammar and can be applied more easily. Mastic is much more expensive than Dammar, however, it does tend to bloom (develop a
chalky surface) in humid climates, as well as yellow and crack with age more than Dammar. Therefore Mastic was almost replaced by Dammar in the 20th century. Today, mastic is usually used as a mixing varnish and rarely as a picture varnish.

**Mica powders**  Iridescent mica pigments are mica flakes or platelet coated with very thin layers of a mixture of titanium dioxide, and ferric oxide. According to Thornton (1991), iridescent mica powders have poor covering or hiding capabilities due to the transparency of mica. Combined with acrylic mediums, they have a low gloss compared with oil and water gilding, but are chemically stable, so they retain their original colour and remain reversible in organic solvents.

**Ogee**  Moulding with S-shaped profile. An ogee changing from convex at sight edge to concave at outer part is called a cyma recta, while one that is concave at sight edge and convex at outer part is a cyma reversa.

**Oil gilding**  See: gilding

**Ormolu;**  This term has double meaning. According to the Encyclopaedia Britannica (1996), this term comes from French dorure d’or moulu: “gilding with gold paste”, and is a gold coloured alloy of copper, zinc, and sometimes tin, in various proportions but usually containing at least 50% copper. Ormolu is used in mounts (ornaments on borders, edges, and as angle guards) for furniture, and for other decorative purposes. The earliest ormolu was produced in France in the mid-seventeenth century. Malcolm Green (1979) described ormolu as seed-lac diluted in pure alcohol. In old manuals, with reference to frames, the term describes diluted seed-lac coloured with gamboge and dragon’s blood, (F. Scott-Mitchell. 1905), or a mixture of diluted seed-lac with the addition of parchment size, which was a traditional coating for matte gilding, (The Gilder’s Manual,1876). According to Professor Jonathan Thornton (1996), ormolu is the traditional coating over the un-burnished matte water gilt flats and nowadays is
prepared as a mixture of one part diluted seed-lac and four parts diluted rabbit skin glue, rather than parchment size. In this paper, by the term 'proteinaceous ormolu' I refer to coatings consisting of a mixture of seed-lac and animal glue.

Ovolo ¼ -circle convex moulding. Ovolo may also be quarter elliptical, called Greek ovolo.

Palmette leaf Palmette, also called anthemion is based on the fan-shaped leaves of a palm tree. It was largely employed in the Greek/Roman era as a decoration in architecture. It is also known as the ‘honesuckle’ ornament, from its resemblance to that flower.

Patina Originally the green brown encrustation on bronze, this now includes the natural effects of age or exposure on a surface.

Patination Application of paint or dry pigments in order to imitate an aged patina on a gilded surface.

Pearl course See: bead astragal

Pigment Volume Concentration (PVC) The pigment volume concentration determines the amount of a particular pigment that can be added to the polymer of the coating. The pigment has to have sufficient "wetting" by the polymer to create a protective coating. It means that there must be sufficient amount of polymer, or binder, to completely wet or surround all the pigment particles so to completely fill the voids between the pigment particles. PVC is calculated using following equation:

\[
\% \text{ PVC} = 100 \times \frac{V_{\text{pigment}}}{V_{\text{pigment}} + V_{\text{non-volatile binder}}}
\]

\(V_{\text{pigment}}= \) pigment volume
\[ V_{\text{non-volatile binder}} = \text{non-volatile binder volume} \]

**Punching**  A decoration in gilded surface made with a shaped tool or stamp; the punching was done directly on the gold surface dimpling the gesso beneath it creating a subtle brocaded effect; common on medieval panel paintings, later became popular in decoration of the 16\textsuperscript{th} and 17\textsuperscript{th} c. Italian frames

**Reeding**  Moulding consisting of bands of repeated parallel dowels or plain astragals. A narrow frieze often interrupts this moulding. Reeded frames were popularised at the end of the 19th and first half of the 20th centuries by the designs of Rossetti, Degas, and Whistler.

**Relief**  Raised ornamentation that makes a design prominent by lifting it or cutting away the background or surface of a particular design.

**Ribbon-and-stick**  Decoration that creates the appearance of a ribbon spiralling around a narrow dowel.

**Rocaille**  The dynamic asymmetrical design based on shell, C-\textit{scrolls} and S-\textit{scrolls}, often pierced with rows of holes. Rocaille decoration was distinctive for the Rococo style.

**Rotten stone**  Rotten stone, sometimes spelled as one word, and also known as tripoli, is fine powdered rock used as a polishing abrasive in woodworking; it is usually weathered limestone mixed with diatomaceous, amorphous, or crystalline silica; it has similar applications to pumice, but it is generally sold as a finer powder and used for a more glossy polish after an initial treatment with coarser pumice powder; it can also be dusted on to the gilded surface in order to imitate and aged patina.
‘Salvator Rosa’ frame  See: ‘Carlo Maratta’ frame

Scotia  Deep concave moulding based on ellipse or two cavetto mouldings of different sizes, resulting in a projecting lower edge, used for example at the base of a column between two torus mouldings.

Scrolls  Any motif with spiral scroll-like ends (volutes). Scrolls may be in the shape of the letter S (S-scroll) or C (C-scroll).

Shell-gold  A genuine gold powder suspended in gum Arabic and formed into little circular shapes that look like small (about 0.25 to 0.5 inch diameter) watercolour blocks. Shell gold is applied with a soft-hair brush like paint, and when dry has a finely grained, matte finish. It can be brightened up quite a lot with burnishing, but it can never quite equal the brilliance of gold leaf.

Sight edge  Inner edge of the frame next to the image of the painting.

Slip  Simple inner frame consisting of flat with cavetto or bevel at sight edge. Slips became common in the 19th century. They are often matte water-gilded and sometimes burnished at the sight edge.

Stratigraphic window  A section of the surface of the polychrome object with exposed subsequent paint/ gilding/ foundation layers.

Taenia  Flat raised band.

Torus  $\frac{1}{2}$-circle convex moulding.

Twisted ribbon-and-stick  Decoration that creates the appearance of a ribbon
spiralling around a narrow dowel.

**Volute** A spiral *scroll* ornament derived from column capitals of the Ionic order

**Water-gilding** See: gilding
10.0 MATERIALS AND SUPPLIERS

Aerosol® OT  Wetting agent and emulsifier, C\textsubscript{2}H\textsubscript{3}O\textsubscript{3}NaS; manufactured by CYTEC Industries Inc., Process Chemical, Five Garret Mountain Plaza, West Paterson, NJ 07424-3360, http://www.cytec.com.

Aquazol® 500  Poly(2-Ethyl-2-Oxazoline), PEOX; manufactured by Polymer Chemistry Innovations, Inc., 1691 West College Ave., State College, PA 16801, USA.

ArtSorb®  Silica gel; amorphous silica, SiO\textsubscript{2}, Lithium Chloride, LiCl; manufactured by Fuji Silysia Chemical Ltd, 2-1846 Kozoji-cho, Kasugai-shi, Aichi-ken, JAPAN 487-0013.

Blancophor R  Brightening agents, a fluorescent dye for cellulose, protein, nylon, wool, and paper; distributed by chemical suppliers.

Barium Sulphate  An X-Ray dense material; distributed by the chemical suppliers.


Glycerol  HOCH\textsubscript{2}CH(OH)CH\textsubscript{2}OH, commonly called glycerin or glycerine, it is a sugar alcohol with three hydrophilic alcoholic hydroxyl groups; distributed by chemical suppliers.

Hyplar®  An acrylic dispersion; manufactured by M.Grumbacher, Inc.

Kölner® gilding materials  Commercially available modern gilding materials; cellulose ether is a binder in Kölner® Burnishing Clay, while polyvinyl alcohol is a component of Colnasol® adhesive; manufactured by Kolner Coatings, LLC, 23 Grant Avenue, New Providence, NJ 07974, distributed by gilders and artists suppliers.

Kraton® G1657 or G1650  A plasticizer; a rubber additive used in conjunction with Regalrez® 1094; Kraton G1650M is used in compound formulations and as a modifier of thermoplastics.; manufactured by Kraton Polymers U.S. LLC 15710 John F. Kennedy Blvd.,Suite 300,Houston, TX 77032 http://www.kraton.com/

Microcrystalline wax M80A  Microcrystalline waxes are produced by de-oiling petrolatum, as part of the petroleum refining process. In contrast to the more familiar paraffin wax, which contains mostly unbranched alkanes, microcrystalline wax contains a higher percentage of isoparaffinic (branched) hydrocarbons and naphthenic hydrocarbons; characterized by the fineness of its crystals in contrast to the larger crystal of paraffin wax; it consists of high molecular weight saturated aliphatic hydrocarbons; generally darker, more viscous, denser, tackier and more elastic and flexible than paraffin waxes; distributed by conservation product suppliers.

Liquitex® Matte Medium; Liquitex® mediums and varnishes; acrylic dispersions available in different viscosities (low, medium, high, extra high) and sheens (gloss and matte); based on the copolymer of ethylacrylate, methyl methacrylate, and ethylmethacrylate; manufactured by Binney and Smith, 1100 Cranbury, NJ 085122372 USA.
Church Lane, Easton, Pennsylvania. 18044-0431, USA.

**Paraflint® wax**  Paraflint H1; a brittle, white synthetic Paraffin wax, solid saturated hydrocarbons CnH2N+2, with a melting point of +97°C; manufactured by Schumann Sasol Pty. Ltd., South Africa.

**Paraloid® B72**  A copolymer of ethyl methacrylate and methyl acrylate (70:30); manufactured by Rohm and Hass Company, Philadelphia, PA 19105, USA.

**Plextol® B500**  A copolymer of ethylacrylate, methyl methacrylate, and ethylmethacrylate, at 50% solid content concentration; manufactured by Rohm GmbH Chemische Fabrik, Postfach 4242, 6100 Darmstadt 1, Germany.

**Plextol® D360**  A copolymer of methyl methacrylate (MMA), butyl methacrylate (BMA), and ethyl methacrylate (EMA); manufactured by Rohm GmbH Chemische Fabrik, Postfach 4242, 6100 Darmstadt 1, Germany.

**Primal®2245**  An acrylic dispersion of ethylacrylate, methylvmethacrylate and ethylmethacrylate; discontinued, used to be made by Rohm and Hass Company, Philadelphia, PA 19105, USA.

**PVAC AYAF**  Polyvinyl acetate resin AYAF (MW = 169,000); manufactured by Union Carbide Corporation, Old Ridgebury Road, Danbury, CT 06817, USA.

**Regalrez® 1094**  A hydrogenated hydrocarbon resin of low molecular weight; manufactured by Hercules Resins Group, Hercules Plaza, Wilmington, DE 19894, USA.

**Rhoplex® AC33**  An acrylic dispersion based on a copolymer of ethylacrylate (EA) and methylacrylate (MA), with 1% of acrylic acid, at the 42% solid contents
concentration; manufactured by Rohm and Hass Company, Philadelphia, PA 19105, USA.

**Rhoplex® N580**  an acrylic dispersion based on n-butylacrylate homopolymer at 54-56 % (w/w) solid contents concentration; manufactured by Rohm and Hass Company, Philadelphia, PA 19105, USA.

**Rosin**  also known as colophony or Greek pitch; a solid form of resin obtained from pines and some other conifers, produced by heating fresh liquid resin to vaporize the volatile liquid terpene components; chiefly consists of different resin acids, especially abietic acid; distributed by artists and gilding materials suppliers.

**Savynil® colours**  Dyes manufactured by Sandoz, Industriestrasse 25, 83607 Holzkirchen, Germany, http://www.sandoz.com

**Sculpey®**  Polymer clay; moulding products; manufactured by Polyform Products Co. 1901 Estes Elk Grove Village, IL 60007, http://www.sculpey.com

**Shellac**  Natural resin made of flaky secretion of the lac insect *Kerria lacca*, found in the forests of Assam and Thailand. Freed from wood it is called “seedlac”; dilute in ethanol forms clear yellow varnish used mostly as a wood coating (French polishing); distributed by artists and gilders suppliers.

**Soluvar®**  A 1:1 mixture of F-10, poly n-butyl methacrylate, and B-67, polyisobutyl methacrylate, 40% solids in a slow-drying petroleum distillate; manufactured by Binney and Smith, 1100 Church Lane, Easton, Pennsylvania, 18044-0431, USA.

**Tinuvin®292**  A light stabiliser a general-purpose liquid hindered-amine light stabilizer (HALS) especially developed for incorporation with a wide variety of paint systems, offering extended protection to coatings when used in the
exterior environment; manufactured by Ciba Specialty Chemicals Pty

**Tri-ammonium citrate**  Chelating agent; used also as an emulsifier in dairy
products and acidity regulator; distributed by chemical suppliers.

**Tween®80** A surfactant; a nonionic detergent and emulsifier derived from
polyoxylated sorbitol and oleic acid, often used in foods; distributed by chemical
suppliers.

**Vinamul®3252**: Copolymer of vinyl acetate (50) and ethylene (50); a very low
formaldehyde dispersion with good plasticizer resistance; manufactured by the
Celanese Emulsions, De Asselen Kuil 20, 6161RD Geleen, Netherlands,
www.celanese.com