AS GOOD AS GOLD:
ALTERNATIVE FILL MATERIALS FOR GILDING CONSERVATION

FLSY1

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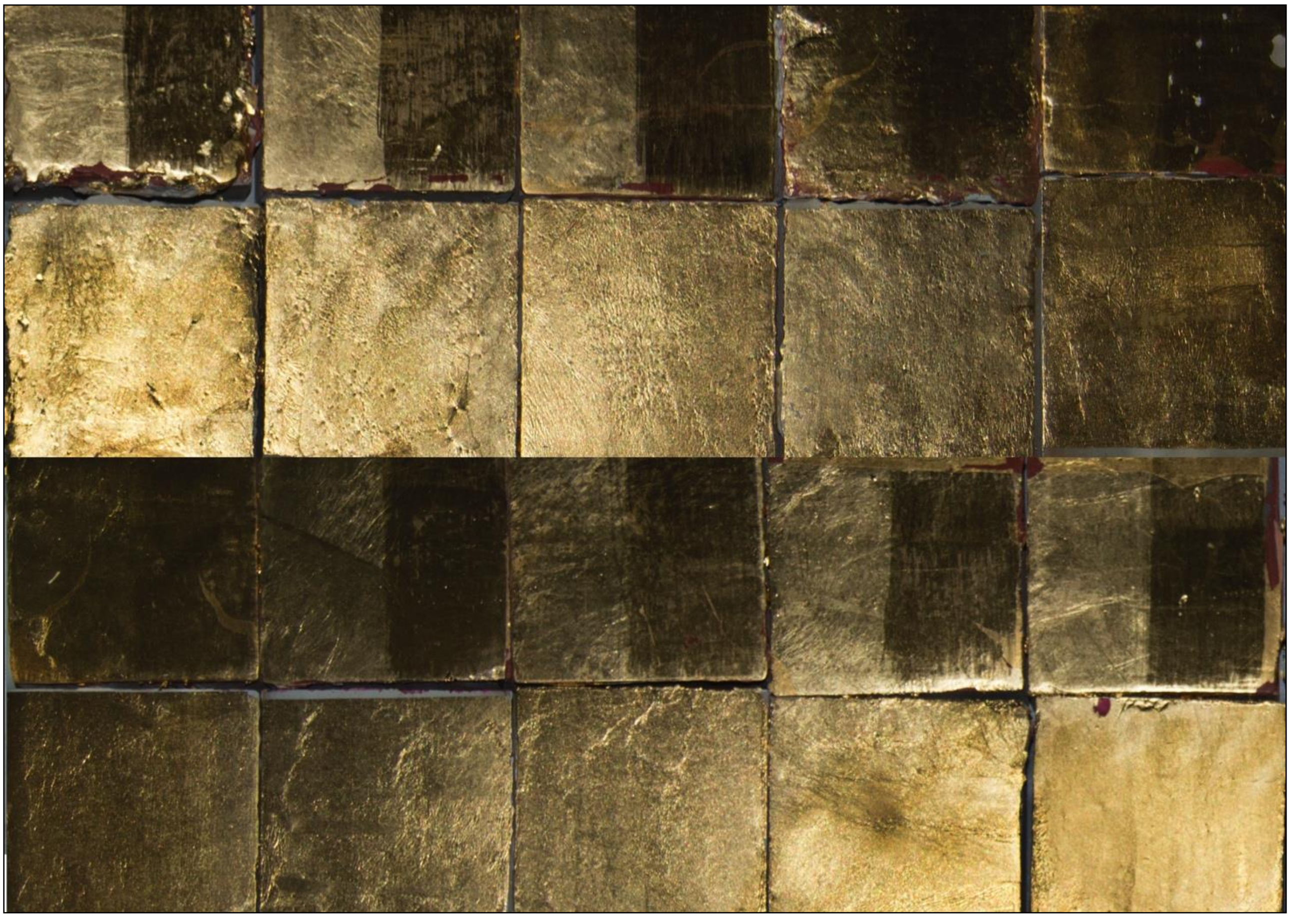
UCL INSTITUTE OF ARCHAEOLOGY

As Good As Gold

Alternative Fill Materials for Gilding Conservation

FLSY1 – September 15, 2015



Abstract

This research aims to determine the best synthetic material for fills for oil and water gilding conservation. Paraloid B-72, Paraloid B-67, Butvar B-98, Ronseal epoxy putty, Flügger, Klucel G, Modostuc, and Polyvinyl alcohol (PVOH) are compared to traditional gesso and composition to compare surfaces. Surface finishing is tested, along with working properties of the different materials, their solvent reversibility and its effects on oil and water gilt substrates. It is found that synthetic materials, particularly PVOH, Modostuc, and Flügger, can reproduce acceptable surfaces. Other materials that could be considered are B-67, B-98, and B-72.

Acknowledgments

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Preface

Genesis of Research

The focus of this dissertation originated during an internship during the summer 2014 with the Frick Collection in New York City. The main focus of the placement was the conservation of 9 frames being loaned to the Mauritshuis in the Netherlands for an exhibition in February 2015. The treatments required extensive conservation including the filling areas of loss in the gesso ground as well as stabilisation and toning of historically applied gilding.

Discussions on treatment options were held between the Frick Collection conservation team and Cynthia Moyer, Frames Conservator at the Metropolitan Museum of Art. As a result of these discussions, modern alternatives to traditional materials were considered for the repair of the frames. Additionally, it became apparent that while there was a bias toward the use of traditional materials in the conservation of picture frames and gilded surfaces (Thompson 1909; Green 1979; Ashley-Smith 1982; Thorn 1987; Anderson & Malenka 1991; Green 1991; McGrath 1991; Payer 1991; van Horne 1991; von Reventlow 1991; Hanlon 1992; Anderson 2001; Davey 2001; Gribbon 2001; Powell 2001; Salimnejad 2002; Salimnejad 2005; Cox 2013; Chao *et.al.* 2014; Wheeler 2014), it was not clear if this was due simply to tradition, or due to an inability of modern alternative materials to perform to the desired standard. As a result it was decided that in investigation into the use of both modern and traditional repair materials for picture frames and gilded surfaces, and the reasons why the use of traditional approaches dominates would be both pertinent and valuable.

Gilding is a skill that requires patience and a steady hand. It is a craft firmly grounded in tradition; recipes passed down from master to apprentice, each workshop with their own modifications to perfect the art (Thompson 1909; Considine 1991; Green 1991; Gregory 1991). This skill brought gilders not only work to be newly gilded but also damaged gilded objects in need of repair. Gilded objects were regarded more for their appearance than their historical value and were generally regilded when they became damaged or worn (Thompson 1909; Powell 1999; Chao *et.al.* 2014).

However, as conservation as a field has developed, ethical and practical issues have arisen when treating these surfaces (Ashley-Smith 1982; Cornu 1986; Appelbaum 1987; Podmaniczky 1991; Newman 1998; Samet 1998). While traditional materials have been used in the past, an emphasis on using materials that are sympathetic to but different from the original surface has emerged in conservation practice. This issue is addressed in both codes of ethics for the American Institute for Conservation of Historic and Artistic Works (AIC) and the Institute for Conservation (ICON). However, current research into the use of synthetic materials for gap filling in gilding conservation is fairly limited (Hebrard & Small 1991; Thornton 1991; Wilson 1992; Shelton 1996; Glover 2006). While a few materials have been tested for gilding applications (described below), there is potential for other materials more commonly used for fills in wooden artefact, panel paintings, marble, or lacquer conservation to be applied to this conservation issue.

Outline Summary

This dissertation will be divided into several sections. The aim of the research will be introduced, followed by a general review of the history of gilding, its degradation, and the background information on the gilding process and conservation in the second section. The third section introduces the materials tested and the experimental method. The fourth section covers the results and discusses their applications for gilding conservation. Lastly, recommendations for future research and issues within the research methodology are addressed.

Research Questions

A topic as broad as fills for gilding conservation is impossible to contain within the limitations of this essay. Lins (1998, 17) describes the diversity of the field as an ‘amazing variety of ways in which gold has been applied as a thin film of gilding to metals and other substrates’ ranging from electroplating to gilt leather. Covering each of these processes and substrates thoroughly falls outside the scope and capabilities of this work. Instead, the focus of this dissertation will be on water and oil gilded wooden surfaces, with an emphasis on those with gessoed grounds. The purpose of this dissertation is to identify and analyse synthetic fill materials based on their ability to obtain a suitable surface for gilding and to ‘fill the gap’ in current literature. Ideally, the fill materials must be:

- easily accessible
- used within the conservation profession as fill materials or adhesives
- removable with solvents that do not damage the original gilded surface
- are considered a low health risk according to their Material Safety Data Sheets (MSDS) or Control of Substances Hazardous to Health (COSHH) Risk Assessments

Hopefully this research will demonstrate that synthetic materials are capable of producing satisfactory surfaces for gilding in a conservation context. It aims to answer the following questions:

- Is it possible to obtain the same level of finish using synthetic materials as traditional gilding materials?
- If so, are those materials easy to work with and apply?
- Are these materials reversible in a way that is not damaging to the original gilded surface?

As the emphasis of this research falls heavily on the surface finishing capabilities of the fill materials, in depth investigation into the mechanical properties will not be pursued. While the mechanical properties of each material (compression and shear strength, microhardness) are important in understanding the material for structural applications, they are not as informative or useful for a conservator choosing a material for a surface fill as the quality of the finished surface is not reflected. Instead, experimentation will focus on the more practical applications of the materials, analysing working properties such as ease of application, casting, and carving.

Background Information

Gilding Techniques

Gold has been applied to surfaces for thousands of years across a wide spectrum of cultures. While it is an interesting subject, the history of gilding is not essential to understand this research. Investigations into gilding's use and purpose have been conducted by various authors should readers seek more information: Serck-Dewaide 1991; Bryant 2001; Hughes 2001; Bortolot 2003; Ridgeway 2014; Wheeler 2014; Jacobs 2015; Warren 2015. However, gilding techniques, deterioration, and conservation must be addressed in order to provide a foundation for the successive research.

Water Gilding

Water gilding is gold leaf that is adhered with a water-based adhesive size. The benefit of water gilding is that it can take a high shine known as burnishing (*image 1)*. Burnishing creates a mirror-like surface and requires a clay substrate called 'bole' to allow for the compression and polishing of the gold leaf. In addition, the bole surface can further enhance the colour of the gold, making it either warmer or cooler depending on the preferred end result.

Figure 1: Burnishing of the water gilded samples using an agate burnisher. To the right are burnished samples with the reflective surface on the lower half of the squares. (Photo taken by author).

Water gilding requires extensive preparation of the substrate. There are different techniques for preparing the substrate, but all use multiple layers of gesso to create a perfectly smooth, even surface. First, the wood is sealed to prevent moisture from the gesso layers absorbing into the substrate. Next, multiple layers (4 to 10 according to MacTaggart & MacTaggart 2011) of gesso are applied. In some instances a heavier *gesso grosso* is applied first followed by a *gesso sottile,* which is a finer version of *gesso grosso* (Thompson 1909; Cennini 1960), but modern techniques recommend using thin gesso built up in multiple layers (MacTaggart & MacTaggart 2011). Great care must be taken to create a smooth, flat surface for water gilding as any imperfections will be highlighted by the burnished surface (MacTaggart & MacTaggart 2011). To achieve a flat surface, some gilders apply either graphite or a coloured watercolour paint to show high points as the surface is scraped or sanded back (see *Figure 2* below). This process continues until the surface is completely flat. It is then buffed with a dampened piece of cloth to polish the surface and ensure it is perfectly smooth (MacTaggart & MacTaggart 2011, 38-40).

Figure 2: Gesso boards being sanded back. Above is a board before sanding; below is a board in the process of being leveled. The high points on the board have been sanded back, showing the white gesso beneath. (Photo taken by author).

Once the gesso surface is completely smooth, two 'bole' layers are applied, a yellow and a red. The bole is a combination of a fine clay and animal glue which, when reactivated with the gilder's liquor, acts as the adhesive layer for water gilding. Yellow bole is made by mixing 'five or six parts by volume of the [gesso] size […], and one part of yellow clay paste' (Taggart & MacTaggart 2011, 42). One to two coats of the yellow bole are applied, followed by the red bole (mixed to resemble single cream [MacTaggart & MacTaggart 2011, 43]). The glue is added slowly to the clay until the bole is the correct consistency then brushed onto the surface. A new coat can be applied once the previous layer becomes matte. The bole is polished and smoothed to create a flat surface in preparation for the leaf (MacTaggart & MacTaggart 2011, 43). If the area will be burnished, the bole layer can be burnished with an agate burnishing tool (A in *Figure 3*) before laying the leaf (MacTaggart & MacTaggart 2011).

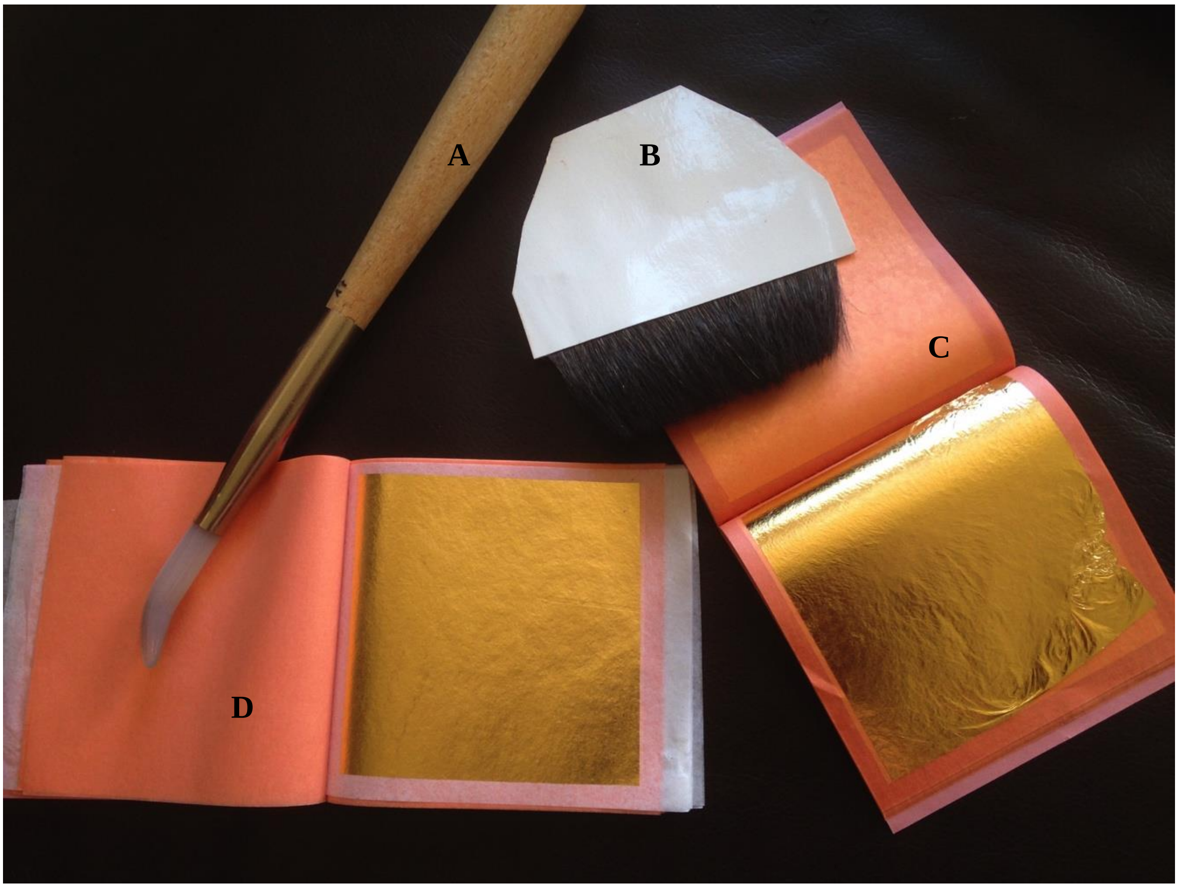


Figure 3: (A) Agate burnisher for burnishing gold leaf. (B) Gilder's tip for lifting loose-leaf gold. (C) Loose-leaf gold, individual leaves that are not attached to the pink booklet. (D) Transfer-leaf gold. The gold leaf is statically attached to the white tissue and lay flatter than the loose-leaf.

To gild, a 'gilder's liquor,' a combination of water, glue, and ethanol, is brushed onto the surface (Thompson 1909; MacTaggart & MacTaggart 2011). The alcohol breaks the surface tension of the water, allowing the solution to spread more evenly (MacTaggart & MacTaggart 2011, Huber 2015). Loose leaf gold (leaf left as individual sheets, C in *Figure 3*) is transferred to the wetted surface using the static of the oil in hair or skin on a flat squirrel hair brush known as a gilder's tip (C in *Figure 3,* MacTaggart & MacTaggart 2011). This process is very delicate as the gold can easily be wrinkled, crumpled, or torn during this process. Airflow should be limited as even gentle breath can disrupt the leaf. With a steady hand, the gilder lifts the leaf, moves it to the wetted surface, and places it, lifting the tip away quickly and allowing the gold to be sucked down to the surface of the object (see *Figure 4* below). A second layer of gold can be applied then allowed to dry before burnishing (MacTaggart & MacTaggart 2011).

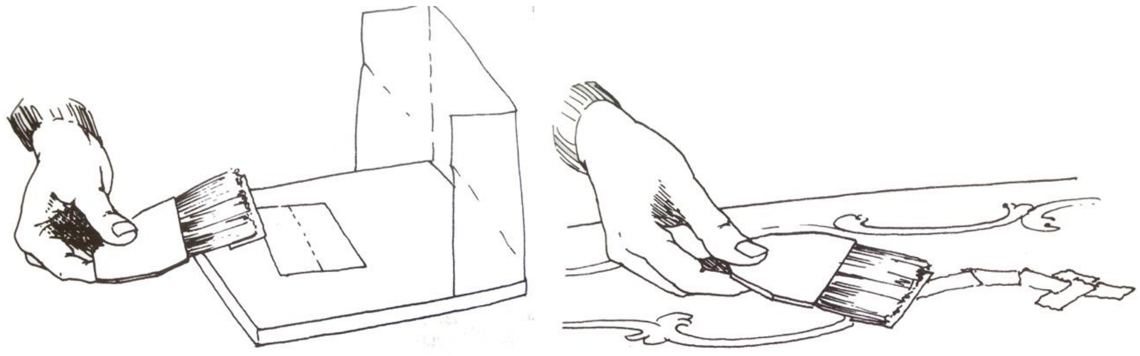


Figure 4: (Left) lifting the leaf with the gilder's tip. (Right) laying gold on the object's surface keeping the tip as parallel to the object as possible (MacTaggart & Mactaggart 2011, 28-29).

Oil Gilding

Oil gilding is a technique that produces a matte gold finish. Instead of being 'sucked down' onto the surface, the glue is adhered to the oil size just as it reaches the appropriate tack. The main advantage of oil gilding is that it is a quicker, therefore cheaper, method. It can be used on metals as well as exterior surfaces. Additionally, it can be used for line designs or in combination with gold dust to create gradient shading on gilding (Moyer 1991). However, there is a stigma against oil gilding that has persisted over the centuries. There is a general belief that because it was quicker and cheaper, oil gilding was only used as a replacement or patch on damaged water gilded surfaces. Hanlon (1992) and Powell (1999) disprove this through their research, showing that oil gilding, while not as brilliant as burnished gold, still had a place, purpose, and aesthetic value in historic settings.

The preparation required for oil gilding is less involved than that for water gilding. Because the oil cannot take a burnished shine, the gesso and bole layers are not necessary. The wooden surface must first be sealed with a glue size to prevent the oil mordant from absorbing into the wood fibres. After, a layer of yellow oil paint can be applied to both enhance the colour of the gold and to colour faults (areas of missing gold) in deep recesses. After, the oil size is applied and allowed to tack before laying the gold. Oil size is listed by drying time as '2-4 hour, 8 hour and 16 hour' (MacTaggart & MacTaggart 2011, 11). Waiting for the correct amount of tack is vital. Gold applied while the size is too wet can be easily damaged and will have a much more matte appearance than if applied at the correct time; too dry and the leaf will not adhere at all. Additionally, if the gold is applied too early, wrinkles will form and become trapped in the leaf. The wet oil size will dry slower and form a thicker layer, disrupting the surface.

Oil gilding has the advantage of being able to use 'transfer-leaf,' gold leaf statically attached to a tissue backing (D in *Figure 3*). Because the mordant is almost dry when the leaf is applied, it will not soak through to the tissue backing allowing for a clean removal of the leaf. The tissue adds support and prevents the leaf from wrinkling during application.

Gilding Repair and Conservation

There is a large amount of research on gilded objects, however, the focus is more on the art historical aspect of gilding and gilding conservation (Considine 1991; Fennimore 1991; Gregory 1991; Westoff 1991; Zimmerman 1991; Chao 2014). Others have focused on the ethical implications of in-gilding losses (Cornu 1986; Powell 1999; Allen & Wegwitz 2014; Kay 2014; Köster & Houston 2014; Wheeler 2014). There are multiple articles detailing treatments, such as the cleaning performed by Johnson & Couture-Rigert 1991, or the use of synthetic adhesives instead of traditional sizes (Moyer & Hanlon 1991; Dunkerton 2001; Sawicki 2007; Sawicki 2010). Treatments specifically mentioning replacement of gesso losses are discussed in *Traditional Materials* and *Synthetics*.

Damage to Gilding

Figure 5: Damage to gilded frame 19590309_fr where gesso has been lost. Damage on right most likely caused by fluctuation of substrate at the mitred joint. Images courtesy of The Frick Collection.

Damage to gilding may occur as abrasion of the surface, loss or breakage of the gesso ground, or damage to the structural support causing loss to the subsequent layers (*Figure 5*). There are many reasons for the deterioration of gilding, from inherent vice in the materials to physical damage caused by use. Gilding is comprised of multiple layers: the wooden substrate, gesso, bole, leaf, and potentially a protective varnish layer. Deterioration and changes in the layers will affect the overlying layers. If the wood expands at a rate that is incompatible to the gesso layer, then the cracking and flaking of gesso will also cause loss to the gilded surface. In a way, the substrate and its coatings have a codependent relationship, both relying on the stability of the other (Hoadley 1998, 15). The layers act as a buffer against changes in the environment, keeping the wood substrate from fluctuating and damaging the gilding (Michalski 1991; Mecklenburg *et.al.* 1998).

Wood Substrate

There is a large body of information on the behaviour of wood in relation to changes in relative humidity (RH) both on its own (Tsoumis 1991, 145; Hoadley 2000, 116; Rivers & Umney 2003, 76-80) and as a substrate for painted or gilded surfaces (McGiffin 1983; Robertson 1991; Hoadley 1998; Mecklenburg *et.al.* 1998; Melin & Legnér 2014). Wood is hygroscopic, shrinking and swelling with changes to humidity in the air. This fluctuation can wreck havoc on a painted or gilded surface as the surface layers do not react and expand at the same rate. To mitigate this, environmental control and monitoring is used to create a stable environment for the gilded pieces. General recommendations are to keep the relative humidity at 50%RH ±5% depending on the object, although there is some flexibility (Robertson 1991; Mecklenburg *et.al.* 1998),.

Gesso and Bole

Gesso and bole layers can be affected by changes in RH (Buck 1990). The animal glue binder is ‘one of the materials most dimensionally responsive to moisture,’ making it the most damaging component when RH fluctuates (Mecklenburg *et.al.* 1998, 472). Gesso’s responsiveness to changes in RH is also dependent on how much filler has been used: the more filler, the less responsive and more brittle the material (Mecklenburg 1991; von Endt & Baker 1991; Mecklenburg *et.al.* 1998). Michalski’s 1991 research into the crack mechanisms of gilded surfaces directly ties the correlation between fluctuations in RH causing differential expansion between the wooden substrate and the gesso ground.

Gold Leaf

The manufacture of leaf affects its eventual stability as the reduction in thickness increases its risk of mechanical damage (see MacTaggart & MacTaggart 2011 for more detail). Because the leaf is so thin it is easily abraded, even by fine particles of dust in the air (Lins 1991; Glover 2006; Chao *et.al.* 2014). Additionally, the type of gilding may affect the damage to the gilding caused by environmental fluctuations. While Melin & Legnér 2014 may have focused on oil-based paints in churches, the binding medium is very similar to oil size. It can be extrapolated that while oil gilding may be more durable, it may also be sensitive to fluctuations in temperature particularly in low RH settings, a theory supported by Mecklenburg *et.al.* 2004.

Varnish or Toning Layer

A final toning layer would often be applied to gilded surfaces, particularly on silver leaf to protect from oxidation (MacTaggart & MacTaggart 2011). These surfaces were the most susceptible to abrasion and damage. Damage can occur during conservation treatment, especially to these delicate coatings that can be confused for deteriorated varnish (Serck-Dewaide 1991). The toning layers are crucial to the overall appearance of the gilded surface, and are used in modern treatments to tone fills and losses (Westhoff 1991; Aughey 2015).

Repair

If a gilded object was damaged, it was not uncommon for it to be regilded (Chao, *et.al* 2014). Unfortunately, the new gilding did not always correspond to the previous scheme, and it was common for oil gilding to replace water-gilt passages due to time and cost restrictions. If the whole surface was not regilded, losses would be toned with bronze powder paints (*Figure 6)* which are damaging and very difficult to remove (Chao *et. al.* 2014). Bronze powders also tarnish, causing them to darken and discolour with time and making the lost areas more obvious (Glover 2006).

Figure 6: Bronze paint thickly applied over the surface of the frame. Original gilding can be seen in the upper left half of the image where the paint has flaked off. Image by author, personal collection.

Traditional Materials

Historically, guild members or craftsmen performed repairs to gilded surfaces. This follows the same tradition as furniture conservation, which moved from a craft based field into a more scientific one (Wilmering 2004). It has been believed that those who could make furniture (or, in this case, could gild) would also understand best how to repair its damage. Gilders would fill losses with traditional materials as they produced the best surface for gilding. As gilding conservation as a field developed, the same materials continued to be used.

There is an obvious draw to traditional gesso and composition, even with the advent of synthetic materials. Using gesso or composition for repairs makes fills compatible with the surrounding materials when reacting to changes in temperature and RH. Additionally, the same level of finish should be replicable using traditional gesso and composition as they were the original materials used for gilding applications. The ageing properties are known and understood as objects with gesso and composition decoration have survived hundreds of years. This preference is evident in the continued use of traditional gesso in modern treatments (Thorn 1987; Anderson & Malenka 1991; McGrath 1991; Payer 1991; van Horne 1991; Hanlon 1992; Anderson 2001; Davey 2001; Wheeler 2014).

There is a passionate debate between the use of synthetics and traditional materials, with those who prefer traditional techniques staunchly defending their position. Opinions fluctuate from the more neutral Ashley-Smith's (1982, 4) 'it is difficult to decide wether virtually undetectable replacement with original material or misleading substitution by some alien substance is more ethical' to flat out rejection of the use of synthetics by Green (1979; 1991). Synthetic materials have been described as 'alien, and often incompatible' (von Reventlow 1991, 269) and can cause treatments 'to become increasingly complex and difficult, as new properties of alien substances are combined with the gesso structure' (von Reventlow 1991, 269). While these are valid concerns as the degradation of synthetic materials is not certain, they do not address the ethical complications of using traditional materials, focusing instead on the continuation of the craft knowledge (Green 1979).

The main downfall of the traditional materials is the ethical implications of using a material that is indistinguishable from the original object. The belief that 'written and photographic records of each step of [the] restoration [will be] made and kept in an individual file for each object' is a cornerstone of conservation ethical practice (Green 1979, 41). However, even with extensive documentation, there is no guarantee that the paperwork associated with an object will remain with it throughout its lifetime (Ashley-Smith 1982; Podmaniczky 1991). The AIC's approach to the ethics of loss compensation relies on documentation, stating that 'any intervention to compensate for loss should be documented in treatment records and reports and should be detectable by common examination methods" (2015, c.23). Both ICON's Professional Standards and Code of Conduct avoid the issue, instead emphasising the conservator's knowledge of materials and treatments, relying on the conservator to use their best judgement (ICON 2014a; 2014b) . It may be possible to identify the new gesso from the old with analytical tests, but they can be invasive, damaging, and cost-prohibitive (Chao, *et.al.* 2014). A smaller institution may not have the means to run the tests, while larger museums may not have the time.

This ethical clash has caused conservators to be creative in finding new ways to make fills obvious or easily reversible. Paraloid B-72 (an ethyl-methacrylate copolymer) has been used as a barrier coating between original gesso and replacement elements (Gribbon 2001) or microballoons are mixed into the gesso putty, a non-traditional bulking material and easily identifiable under magnification (Powell 2001). Barium sulphate has been a popular additive mixed into gesso fills to make restorations opaque during x-ray examination (Thornton 1991). However, when retreating an object Salimnejad (2002) discovered that the fill was not identifiable, leading to experimentation with bismuth oxide (*Figure 7)* as a replacement filler (Salimnejad 2005). The concept is effective, but requires the institution to have x-ray capabilities, which many do not have. Additionally, the size of the x-radiograph will limit the size of the object to be imaged, even with the advent of digital technologies (Crombie 2007).

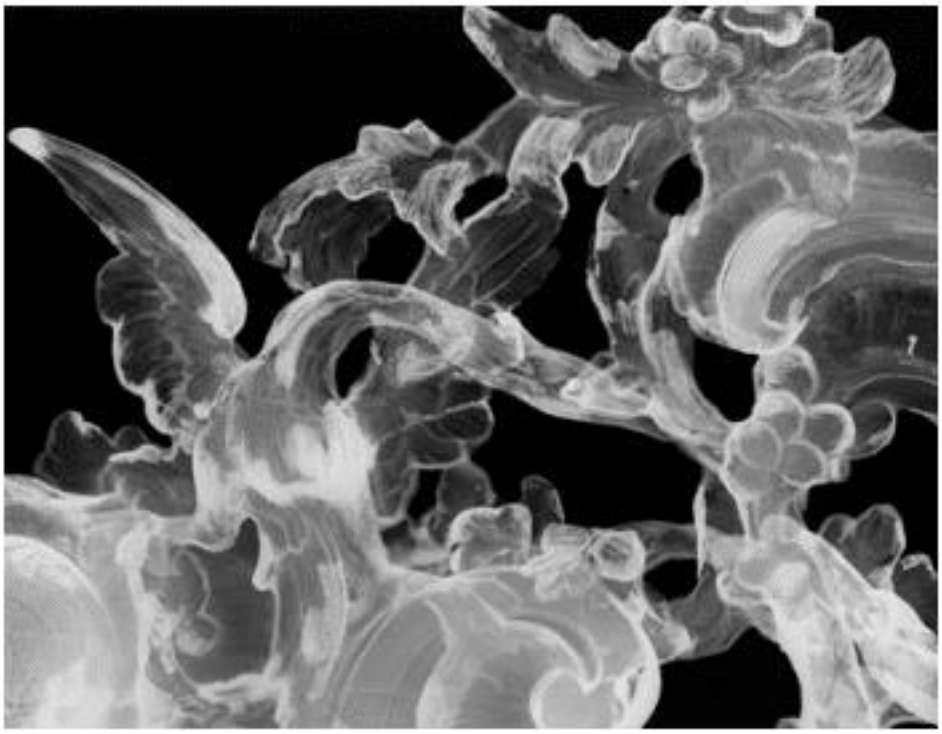


Figure 7: X-ray of object with losses filled with bismouth oxide bulked gesso. The areas are clearly opaque. Photo from Salimnejad 2005, p3.

Alternatively, in 2013 Cox published a brief summary of his research into the use of ultraviolet (UV) reflective fillers (see *Figure 8* below). The advantage of this technique is that UV examination is quick and easy to perform and UV lights have become increasingly inexpensive. It is a very effective marker when applying gesso fills and is accurate until the new gold layer is applied (Slight 2015). The gold leaf blocks the UV rays from hitting the fill surface; more of the UV filler must be mixed into the toning layer. While this technique is not perfect, it is better than relying solely on documentation.

Figure 8: Detail of gesso fills bulked with UV fluorescent pigments. While this specific application was to replace inlay on a chest, the same technique has been applied to gilded surface based on Cox's research. Image from Cox 2013, p 36.

Synthetics

While identifying markers and documentation do make fills made with traditional materials more identifiable, the solvent issue of using an identical material remains. The aim of 'reversibility' or 'retreatability' is the driving force behind conservation ethics (Appelbaum 1987). Investigation into synthetic fill materials with different solubilities has been undertaken to help solve this issue, particularly focusing on Paraloid B-72 (Hatchfield 1986; Thornton 1991; Wilson 1998; Webb 2000). In addition, polyvinyl alcohol(PVOH) (Hebrard & Small 1991; Webb 2000), and aquazol (poly[2-ethyl-2oxazoline]) (Shelton 1996) have ben found to be suitable replacements for gesso losses on gilded objects. Other synthetic materials, such as room temperature vulcanising silicones (Grattan & Barclay 1988; Storch 1994), acrylics (Buck 1993; Webb 2000); polyvinyl acetal resins (Spirydowicz, *et.al.* 2001), epoxy resins (Barclay & Mathias 1989; Galassi, *et.al.* 1991; Ellis & Heginbotham 2002; Glover 2002), and premixed acrylic gessoes (Craft & Solz 1998; Parker & Sixbey 1998) have all been used as fill materials within the conservation field.

Synthetic materials have been popular within conservation since the 1980s. The main argument for their use has been their long-term stability; anything added to an object should not cause harm to the original materials (Appelbaum 2007). While artificial age tests have been performed on most conservation materials, these tests may not accurately reflect how materials will age in a 'real life' scenario (Hebrard & Small 1991). As synthetics degrade with time and exposure they may become cross-linked and impossible to remove, causing more damage (Appelbaum 1987; Green 1991; von Reventlow 1991; Appelbaum 2007).

Materials Tested

The Ideal Fill

There are several criteria for the ideal fill material for organic materials. Barclay & Mathias (1989, 32) list ‘matched to the physical characteristics of the wood; removable (“reversible”); very low shrinkage; easily applied; easily worked; easily inpainted; easily available; relatively inexpensive; good ageing characteristics.’ The importance of good ageing characteristics is carried across the literature (Hebrard & Small 1991; Shelton 1996; Webb 1998; Wilson 1998; Webb 2000; Appelbaum 2007), but the ‘ideal’ varies based upon the need of the treatment. For gilding conservation, it is important that the materials not damage original water gilding and, if filling losses in water gilding, it must be able to withstand burnishing (Hebrard & Small 1991; Shelton 1996; Wilson 1998).

Selection Process

Nine synthetic materials were tested against traditional gesso and composition. Materials and concentrations were chosen based on previous research conducted in the field. While few materials have been tested specifically for gilding applications (see *Synthetics* section), research into the conservation of materials with similar high finish demands such as marble (Wolfe & O’Conner 2005; Kemp 2009) or lacquer (Webb 1998; Wilson 1998; Webb 2000) was required. Additionally, investigation into fill materials for wooden artefacts was conducted to see if any materials commonly used for gap filling might be applicable to a gilding application (Hatchfield 1986; Grattan & Barclay 1988; Barclay & Mathias 1989; Storch 1994; Thornton 1998; Fuster-López 2012; Ormsby & Gottsegen 2012; Fulcher 2014). A summary of the relevant research pertaining to each material can be found in *Table 1.*

Table 1: Synthetic Materials Previously Investigated for Wooden and Gilded Object Fills		
Material	**Article**	**Result**
Flügger	Craft & Solz 1998; Parker & Sixbey 1998	Soft and easy to carve, but difficult to cast, no set recipe; used for shallow fills successfully
Lascaux Gesso	Craft & Solz 1998; Parker & Sixbey 1998	Slightly rubbery, no set recipe; used for shallow fills successfully
Epoxy Resins	Grattan & Barclay 1988; Barclay & Mathias 1989; Galassi *et.al.* 1991; Storch 1994; Webb 2000; Ellis & Heginbotham 2002; Glover 2002	Good working properties and structural support, issues with reversibility; Suitable for gap filling when mixed with microballons; used to attach broken elements, mimics wood; structurally strong; premixed putties can be worked wet for a smooth surface; reversible with the use of a barrier coating; useful for casting applied elements
Modostuc	Craft & Solz 1998; Parker & Sixbey 1998	Soft and easy to carve, but difficult to cast, no set recipe; used for shallow fills successfully
Paraloid B-72	Storch 1994; Hatchfield 1986; Wilson 1998; Webb 2000; Ellis & Heginbotham 2002; Glover 2002; Wolf & O'Connor 2005	Can be used for structural fills; Good on water sensitive materials; useful as a base for lacquer conservation, not reflective enough and must be coated to alter shine; successful for can be burnished and smoothed to replicate a gilded surface and identifiable under UV light; can be used as a barrier coating; useful as a synthetic bole material; can be combined with microballoons or chalk and obtain a high polish
Paraloid B-67	Buck 1993; Webb 2000	Used for fills successfully and as a binding agent for inpainting with pigments; useful as a base for lacquer conservation, not reflective enough and must be coated to alter shine
Polyvinyl Alcohol (PVOH)	Hebrard & Small 1991; Webb 1998; Webb 2000	Obtained a good surface for gilding, highly dependent on concentration, molecular weight, and ratio of material to filler; Can be combined with calcium carbonate for a smooth fill
Klucel G	Grattan & Barclay 1988; Feller & Wilt 1990	Good working properties, but does slump and shrink on drying; fairly stable for conservation purposes but issues with discolouration and cross linking over time
Butvar B-98	Grattan & Barclay 1988; Craft & Solz 1998; Spirydowicz *et.al.* 2001	Poor surface texture and reversiblity, good working properties; Soft and easy to carve, but difficult to cast, no set recipe; stable over intense environmental fluctuations but generally used for consolidation

Another factor in choosing these materials was whether they were considered ‘safe’ for use by examining the MSDS and COSHH Risk Assessments for each material or solvent. Most of the solvents, (acetone, IMS, White Spirits) are deemed ‘unexceptional laboratory hazards’ if the appropriate ventilation and personal protective equipment (PPE) such as gloves or safety glasses are used (UCL COSHH Risk Assessments 2005a, 2005b, 2011). Xylene, which is listed as a solvent for many of the materials above, is categorised slightly more seriously, as it is a possible carcinogenic and requires either a fume hood or an organic vapour mask to filter fumes (UCL 2005c). The premixed materials Modostuc and Lascaux Gesso are both listed as non harmful to humans (Lascaux 2006, Modostuc 2009). MSDS information was difficult to find for Flügger, although it is believed to be non-toxic. Ronseal epoxy resin states very clearly on the can that it ‘contains Styrene. Flammable. Harmful; by inhalation.[…] Do not breathe fumes’ (Ronseal 2015). Because the size of the sample boards is so small, the fume hood size is not an issue, but materials should be reconsidered if appropriate ventilation is not available.

Based on previous research and use, PVOH and Paraloid B-72 should create a smooth surface for gilding applications. Additionally, Paraloid B-67 and the epoxy should also create a smooth surface based on their uses in lacquer conservation. Having used Flügger as a fill material previously, its working properties are familiar and it is expected to be easy to work with. However, there are doubts to its burnishing capabilities, which extends to the rest of the premixed materials as well as the Klucel G mixture. Lascaux and Klucel G are both flexible and soft and may not be able to provide the level of burnish necessary to replicate gilded surfaces. Most importantly, all of the materials above are soluble in solvents other than water, which will protect the original gesso grounds from exposure to water. Additionally, none of the materials need to be heated to make them workable, which is another advantage over animal glue based materials which require a gentle heat source in order to maintain its viscosity (Hebrard & Small 1991). Additionally, for consistency between materials, lab-mixed materials were bulked with calcium carbonate (gilder’s whiting).

For the sake of simplicity, 'traditional materials' will refer to animal skin based gesso and composition, and 'synthetic materials' will refer to the rest of the materials (acrylic, vinyl, epoxy, etc. see *Table 2.* A summary of concentrations can be found in *Table 3*).

Table 2: Traditional Vs. Synthetic Materials	
Traditional	**Synthetic**
Gesso	Flügger
Composition	Lascaux Gesso
	Ronseal Epoxy Putty
	Modostuc
	Paraloid B-72
	Paraloid B-67
	Polyvinyl Alcohol
	Klucel G
	Butvar B-98

Materials Selected

Gesso and Composition

Gesso

The gesso was made using rabbit skin glue (approximately 5% concentration) and whiting. A more detailed description of the process for making gesso can be found in Appendix 1. Gesso was used to mimic the flat areas of gilding and was painted on in 6 layers. Its main component, rabbit skin glue, is soluble in water and can be softened with heat and humidity (Brandis 1990, 127; Down 2015; 42-43). In some instances, ethanol or methylated spirits can aid in softening the animal glue and is frequently used to help reduce surface tension in fresh mixtures (Schnellman 2007, 60)

Composition

The composition was made using the recipe from the Tate (per Alabone 2012, described in Appendix 2). It is a combination of whiting, linseed oil, glycerol, rosin, hide glue, and turpentine. Composition was used for cast elements.

Premixed Materials

Flügger

Flügger is an acrylic polybutyl methacrylate bulked with calcium carbonate. It was applied directly from the tube without diluting it (*Figure 10)*. It was spread on the boards using a flat metal spatula to obtain a smooth surface. Flügger is soluble in water and white spirits (Down 2015, 90).

Figure 9: Tube of Flügger

Lascaux Gesso

Figure 10: Tub of Lascaux Gesso

Lascaux Gesso (*Figure 10)* is a "pure acrylic resin dispersion with rutile titanium dioxide and mineral based extenders" (Lascaux 2015). The acrylic compound is not identified but is advertised as 'age resistant' on both the website and the label but is most likely a combination of butyl acrylate and methyl methacrylate (Down 2015, 85). Because most of the Lascaux brand is soluble in acetone, alcohol, toluene, and xylene, it was assumed that the gesso would also be softened by these materials (Lascaux 2015).

Ronseal Epoxy Putty

Figure 11: Ronseal Epoxy Putty container

Ronseal is a two-part pre-bulked epoxy putty commonly used in furniture conservation in the UK (*Figure 11*). It was applied by spatula to the surface of the boards. Because epoxy resins are not easily reversible in any solvents that are safe for both objects and conservators, a barrier layer of 20% w/v Paraloid B-72 was applied to the surface of the loss per Ellis & Heginbotham 2002 to aid with removal. Paraloid B-72's solubility can be found below in the next section.

Modostuc

Figure 12: Tube of Modostuc

Modostuc is a polyvinyl acetate copolymer binder bulked with calcium carbonate and barium sulphate (*Figure 12*). It was applied by spatula straight from the tube to the surface of the boards. Polyvinyl acetates are generally soluble in 'aromatic and chlorinated hydrocarbons (e.g. toluene, cloroform), ketones, lower alcohols (with a little water), esters (e.g. ethyl acetate), and ethylene dichloride/alcohol (20:80)' (Down 2015, 74). The solubilities are based on results found by Roff & Scott 1971 and Norris & Dragetti 1962.

Lab Mixed Materials

Paraloid B-72 in Acetone

Paraloid B-72 is an ethyl methacrylate copolymer. Two concentrations were used: 60% w/v B-72 in acetone and 20%w/v B-72 in acetone. The second concentration was used after the first was deemed too hard to sand flat using a block. The B-72 was bulked with whiting to a heavy cream consistency. Because the acetone evaporates so quickly, by the time the mixture had been applied to the flat boards by spatula what was left in the cup was thick enough to use for the mould and the fill board. Paraloid B-72 is soluble in 'aromatic and most chlorinated hydrocarbons (e.g. toluene, chloroform), esters, (e.g. ethyl acetate), ketones and tetrahydrofuran' (Down 2015, 90) based on the work performed by Roff& Scott 1971 (90). It is also listed on CAMEO Materials Database as being soluble in 'toluene, xylene, acetone, carbon tetrachloride, and MEK' (CAMEO 2015b).

Paraloid B-67 in IMS

Paraloid B-67 is an isobutyl methacrylate copolymer. A 20% w/v concentration in IMS was bulked to two consistencies: one 'gesso' consistency similar to heavy cream and one to a thicker paste for the mould and fill board. Paraloid B-67 is soluble in 'toluene, xylene, methylene chloride, ethyl acetate, mineral spirits, VM&P naptha, acetone, methyl ethyl ketone, and isopropanol' (CAMEO 2015a). B-67 has done well in age tests and does not crosslink severely over time (Down, *et.al.* 1996; Down 2015, 90).

Polyvinyl Alcohol (PVOH) in Deionised Water

Polyvinyl alcohols are synthetic polymers comprised of repeating ethenol groups. A 6% w/v solution in deionised water was mixed, then combined with a 90:10 whiting:kaolin mixture. Two consistencies were made: a 'gesso' consistency and a thicker paste for the mould and fill board. The gesso was applied in multiple coats by brush, while the paste was applied by spatula. Polyvinyl alcohol is soluble in water and in alcohols (Down 2015, 77; Hebrard & Small 1991, 279-282).

There has been concern about the reversibility of this material as it contains 'hydroxyl groups that are very reactive' (Down 2015, 77). Research performed on the ageing properties of PVOH have concluded that despite the estimates that it should be stable for centuries, it can crosslink in acidic and alkaline conditions, when exposed to organic salts, or when exposed to high heat (Down 2015, 77; Hebrard & Small 1991, 281; Horie 1996,97-99; Jaffe & Rosenblum 1990). While these are valid concerns, the circumstances can be mitigated enough to minimise the threat of cross linking.

Klucel G in IMS

Klucel G is a low molecular weight hydroxyropyl cellulose compound. Two concentrations were mixed: 5% w/v in IMS and 2% w/v in IMS. The first concentration, when bulked with whiting to a thick paste, separated into islands with large cracks between the areas. The 2% solution was bulked with whiting to a thinner heavy cream consistency then applied over the sanded over sample. The cracking is suspected to be caused by the high concentration of the solution, when the thinner solution was applied, cracking occurred but to a significantly lower extent.

Klucel G is soluble in alcohols such as IMS and ethanol as well as water (Down 2015, 57; Feller & Wilt 1990). Feller & Wilt 1990 have done extensive research into the properties and degradation of cellulose ethers in conservation applications and have found that the lower molecular weight Klucel G is more stable than its higher molecular weight counterparts. However, it only passed as an ‘intermediate’ material rather than a ‘stable’ one, and will degrade over time (Feller & Wilt 1990, 94).

Butvar B-98 in IMS

Butvar B-98 is a polyvinyl butyral resin. A 5% solution was mixed in IMS, bulked with whiting to a gesso-like consistency and painted onto the surface. A thicker consistency was mixed for the cast and loss elements. B-98 is soluble in ‘very polar solvents [e.g *n*-butanol, diacetone alcohol, dimethylformamide (DMF), 95%ethanol, 95%isopropaol, methanol—but not acetone, methyethylp ketone (MEK) and toluene] (Down 2015, 80). It is considered to be very stable when subjected to artificial ageing tests (Down 2015, 78; Spirydowicz, *et.al.* 2001).

Table 3: Materials Tested and their Concentrations		
Material	**Bulking Ratio Flat**	**Bulking Ratio Casting**
Gesso	See Appendix 1	See Appendix 2
Flügger	From Tube	From Tube
Lascaux Gesso	From Jar	From Jar
Ronseal Epoxy Putty	1 ‘golf ball’ filler: 1 38mm line catalyst	1 ‘golf ball’ filler: 1 38mm line catalyst
Modostuc	From Tube	From Tube
Paraloid B-72	50ml 20% w/v Paraloid B-72 in Acetone: 84g whiting	50ml 20% w/v Paraloid B-72 in Acetone: 84g whiting
Paraloid B-67	50ml 20% w/v B-67 in IMS: 54g whiting	25 ml 20% w/v B-67 in IMS: 67.5g whiting
Polyvinyl Alcohol	30 g 6%w/v PVOH in deionised water: 60g (90:10 whiting:kaolin) filler	25ml 6%w/v PVOH in deionised water: 77g (90:10 whiting:kaolin) filler
Klucel G	50ml 2% w/v Klucel G in IMS: 30g whiting	25ml 2% w/v Klucel G in IMS:27g whiting
Butvar B-98	50ml 5% w/v B-98 in IMS: 77g whiting	15ml 5% w/v B-98 in IMS: 30g whiting

Experimental Method

Because the research question is multifaceted, the experimental method was designed to answer as many questions as possible. The chosen methods are a combination of the techniques employed in previous studies into fillers for wooden artefacts and gilding. Shelton 1996 used a test board reflected in the burnished sample to determine reflectance of the surface. This same technique is applied in this study to compare the burnish quality of the materials. The setup for the gap-filling board was modified from Hebrard & Small's 1991 research on PVOH for gilding applications. The working properties analysed by Grattan & Barclay 1988, such as slump, shrinkage, carving, and sanding, have been investigated in the method below.

Surface Finish

The aim of the surface finish boards was to obtain flat, even surfaces for the application of water and oil gilding. By gilding each surface in in a traditional manner (animal glue-based bole, standard oil size), the differences between the substrates are highlighted. Having small sample boards also allowed for the samples to be handled safely and reorganised for later assessment by an outside group.

Two sample boards for each material were made. The boards are of lime, a straight-grained wood commonly used for carving, that have been machine milled and trimmed to size (7.3 x 20 x 2.2 cm). Two coats of 8% w/v hot hide glue (12:1 water: pearls) were applied to the surface to seal the wood pores. Each board was numbered 1 through 20, and the numbers randomly assigned to each material (*Table 4*). Once the boards were sealed, each fill material was either brushed or spread on with a spatula depending on the consistency of the material. When the material was brush applied, multiple coats were added bulk the surface. If the material was applied with a spatula, one thick coat was applied and allowed to dry.

Table 4: Material Sample Boards		
Material	**Water Gilding**	**Oil Gilding**
Gesso	4	9
Flügger	2	13
Lascaux Gesso	1	18
Ronseal Epoxy Putty	11	14
Modostuc	12	7
Paraloid B-72	5	16
Paraloid B-67	19	10
Polyvinyl Alcohol	17	3
Klucel G	15	8
Butvar B-98	20	6

Once the boards were dry, a thin coat of red watercolour was applied to the surface to highlight low points in the fill layer. Each board was then sanded with a series of sand papers (80 grit, 120 grit, 240 grit, 400 grit, and 600 grit) on a block until a uniform flat surface was achieved.

For oil gilding, the oil size (3 hour oil gold size by Charbonnel) was applied to the surface and allowed to dry to tack before gold leaf was laid down. For the water gilt boards, two types of bole were applied per MacTaggart & MacTaggart 2011. A thinner grey bole was mixed 1:6, clay:0.6% animal glue by volume creating a thin cream or milk consistency. Two coats were brushed onto the surface of each sample. A red clay bole was mixed 1:4 clay:0.6% animal glue (4.5g:750ml glue pearls: deionised water) creating a heavy cream consistency. Four coats were applied to each sample and allowed to dull to matte between applications. The bole was buffed down and smoothed prior to gilding using 600 and 1200 grit sand paper. The water gilt surface was wetted with a gilder's 'water'. According to MacTaggart & MacTaggart 2011 (p44), the solution 'is made as follows: take a lump of the size as large as a hazelnut and dissolve it in 4 fl oz (100ml) of water in a clean cup; then add 1 fl oz (25ml) of alcohol'. Once the solution was brushed onto the surface gold leaf could be applied.

Half of the surface was burnished to achieve a high gloss. A sample board with 'TEST' written in large black letters was photographed at an angle on each of the burnished surfaces to capture the clarity of the reflection (*Figure 13*). The images were then compared against each other to determine level of burnish. The boards have also been compared against each other and ranked by a group of 10 people based on their opinion of what surface is the most desirable.

Figure 13: Example of TEST board on Paraloid B-67 sample

High resolution (250x magnification) digital photomicrographs of the surfaces of each block after gilding were taken using a Dino-Lite Pro HR AM7000 5 megapixel digital microscope. Additionally, silicone rubber disc moulds were taken of each finished surface for all 20 samples to be examined with the Dino-Lite. Metal rings were held in place with plasticine modelling clay and Tiranti T20 silicone mould rubber was mixed in a 20:1 ratio with the T6 catalyst (*Figure 14*). The moulds were allowed to set overnight before being removed.

Figure 14: Silicone moulds taken on a few finished samples.

Casting Capabilities

Replacing lost decorative elements is a frequent issue within conservation. Therefore, it was important to test how each material cast. A mould was taken of a simple repeated diamond pattern from an unprovenanced frame from a private collection then used to test the casting capabilities of each material. The thicker 'putty' consistency was used for this process.

Figure 15: Dental mould and plaster cast of the decorative moulding. The cast was used to create a larger and sturdier mould for the actual tests.

Working Properties

The working properties, such as ease of application, shrinkage, and the ability to rework or carve the surface were assessed for each material.

One board, 7.3 x 40 x 2.2cm, made of lime wood was sealed with two coats of the same 8% size. The board was coated with 6 layers of traditional gesso, then sanded flat. A simple moulding, a flat with a gentle ogee, was obtained from the stock material at The Wallace Collection and cut to 3 cm lengths. These were attached using hide glue to each side of the substrate every 4cm leaving a 1.3cm gap to test fill materials (see *Figure 16*). One side was left with the original oil gilding, while the other was water gilded. Each gap was filled with each material then assessed for slump, shrinkage, surface, drying time, and ease of application. The materials were removed using different solvent poultices to see if any damage was caused to the gilt surfaces.

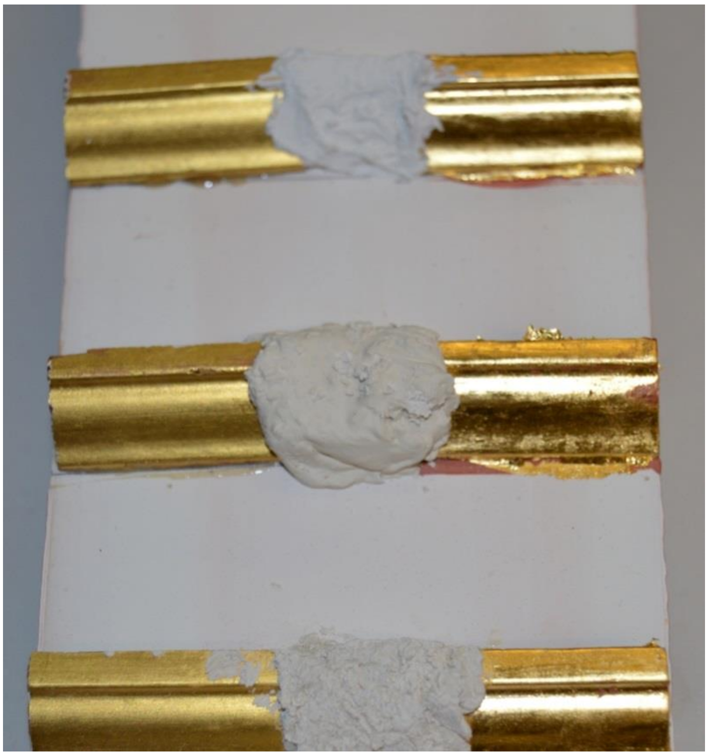


Figure 16: Sample board with fill samples placed. Water gilding is on the right side, and oil is on the left.

Reversibility

While it is technically impossible to completely reverse a treatment, the ability to remove a fill without visual damage to the surface will be referred to as 'reversibility.' To test reversibility, each fill was softened with a cotton wool poultice wetted with between 1-2 ml of solvent. The poultice was left in place for 5 minutes then tested with a spatula to see if it could be removed. If it could not, the poultice was rewetted and replaced for an additional 5 minutes and the process repeated up to 1 half hour. If the material could still not be removed after a half hour, a stronger solvent was tried.

Results

The results of the tests are described in the following sections and are summarised in *Tables 9, 10, 11,* and *12.*

Surface Testing

The samples were sanded flat using a cork sanding block. A nilfisk GD 1000 series vacuum was used to aid in dust removal. The sandpaper was gradually increased in grit to create smooth, even surface starting with 60 grit and ending at 600. In most cases, half of the block was fully finished. The unfinished half of the block was left uncovered as a reference for the appearance and application. The finished surfaces were then cast in silicone to obtain a negative three-dimensional representation of the defects in the surface. Having an inverted surface made bubbles in the surface easier to see. Both the surfaces and the casts were examined with a Dino-Lite Pro HR AM7000 5 megapixel digital microscope at 50x and 250x magnification. A comparison of digital photomicrographs can be seen below.

Figure 17: Nilfisk museum vac dust removal setup. A stronger shop vac is recommended for future tests as sanding produced a large amount of dust. Additionally, a particle dust mask is recommended.

Almost all materials, with the exception of Lascaux Gesso, had issues with bubbles in the surface. Some of these were caused by the application method, particularly for lab-mixed materials. If the mixtures were stirred too vigorously, air became trapped and manifested as bubbles and divots in the surface. Normally these bubbles were very small (such as the ‘pinhole’ bubbles found below), but some, such as those formed on the Klucel G samples, were large (1mm in diameter). Bubbles also formed in the premixed materials, particularly on Ronseal, Modostuc, and Flügger. These bubbles are may have been trapped during mixing, and, due to the thicker consistency, could not escape. The samples are described below from small bubbles to large.

Materials with pinhole bubbles

'Pinhole' bubbles are tiny bubbles in the surface that look like the surface has been dotted with a pin (see image to left). The materials that had small 'pinhole' type bubbles in the surface were gesso, Ronseal, and PVOH. The bubbles on the gesso and PVOH can be seen without magnification, but those on the Ronseal are not as noticeable with the naked eye. Gilding applied over the bubbles was rippled.

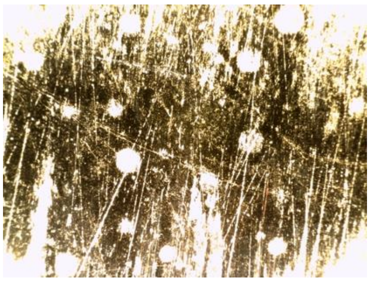


Figure 18: PVOH water gilded surface at 50x magnification

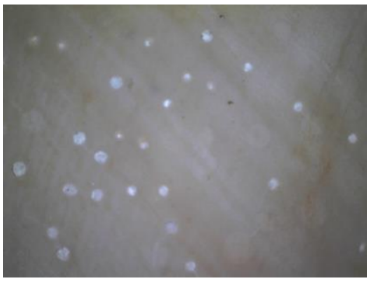


Figure 19: PVOH surface at 50x magnification

Figure 20: PVOH silicone mould 20x magnification

Figure 21: Gesso water gilded surface at 50x magnifiacation

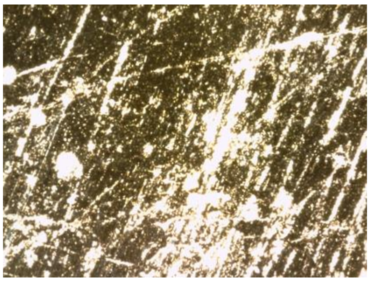


Figure 22: Gesso water gilded surface at 50x magnification

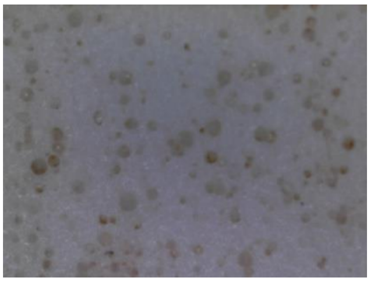


Figure 23: Ronseal silicone mould surface at 50x magnification

Materials with bubbles in the surface - small

'Small bubbles' refer to bubbles that are noticeable to the naked eye but are larger than the pinhole bubbles described above. Materials that had small bubbles were Flügger, Modostuc, and B-98. The bubbles in Flügger and Modostuc were less numerous and spread far apart (*Figures 24-26*). In contrast, there were many bubbles densely congregated on the B-98 samples.

Figure 19: Flügger surface at 50x magnification

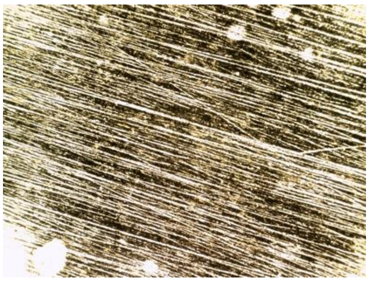


Figure 20: Modostuc water gilded surface at 50x magnification

Figure 26: B-98 silicone mould at 20x magnification

Materials with bubbles in the surface - large

Large bubbles are those with a diameter of approximately 1mm. Paraloid B-67, B-72, and Klucel G had larger bubbles in the surface with B-67 having the least (see *Figures 27-29*). These bubbles can be seen easily without magnification and are particularly amplified after the gold was applied, creating 'puckered' areas on the surface (*Figure 27*).

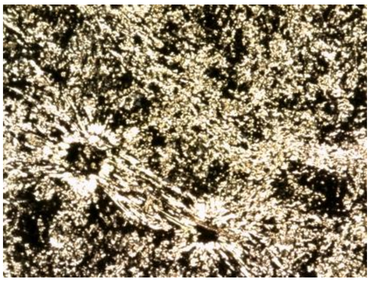


Figure 27: B-67 surface at 50x magnification

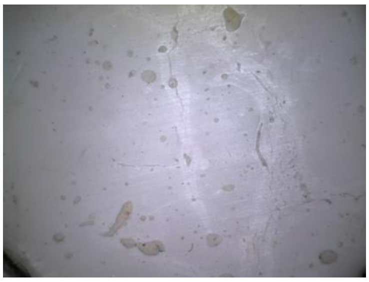


Figure 28: B-72 surface at 20x magnification

Figure 29: Klucel G surface at 50x magnification

Cracking or rough surfaces

Paraloid B-72 and Klucel G both had severe issues with coarse surfaces and cracking. This was noted even from the application stage (see *Figures 30 & 31*) and made them difficult to work with later. Additionally, one of the two sample boards for Butvar B-98 cracked and lifted during drying, with large sheets of the material breaking free from the surface of the wooden block. The B-98 fill was so brittle that downward pressure caused further cracking (*Figures 32 & 33*). Once the broken coating was removed, a new coating was applied.

Figure 30: Klucel G before sanding showing deep cracks in surface

Figure 21: B-72 before sanding showing deep cracks in surface

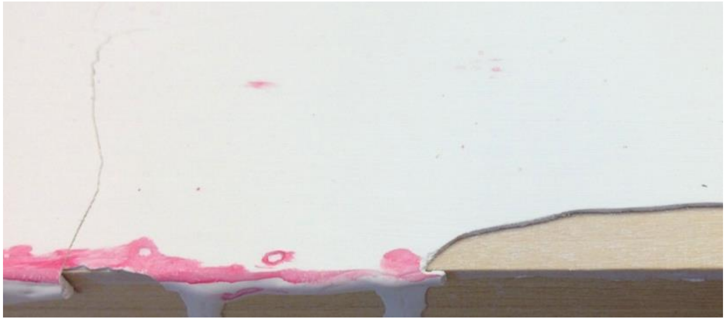


Figure 22: Cracking and lost areas on a B-98 sample

Figure 33: Cracking during burnishing on the B-98 sample. 50x magnification.

Oil Gilding

The area of a square of gold was wetted with size and the time taken to reach optimum tack was recorded for each board. Four of the boards (PVOH, B-98, Modostuc, and Klucel G) absorbed the oil size very quickly into the gesso layer, causing it to dry out within 2-3 minutes. A second layer of size was applied for gilding on these boards. Drying tack times for each of the materials can be found in *Table 5* below.

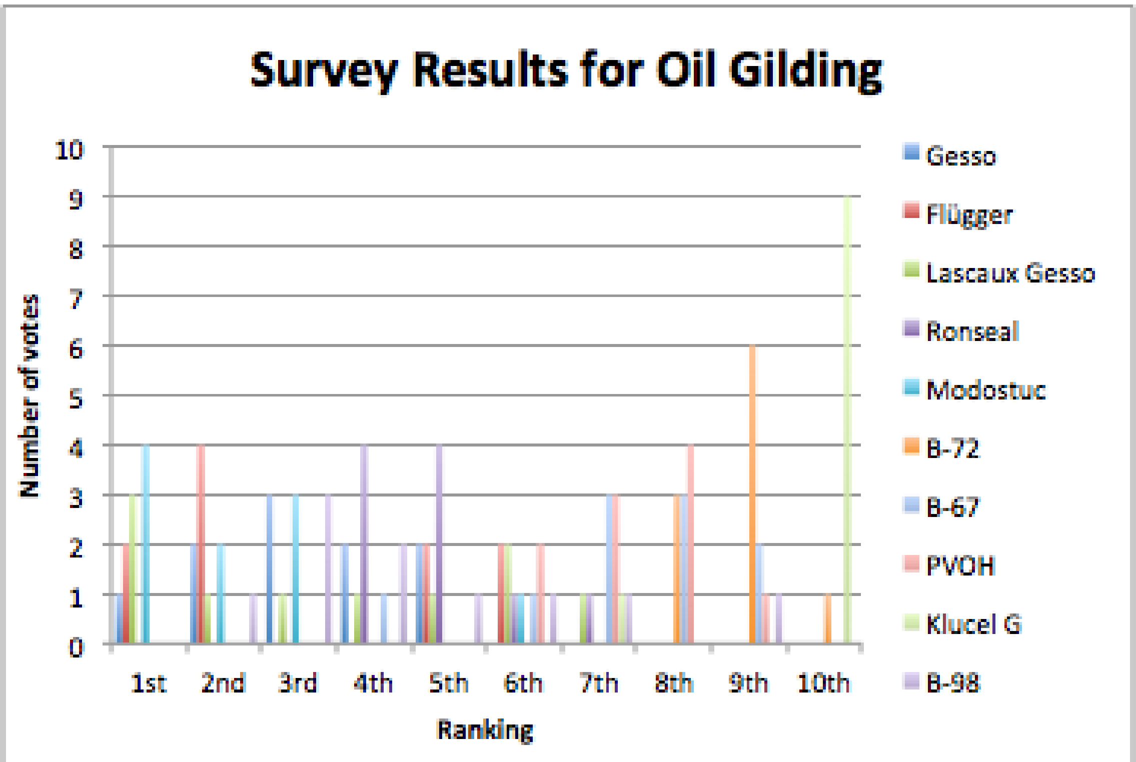
Table 5: Drying times for Oil Gilding

Material	Drying time
Ronseal Epoxy Resin	5 minutes
Paraloid B-67	8 minutes
Flügger	15 minutes
Klucel G	20 minutes
Modostuc	25 minutes
Paraloid B-72	22 minutes
Gesso	30 minutes
Polyvinyl Alcohol	35 minutes
Lascaux Gesso	37 minutes
Butvar B-98	45 minutes

The size was left to set for 24 hours before the overhanging gold was brushed away. Once sanded and gilded, the sample boards were rated by a group of 10 people both with and without conservation or art backgrounds. They were asked to choose their favourite sample (regardless of smoothness) then to rank the samples from best finish to worst based on smoothness and even appearance. The summary of the results of the rankings can be found below in *Table 6* and in more detail in Appendix 4.

Table 6: Ranking of Appearance for Oil Gilding	
Ranking	**Material**
1 (Best)	Modostuc
2	Flügger
3	Gesso
4	Lascaux Gesso
5	B-98
6	Ronseal
7	B-67
8	PVOH
9	B-72
10 (Worst)	Klucel G

The survey participants found that Modostuc, Flügger, and traditional gesso were the best materials for oil gilding. While both Flügger and gesso produced the same overall score (32), Flügger was ranked second four times and first twice, while gesso was ranked second twice and first only once, giving it priority as the better result (See *Graph 1* below).



Graph 1: Graph of survey results comparing number of votes to relative position (1st, 2nd, etc.).

Some of the results were obvious, such as Klucel G and B-72 consistently placing low in the visual assessment, while others, such as second, third, or fourth best

(Flügger, gesso, and Lascaux Gesso respectively), relied on averaged scores (See *Table 7* below).

Table 7: Summary of results for Oil Gilding With Rankings			
Material	**Total**	**Average**	**Ranking**
Gesso	32	3.2	3
Flügger	32	3.2	2
Lascaux Gesso	36	3.6	4
Ronseal	49	4.9	6
Modostuc	23	2.3	1
Paraloid B-72	88	8.8	9
Paraloid B-67	73	7.3	7
Polyvinyl Alcohol	74	7.4	8
Klucel G	97	9.7	10
Butvar B-98	46	4.6	5

Ronseal epoxy putty, Modostuc, Flügger, and Butvar B-98 all had fairly smooth surfaces, but were negatively impacted by the uneven drying of the oil size (*Figures 34-36*). Modostuc produced several areas of flawless surface, but the crinkling caused by the gold crumpling during application marred the surface. The two Paraloids and the Klucel G had too many bubbles in the surface, which

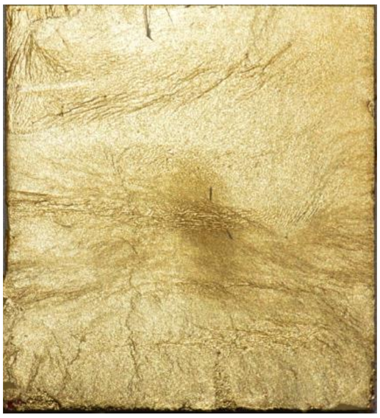


Figure 244: Ronseal oil sample

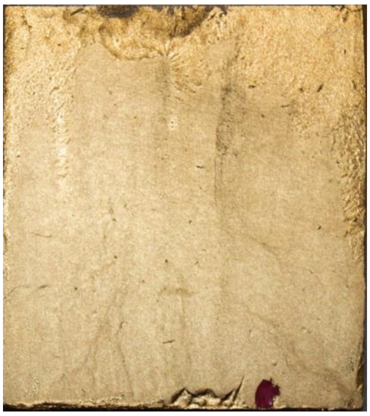


Figure 35: Modostuc oil sample

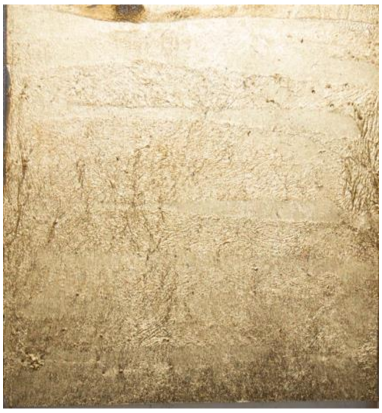


Figure 236: Flügger oil sample

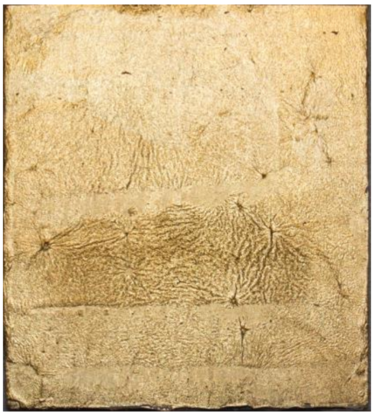


Figure 37: B-98 oil sample

showed through in the gilded layer.

Water Gilding

Figure 38: Area of lifting on Klucel G sample

During the application of the bole, different drying times were observed. Klucel G had the quickest drying time between bole layers, but ended up lifting and cracking along the PR edge (*Figure 38*). Lascaux Gesso, B-98, PVOH, gesso, and Modostuc all had quicker drying times as well. B-67, Flügger, B-72, and Ronseal all had very long drying times, normally drying at half the rate of the other boards (a third coat of the bole could be applied to the surface of the first six boards before a second coat could be applied to these four).

Once applied, the bole was allowed to dry for 24 hours before being polished then burnished with an agate burnisher. After, the gilders liquor was applied and gilding could commence. Two methods were employed: the use of loose sheets of 23.5 carat deep gold gold leaf and transfer sheets of the same material. The loose sheets were very difficult to work with, particularly because of the high rate of air circulation in the lab space. The gold frequently split, folded, or wrinkled during application, even when applying in smaller sheets (¼ sheet pieces). The transfer sheet, while it applied more easily, ended up removing tiny pinpoint speckles of gold when peeled back. Gold surfaces to be burnished are recommended to have two layers of gold to provide a good final product. 23¾ carat rosenoble double weight gold leaf was applied on top of the surface using the same gilder's 'water.' This result was much smoother than the previous attempts. The samples were left to dry overnight before attempting burnishing. The risk of damaging the gold surface is too high if the gold has not dried sufficiently, and while burnishing too dry may not produce the brightest shine, it will still be representative of the overall achievable end result. As mentioned previously, only one half of the sample surface was burnished to allow for the greatest range of surfaces.

Burnishing was easy for almost all of the materials. A good, even shine could be obtained on each material with few exceptions. Butvar B-98 cupped and cracked when pressure was applied, causing areas to flake off. The Lascaux gesso, while it could obtain a burnished surface, appears to be lightly scratched by the burnisher, possibly caused by the naturally soft quality of the fill. These scratches also appear on the samples for B-67, B-72, and Ronseal (*Figures 39-42*).

Figure 39: Lascaux Gesso burnished

Figure 40: B-67 burnished

Figure 41: B-72 burnished

Figure 42: Ronseal burnished

Once sanded, gilded, and burnished, the sample boards were rated by the same group as the oil gilding. The summary of the results of the rankings can be found below in *Table 8* and in more detail in Appendix 4.

Table 8: Ranking of Appearance for Water Gilding

Rankings	Material - Burnished	Material - Matte
1 (Best)	Gesso	Flügger
2	Modostuc	PVOH
3	Flügger	Modostuc
4	PVOH	Gesso
5	B-67	B-72
6	Ronseal	B-67
7	Lascaux Gesso	Lascaux Gesso
8	B-72	Ronseal
9	Klucel G	B-98
10 (worst)	B-98	Klucel G

For water gilding, the appearance of the surface of the materials varied depending on if they were burnished or not. The surfaces providing the best burnished appearance were gesso, Modostuc, and Flügger (*Figures 43-46* below for results). In the areas of the B-67 and PVOH where there were no bubbles, the burnish was also exceptional. There were issues with streaking and ‘smudging’ of the surface on the B-72 sample. The rest of the materials, while they could be burnished, had too many bubbles or surface irregularities to be considered successful. For the matte surface, all of the materials with the exception of Klucel G (*Figure 47*) provided smooth, even surfaces. It may be that because the matte surface does not reflect as brilliantly as the burnished that some of the errors were masked in the softer reflection. For matte water gilding, PVOH, Flügger, and Modostuc were the most successful surfaces.

Figure 43: Gesso water gilding sample

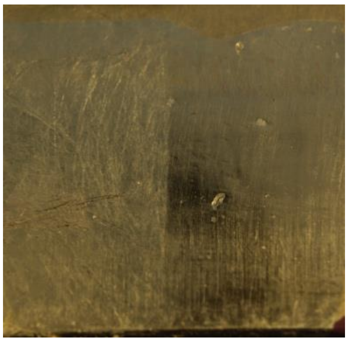


Figure 44: Modostuc water gilding sample

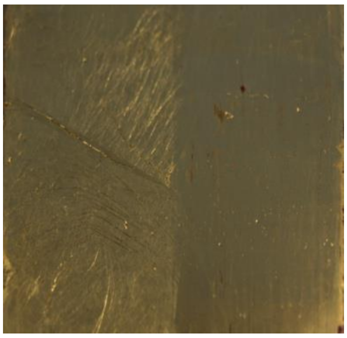


Figure 45: Flügger water gilding sample

Figure 46: PVOH water gilding sample

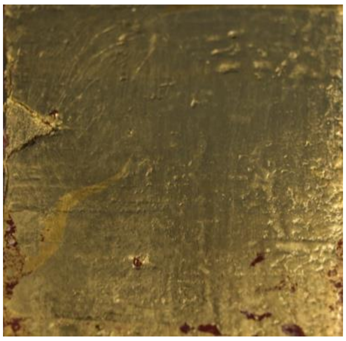


Figure 47: Klucel G water gilding sample

Level of Burnish

When comparing the materials based on highest burnish or most reflective surface, the materials ranked as follows: based purely on the quality of the reflection (how clear and dark the lettering is) B-72, Flügger, Ronseal, Lascaux Gesso, and PVOH all burnished best. Modostuc, gesso, and B-67's reflections were less clear and not as dark. B-98 cracked when burnished, and the reflection for Klucel G was overly distorted due to its uneven surface. However, when looking closer at scratches in the surface, Modostuc, gesso, Flügger, and Klucel G are all scratch free, while PVOH, Ronseal, B-67, Lascaux Gesso and B-72 are all scratched with areas of the bole showing through the gold. *Figures 48 & 49* compare these different surfaces.

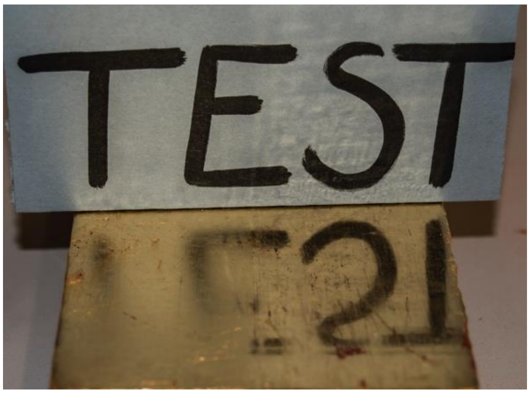


Figure 48: Lascaux Gesso burnish test. High level of burnish but scratched.

Figure 49: Lascaux Gesso burnish test. Softer burnish but better surface.

Table 9: Summary of Surface Finishing Results

Materials	Bubbles	Matte Water	Burnished Water	Scratches in Gilding	Oil Gilding
Gesso	Pinhole	4th	1st	No	2nd
Flügger	small - few	2nd	4th	No	3rd
Lascaux Gesso	None	7th	7th	Light and few	4th
Ronseal	Pinhole	8th	6th	Heavier and few	6th
Modostuc	small - few	3rd	2nd	No	1st
B-72	large - many	6th	8th	Heavier and few	9th
B-67	large - few	5th	5th	Heavy and many	7th
PVOH	Pinhole	1st	3rd	Light and few	8th
Klucel G	large - many	10th	9th	No	10th
B-98	small - many	9th	10th	No - cracking	5th

Casting

There was a continual issue with casting: almost all of the materials shattered because they were too brittle to be removed from the mould. Additionally, the casting quality was very poor, with air bubbles in many of the details and a rounded quality to the design,(see Klucel G). Other issues included shrinkage on drying, which created a shell (most notable in the Lascaux Gesso and Flügger).

Figure 50: Composition cast at 50x magnification

Composition

Composition is an excellent material and as Thornton (1991, 220) remarks, 'fresh composition is tough and flexible at room temperature and is much easier to fit to a loss than precast replacement elements in a rigid material.' The working properties of composition are remarkable and are expanded upon in Appendix 2. The cast moulding captured excellent detail and was flexible enough after approximately 10 minutes of cooling to be removed in a single strip.

Figure 51: Flügger cast at 50x magnification

Flügger

This was not very successful as a casting material. While there are some small areas where the detail is crisp and readable, there is a larger proportion where the details are damaged by bubbles, some of which go all the way through the cast. However, it was very strong and cast into longer sections: 51mm, 50mm, and one small section only 11mm long.

Figure 52: Lascaux Gesso cast at 50x magnification

Lascaux Gesso

There were advantages and disadvantages to the Lascaux Gesso. On the negative, the material did not cast well, with large bubbles destroying part of the surface decoration and shrinkage causing it to collapse in the middle on the back of the mould. However, on the areas that are not damaged by bubbles, the detail is very clear. Additionally, because it is a flexible material, the mould was able to be removed in one piece and can be bent and flexed to shape as needed. It may be possible to cast this in several thinned layers, potentially in a vacuum to remove the bubbles from the surface during casting to obtain a better result.

Figure 53: Ronseal cast at 50x magnification

Ronseal Epoxy Putty

Ronseal cast the best of all the synthetic materials. The detail is the crispest and does not have any bubbles. However, it is slightly brittle and broke into three lengths: 40mm, 30mm, and 26mm.

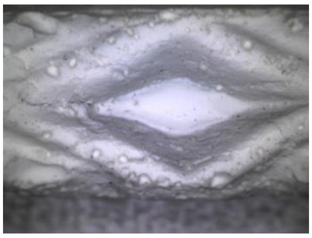


Figure 54: Modostuc cast at 50x magnification

Modostuc

Modostuc had mixed success as a casting material. While it could cast in larger strips (longest 35mm) there were issues with bubbles forming on the peaks of the diamonds and smaller bubbles on the rest of the surface. Additionally, the back of the mould is concave with a crack running through its centre. This may make it structurally weaker than other materials that did not suffer from shrinkage upon drying.

Figure 52: Lascaux Gesso cast at 50x magnification

Paraloid B-72

This material was relatively successful as a casting material. The detail captured is a little softened but there are several diamonds that are very crisp. There is a small issue with bubbling in some areas, but these may be removed if dried within a vacuum chamber. The main drawback is that the material was fairly brittle and cracked into 8 sections. The longest stretch is 24mm long, but that has a superficial crack 9mm in from one end. The next longest is 22mm followed by 15mm. The rest average approximately 10mm long.

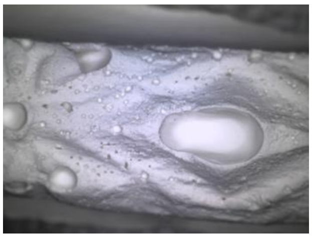


Figure 56: B-67 cast at 50x magnification

Paraloid B-67

Paraloid B-67 was not very satisfactory as a casting material. There are many bubbles in the surface which obscure detail. The bubbles may have been reduced if a vacuum was used during drying. It also cracked as it dried, so a single length was impossible to obtain. It broke into 7 sections, the 3 largest being 36mm, 24mm and 20mm. The rest average around 10mm in length.

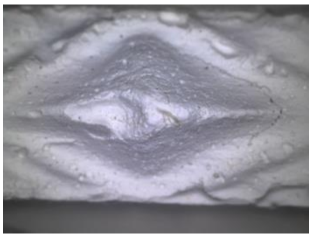


Figure 57: PVOH cast at 50x magnification

PVOH

This material cast was fairly successful for casting. It cast in some of the longer strips. There are three sections measuring 50mm, 40mm, and 25mm. The detail is fairly good, although there are many pinhole bubbles throughout the surface. This may potentially be eliminated if placed in a vacuum while setting.

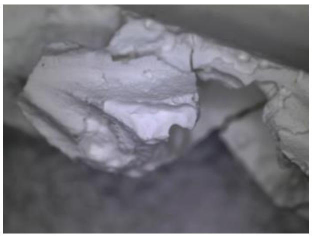


Figure 58: Klucel G cast at 50x magnification

Klucel G

Klucel G was completely unsuccessful as a casting material. The pattern is completely unrecognisable. The bubbles are so large and take up such a high proportion of the moulding that it is completely unreadable. The longest section is 27mm long, but that stretch is so riddled with holes and bubbles that it is completely unusable.

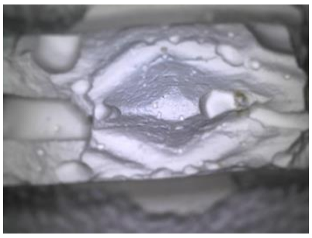


Figure 59: B-98 cast at 50x magnification

B98

B-98 was unsuccessful as a casting material. The moulding broke apart into approximately 15mm lengths and the detail is very poor. There are large areas of loss where bubbles were trapped in the mould, and several smaller ones that mar the surface. There is not a single run of the diamond and star that is not damaged in some way.

Table 10: Summary of Casting Results			
Materials	**Bubbles**	**Length of Cast**	**Level of Detail**
Composition	None	Full length	High
Flügger	Yes - some large	Long (~50mm)	High in some areas
Lascaux Gesso	Yes - some large	Full length	High in some areas
Ronseal	None	Moderate-long (~30-40mm)	High
Modostuc	Yes - large and small	Moderate-long (~30-40mm)	Moderate - bubbles
B-72	Yes - small	Moderate-short (~20-30mm)	High in some areas
B-67	Yes - large and small	Moderate-short (~20-30mm)	Moderate - bubbles
PVOH	Yes - small	Long (~50mm)	High in some areas
Klucel G	Yes - Large	Moderate-short (~20-30mm)	Very Poor
B-98	Yes - large and small	Short (~20mm or less)	Very Poor

Working Properties

Ease of Application

Flat blocks

The majority of the materials were mixed to a gesso-like consistency before being applied to the surface. The method of application for each material is listed above (*Materials* section). The following observations were made during the application process:

Gesso

Gesso is very difficult to work with. Because the adhesive component is rabbit skin glue, the mixture must be warmed first to make it workable. However, the gesso should not be applied hot, as that creates bubbles in the surface, but will gel if allowed to get too cool. Additionally, gesso is highly prone to pinhole bubbles as it dries. These are near impossible to remove from the gesso, and can be formed while mixing the gesso itself (Green1979). For the best results, the whiting must be sifted into the warm glue and allowed to absorb overnight before being gently stirred to incorporate the whiting into the glue. If stirred to vigorously, or if the wrong brush is used (preferably a firm bristled brush) the bubbles will appear as the gesso is applied (MacTaggart & MacTaggart 2011). These issues make it less than ideal to work with, especially for those with little experience making or applying gesso.

Flügger

Flügger is convenient because it can be applied straight from the tube without any manipulation. It dries quickly between coats (approximately 15-30 minutes, less if it is being skimmed on) and can build up a large amount of bulk in a short period of time. However, when applied in too thick of a coat, the surface will crack as it shrinks during drying. Additionally, there were bubbles in the surface, which were especially noticeable on sample 13 (*Figure 60*).

Figure 60: Bubbles in Flügger sample 13 after application.

Lascaux Gesso

The Lascaux gesso was one of the most pleasant materials to apply. It was a little thick straight from the tub, but can be diluted with water to a more paintable consistency (for this dissertation, no alterations to the material were made). It brushed out nicely, and builds bulk slowly, although there are prominent ridges where the brushstrokes overlap so care must be taken to avoid these during application. It dries fairly quickly, similar to gesso, but did not form any bubbles during application. Before sanding it had a very ‘plastic’ appearance.

Figure 61: Ronseal samples before sanding showing texture of the material.

Ronseal Epoxy Putty

The greatest drawback to this material is that it exudes an extremely potent smell while being mixed and curing. A fume hood and good ventilation is an absolute must. The proportions for mixing are not very precise, which leads to an inconsistency in setting times and hardness depending on the ratio. The mixture was very sticky, but could be smoothed over with pressure and a spatula. However, it was very difficult to create a single smooth layer and the surface ended up with steps and divots (*Figure 61*). However, the epoxy sets within a half hour and can be worked right away.

Modostuc

Modostuc was fairly easy to apply straight from the tube. A pile could be laid into the centre of the board then spread out to the edges with a spatula. It is a thinner material, and was very easy to accidentally press too hard or smooth too close to the surface of the substrate. One major advantage is that it dried without cracking and dried quickly so more layers could be applied.

Paraloid B-72

The 60% w/v B-72 was incredibly difficult to apply. Because the evaporation rate for acetone is so high, a film would form over the top layer that would wrinkle and bunch if touched. This made smoothing the surface out very difficult. Additionally, there were enormous bubbles that formed but were trapped beneath the surface of the skin.

The application for the 20% w/v B-72 was easier, although it also had issues with creating a skin due to evaporation. It was also very bumpy and uneven when applied, and cracked extensively when drying.

Paraloid B-67

The B-67 went on really smoothly and nicely. It mixed to a good consistency without much effort and could be applied in even layers by brush. Unfortunately, it did form many tiny bubbles in the surface during application which were not apparent until after sanding.

PVOH

Like gesso, the PVOH had serious issues with application. When mixing in the whiting, bubbles would form and could not be removed, even after being placed in a vacuum chamber under 700 mbar of pressure. There were a large number of tiny pinhole bubbles that would not come out of the surface. Even when a few drops of IMS were added to the mixture to cut surface tension (Schnellmann 2007, 60; Huber 2015) and the next layer rubbed into the surface hard with gloved fingers, there were still tiny bubbles (*Figure 62)*. Despite that, the PVOH applies in nice even layers, and self levels as it dries.

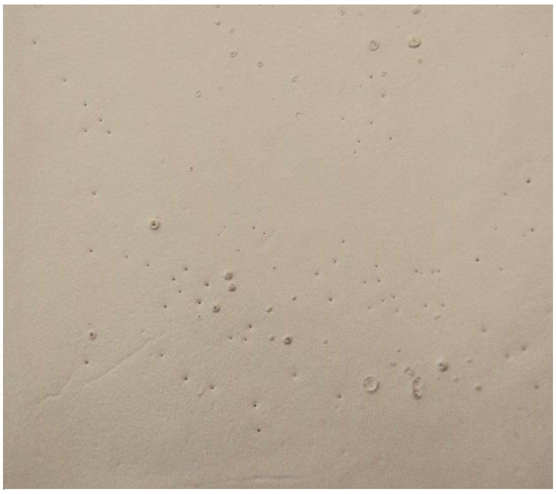


Figure 62: Bubbles in PVOH from application

Klucel G

The 5% solution was difficult to get into a homogenous solution in the first place. It made a very thick gel that formed a very gummy mixture when combined with the whiting. While it initially levels out nicely as it dries, after drying for approximately 30 minutes deep cracks form over the surface (shown in *Surface Finishing*). The first attempt was removed and remixed, taking extra care to thoroughly incorporate the whiting into the Klucel G. However, the exact same results occurred. A 2% solution was then mixed, which was easier to work with. However, there were still issues with it cracking but not as severe.

Butvar B-98

B-98 was surprisingly pleasant to work with, especially when compared to the other lab-mixed materials. It very easily mixed to a gesso-like consistency and could be brushed on smoothly in layers. There were some issues with bubbles during the last few coats, but in general it was a very nice material to work with and apply.

Loss Compensation

Composition

Realistically, composition would never be applied in this specific fashion. It would be cast first and then trimmed to size to fit into the area exactly. However, there is a very good reason that composition is not applied as shown. It tends to collapse in the middle especially as it has to be heated considerably to be able to be pressed into the loss. It is very sticky in this state, is not easy to work with, and does not actually fully fill the loss (noticed in the bottom corners of the back of the fill).

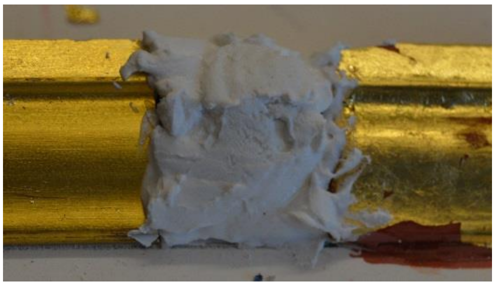


Figure 63: Flügger fill on board

Flügger

Looking at the edges of the fill, the Flügger shrank upon drying and partially detached from the edges (*Figure 63*). There are gaps between it and the walls and the back, which should be flat and straight, is concave inward. It was fairly easy to apply with a small spatula and kept within the confines of the gap.

Figure 64: Lascaux Gesso fill on board

Lascaux Gesso

This material shrank and cracked upon drying, especially on the edge joining the water gilt side (*Figure 64*). There are additional cracks down the back of the fill and on the top edge. It has also slumped and is slightly lower than the actual edge of the mouldings. This was fairly easy to apply, although its softness and stickiness was difficult to work around.

Ronseal Epoxy Putty

This material did not shrink, but is very messy to apply. It is very sticky and spread out onto the moulding, which is damaging to the gilded surface. This could potentially be avoided with a barrier coat of B-72 (Ellis & Heginbotham 2002). Also, because the mixing ration is not weight specific, it is difficult to mix a smaller quantity of filler. Working with a quantity large than needed for the fill was cumbersome and lead to the spreading on the gilded surface and subsequent damage.

Modostuc

The Modostuc doesn't appear to have shrunk but has slumped slightly. This is most noticeable on the back of the fill where it bulges out, and on the front bottom of the fill, which also looks slightly bulged (*Figure 65*). There are no cracks to the surface and it was fairly easy to apply with a small spatula, keeping within the designated space.

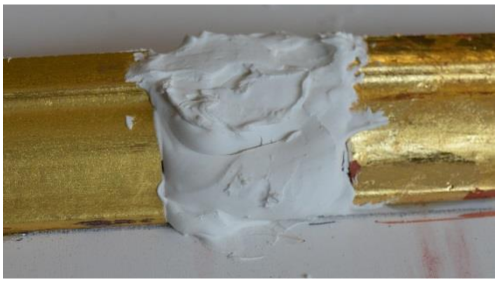


Figure 65: Modostuc fill on board

Paraloid B-72

The whole surface of the fill crazed and cracked (*Figure 66*). It spilled over onto the surface of the gilding, but additionally does not appear to have bonded well with the wooden surface due to the skin that was formed while drying. Because of the quick evaporation of the acetone, placing the fill had to be undertaken very quickly to ensure that it would stick to the surface as required.

Figure 66: Crazing on the B-72 fill

Paraloid B-67

The fill is surprisingly smooth with few cracks around the edges of the fill from drying (*Figure 67*). It was easy to mould and press into place. Similar to composition, it did have a tendency to spread onto the gilded surface, but it held its form without slumping or collapsing.

Figure 67: B-67 fill on board

PVOH

As mentioned previously, the PVOH needed to be supported on the front and back using tongue depressors to prevent spreading forward. However, it could be easily applied, either by a spatula or 'piped' through a plastic baggie or syringe. The surface is smooth, and while the PVOH did spread onto the surface, it was not as drastic as a film had formed and held the centre in place.

Klucel G

Klucel G was a complete failure as a fill material. It cracked down one side, slumped, and was difficult to apply. It needed to be partially poured, partially pressed with a spatula and was very difficult to work with as it was very sticky and pulled on the spatula.

Butvar B-98

The fill did not have a very pleasing surface at all (*Figure 68*). There are several areas where it has slightly cracked and chipped up on the surface. It appears to have slightly slumped, but not below the surface of the mouldings. It has also spread onto the gilded surfaces. It was fairly easy to work with, it could be placed using a spatula and then formed with gloved fingers.

Figure 68: B-98 fill on board

Sanding

The materials varied in difficulty for sanding. Some were too hard to sand easily, requiring an hour or more to work the surface flat. Others sanded very quickly and evenly. The application properties of each of the materials heavily affected the overall time for sanding. For instance, a material that applied in an even, self-levelling coat was easier to sand flat than one that applied in an uneven and bumpy surface.

The easiest materials to obtain a flat, even surface were gesso, Modostuc, Ronseal, B-98, Flügger, and PVOH. These all sanded within 20-30 minutes. The rest of the materials were very difficult to sand, taking from 45 minutes to 2 hours. Klucel G never actually sanded to a flat surface due to all of the bubbles trapped within the matrix of the material. B-67 took multiple hours of sanding to obtain a smooth surface because of the hardness of the material, which was also an issue with B-72. Lascaux Gesso, due to its flexibility, was difficult to sand as the dust tended to bead and pearl under the sanding block. However, it did create a smooth surface once it was sanded.

Carving and Shaping

Once all of the materials were set, they were reworked using a sharp No 10A and No 15 blade scalpel. A new blade was used for each material and observations about the process were recorded as well as photographs. The fills were only roughly finished as it was deemed more important to see how bulked material can be removed because sanding and finishing was covered on the flat sample boards.

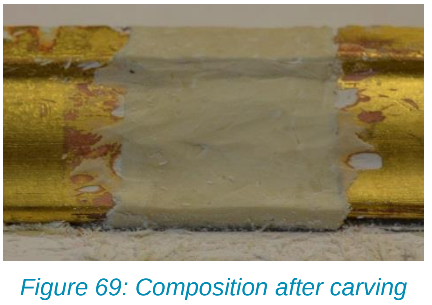


Figure 69: Composition after carving

Composition

Composition was one of the most difficult materials to carve (*Figure 69*). It was very hard and required the blade to be replaced halfway through shaping. Where the composition had spread over onto the gilded surface, it stuck to and lifted the gold surface while attempting to carve away. As mentioned before, composition would never be used in this way, and most likely would never be left to sit for six weeks before carving as was the case in this dissertation. The hardness of the material most likely was affected by the extended drying time. If it had been carved sooner, the process may have been easier. **Time: 3 hours**

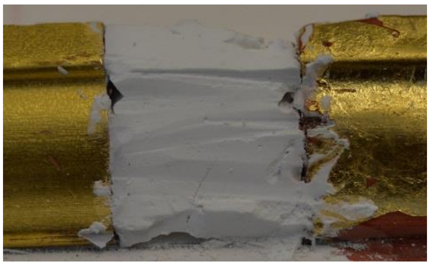


Figure 70: Flügger after carving

Flügger

Flügger was more difficult to carve, but presented a smooth surface after carving (*Figure 70*). However, because it had shrunk during drying, there are gaps on the sides of the fill and it does not quite sit well within the loss. There were no obvious bubbles beneath the surface, but skimming fresh material over the top can easily fill any gaps or low areas. **Time: 5-10 minutes**

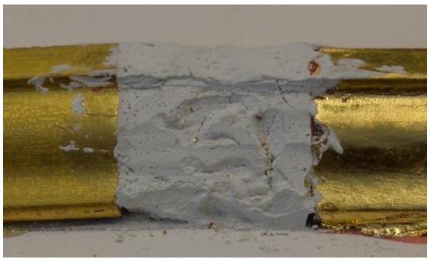


Figure 71: Lascaux Gesso fill after carving

Lascaux Gesso

Because the Lascaux Gesso retains its flexibility after drying, it had a very rubbery consistency and lots of resistance when trying to carve it to shape (*Figure 71*). The removed pieces peeled off in thick shavings. Carving revealed tiny bubbles beneath the surface. The Lascaux Gesso partially bonded with the gold surfaces it touched, and when it is peeled away from the gilded surface a layer of gold comes with it. Extra care must be taken when applying this material to a fill to prevent contact with the gilded surface. **Time: 10-15 minutes**

Figure 72: Ronseal fill after carving

Ronseal Epoxy Putty

The Ronseal epoxy putty carves fairly easily, which is one of its greatest strengths (*Figure 72*). When the epoxy is carved, it reveals a nice smooth surface below which is partially burnished by the passing blade. Surprisingly, there is still a strong styrene smell to the fill, even though it has been weeks since application and setting. There were some gaps and holes below the surface, most likely caused by inability to fully press down on the fill to squeeze out any air and create good contact with the loss surface. **Time: 15-20 minutes**

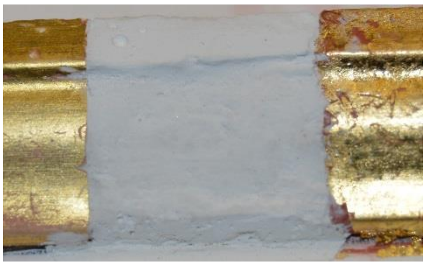


Figure 73: Modostuc fill after carving

Modostuc

Modostuc carves really easily, providing a good resistance but not so much that heavy force is required. The fill is one of the softest tested. Divots where the original fill slumped can be skimmed with more material (*Figure 73*). Because it is a premixed solution, a consistent mixture is guaranteed. The Modostuc does tend to break off in chunks if large amounts of material are being removed: this causes ‘blowout,’ or large divots, in some areas, requiring further filling. There are some small cracks and bubbles that were trapped beneath the surface and revealed during carving. **Time: 5-10 minutes**

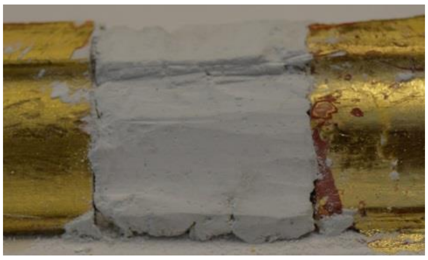


Figure 74: Paraloid B-72 fill after carving

Paraloid B-72

This was one of the hardest materials to carve, similar to composition (*Figure 74*). The B-72 carves off in tiny shavings and is very difficult to work down to the correct level and shape. The fill is made of the 20% w/v B-72 which should have been easier to carve and work than the original 60% w/v solution. Even with the decreased concentration, it took over an hour to rework the fill to a close approximation of the moulding. **Time: 1 hour-1 hour 20 min**

Figure 75: B-67 fill after carving

Paraloid B-67

The B-67 is brittle, but carves fairly easily. It is one of the softer materials carved (*Figure 75*). Strangely, the fill breaks off into chunks above the blade but leaves a smooth surface underneath. The fill is very powdery and can be scraped into shape. The B-67 fill is capable of holding an edge, but that edge is very brittle and prone to snapping. **Time: 15-20 minutes**

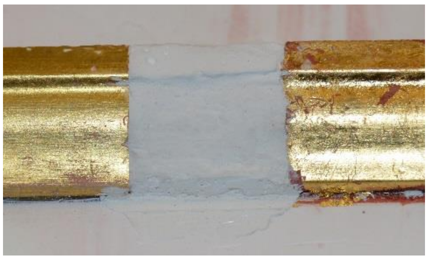


Figure 76: PVOH fill after carving

PVOH

The PVOH had good resistance when carving, slightly on the harder end of the spectra, and shaved off in small curls. Carving revealed bubbles trapped below the surface, which do not fully disappear when rubbed with a damp silicon brush (*Figure 76*). When carved, it holds a good, sharp corner which is strong and less prone to breakage. **Time: 30-35 minutes**

Figure 77: Klucel G fill after carving

Klucel G

This material was very soft and crumbly (*Figure 77*). If it was pried up, it broke into little pieces. There was a large hole discovered when smoothing out the back edge. There were more cracks found on the front face when carving away as well. **Time: 5-10 minutes**

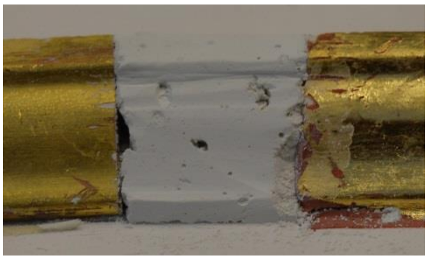


Figure 78: B-98 fill after carving

Butvar B-98

This fill was very soft and broke apart in clumps. Because of this, it tended to take out chunks from the fill, bringing the surface below that of the moulding (*Figure 78*). The fill also felt very loose, not well adhered to the sides of the mouldings and wiggled slightly with pressure. There are also bubbles trapped beneath the surface of the fill, which are exposed during shaping. **Time: 10-15 minutes**

Table 11: Summary of Working Properties						
Material	**Flat Blocks**	**Fills**	**Sanding**	**Carving**	**Slump**	**Shrinkage**
Gesso/ Composition	Difficult	Difficult	Easy	Difficult	Some	None
Flügger	Easy	Easy	Easy	Easy-Moderate	No	Yes
Lascaux Gesso	Easy	Easy-Moderate	Difficult	Moderate	Some	Yes
Ronseal	Moderate	Moderate	Easy	Easy	No	None
Modostuc	Easy	Easy	Easy	Easy	Some	None
B-72	Difficult	Moderate	Difficult	Difficult	No	Surface cracks
B-67	Easy	Easy	Difficult	Easy	Some	None
PVOH	Moderate	Moderate	Easy	Moderate	Buffered-would have without	None
Klucel G	Difficult	Difficult	Moderate	Easy	Yes	Yes
B-98	Easy	Easy	Moderate (brittle)	Moderate - chunks	Some	Surface cracks

Reversibility

The materials were assessed both on ease of removal (based on time) and the damage caused by solvents to the oil and water gilt surfaces. A summary of the findings can be found in *Table 12* at the end of the section. An isolating barrier of 20% w/v Paraloid B-72 was applied to the edges and interior surfaces of the fill for Ronseal per Ellis & Heginbotham 2002. While barrier layers were not used for any of the other materials, it seemed particularly important to use one for the epoxy as it would generally not be used without some isolating layer in a conservation application.

Composition

Solvents were generally ineffective when softening the composition. Previous research into the removal of linseed oil based coatings recommend either organic solvents like xylene (Phenix 2002) or swelling with hot water (Kerschner &Ravenel 2006). A cotton wool poultice of xylene was applied and checked every 5 minutes for 30 minutes but the fill was not softened at all. Instead, controlled exposure to steam for approximately 30 seconds was used which succeeded in loosening the fill. However, the steam was very damaging to the gesso below the water gilding.

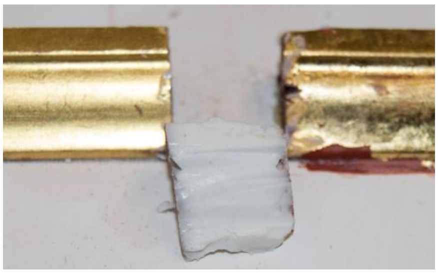


Figure 79: Flügger after removal. No damage is shown on mouldings

Flügger

After 5 minutes with a White Spirit Poultice, the fill came out cleanly in one piece (*Figure 79*). There was no damage to the surface for water or oil gilding.


Figure 80: Lascaux Gesso fill after removal.

Lascaux Gesso

After 5 minutes, the fill was still not soft enough to remove. Pressure with the spatula at the join of the fill and moulding produced no results. An additional 5 minutes under the poultice did finally soften it enough to remove, but it broke into several pieces (*Figure 80*). The surface texture was also very gummy.


Figure 81: Damage to gilding caused by the acetone poultice.

Ronseal Epoxy Putty

The Ronseal was more difficult to remove than anticipated. The barrier layer of B-72 did not appear to be softening. After 20 minutes of poulticing, the barrier softened enough to remove the fill. Removal required heavy pressure on the edges to try to break them free of the mouldings, and it appears that the acetone has damaged both the oil and the water gilded surfaces (*Figure 81*). Interestingly, the Ronseal itself became slightly softened and gummy under the acetone poultice.


Figure 82: Modostuc fill after removal

Modostuc

The Modostuc was barely softened at all after 5 minutes of poulticing. An additional 5 minutes softened it enough to be removed. The fill broke apart into large chunks (*Figure 82*). There does not appear to be any damage to the surface for either moulding.

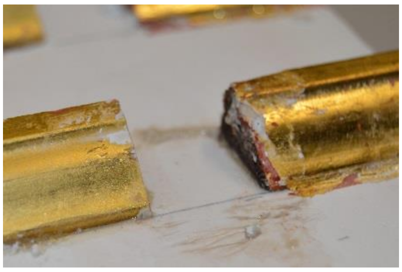


Figure 83: B-72 fill after removal.

Paraloid B-72

Xylene was used instead of acetone because of the surface damage caused when removing the Ronseal fill. COSHH recommends that xylene be used with good ventilation either within a fume hood or with a good extractor unit. This can potentially be a limitation should this material be used in the future. Removal was easy. After 5 minutes of a cotton wool poultice, the sides could be sliced from the moulding and the fill came out in one piece. There does not appear to be any damage to the gilding, although there is a ghost line from where the B-72 spread on top of the gold (*Figure 83*).

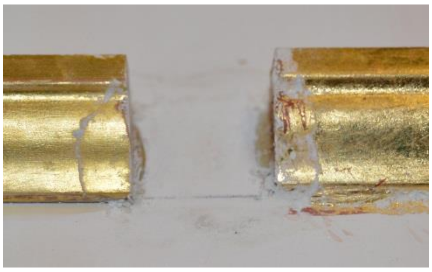


Figure 84: B-67 ghosting on surface of mouldings.

Paraloid B-67

The fill broke apart after 5 minutes of an IMS cotton wool poultice. It was very soft and very easy to remove. There is a slight ghost line left on the oil gilt moulding from where the fill overlap the gilding (*Figure 84*).

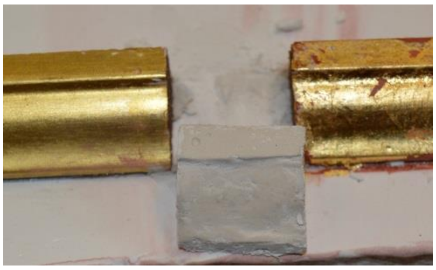


Figure 85: PVOH fill after removal.

PVOH

The PVOH fill popped off in one piece after a 5 minute cotton wool poultice of IMS. The top surface of the fill had softened slightly and could be scraped with the spatula, but still held its shape during removal (*Figure 85*). However, the fill required a prying force to remove it and felt like it was pulling at the mouldings quite strongly. Softening for an additional 5 minutes may make removal easier and safer for more delicate pieces.

Figure 86: Klucel G fill after removal.

Klucel G

The fill crumbled after 5 minutes of the IMS cotton wool poultice (*Figure 86*). It was very soft and came away from the sides without any problems.

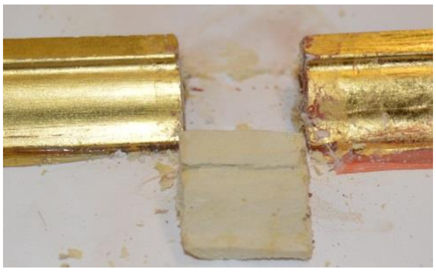


Figure 87: B-98 fill after removal.

Butvar B-98

After 5 minutes, the fill had softened enough to be able to cut it away from the sides of the moulding (*Figure 87*). After freeing the sides, the fill slid out in a complete piece. There is no damage to the water or oil gilded surfaces.

Table 12: Results of reversibility tests on materials

Material	Solvent	Time	Surface damage
Composition	Xylene Steam	30 minutes 30 seconds	The Xylene was ineffective at softening the fill but did not damage the gilding. The Steam was not damaging to the oil, but very damaging to the water and gesso.
Flügger	White Spirits	5 minutes	None to either water or oil
Lascaux Gesso	IMS	10 minutes	None to either water or oil
Ronseal	Acetone	20 minutes	Damage to both water and oil. The shine was matted on both surfaces, and gentle wiping with a solvent wetted cotton swab removed gold.
Modostuc	IMS	10 minutes	None to either water or oil.
Paraloid B-72	Xylene	5 minutes	None to either water or oil
Paraloid B-67	IMS	5 minutes	None to either water or oil. Did leave ghost pattern on Oil from overlap.
PVOH	IMS	5 minutes	None to either water or oil
Klucel G	IMS	5 minutes	None to either water or oil
Butvar B-98	IMS	5 minutes	None to either water or oil

Discussion

To review, this study aimed to answer the following questions:

- Is it possible to obtain the same level of finish using synthetic materials as traditional gilding materials?
- If so, are those materials that performed well easy to work with and apply?
- Are these materials reversible in a way that is not damaging to the original gilded surface?

Each material has been assessed based on the criteria above and ranked based on their performance in *Table 13* below. The materials are more fully described based on their overall score below, with priority given to appearance followed by working properties.

Table 13: Summary of All Rankings in Tests for All Materials									
Material	Matte Water	Burnished Water	Oil	Application	Sanding	Bubbles	Casting	Carving	Reversibility
Gesso	4	1	3	10	2	3	1	10	10
Flügger	1	3	2	2	3	6	5	5	1
Lascaux Gesso	7	7	4	1	8	1	8	7	8
Ronseal	8	6	6	7	4	2	2	3	9
Modostuc	3	2	1	3	1	5	6	1	7
B-72	5	8	9	8	9	9	4	9	3
B-67	6	5	7	5	10	8	7	4	6
PVOH	2	4	8	6	5	4	3	6	5
Klucel G	10	9	10	9	7	10	10	2	4
B-98	9	10	5	4	6	7	9	8	2

Ranked Materials

1- Flügger

Flügger performed consistently well on all of the tests except for casting. It scored within the top three for both water and oil gilding and ranked second overall best surface when scores were averaged. It was easy to apply and reversible in materials that are non-destructive to the gilded surfaces. There were some issues with shrinkage, cracking, and bubbles in the fills, but modification by dilution or thinner application may eradicate these issues. It is not recommended as a casting material due to its brittleness, shrinkage, and quantity of bubbles in the cast.

2- Modostuc

Modostuc also performed consistently well. It ranked in the top three for water and oil gilding, and was the overall best surface when all the surface scores were averaged. While Modostuc was fairly easy to carve, there was evidence of slumping and the tendency to break apart. Additionally, it required ten minutes of poulticing to soften enough for removal. It may benefit from having multiple layers applied over time to prevent uneven application and bubbles. It was very unsuccessful as a casting material with numerous bubbles and fractures in the cast.

3- Polyvinyl Alcohol

PVOH ranked well during the surface tests, averaging fourth overall surface. However, its working properties were better than those of traditional gesso, placing it just above for the overall assessment. While there were issues with pinhole bubbles in the surface, alterations to the application should eliminate this issue for future use. Similar issues with casting may be eradicated by altering the consistency of the putty.

4- Gesso and Composition

As the ‘control’ sample for comparison for all other samples, traditional gesso performed well. Its strengths were that it burnished well, sanded easily, and created a smooth surface for both water and oil gilding. It ranked consistently within the top four for both kinds of gilding and ranked third overall when all the surface results were averaged. However, there were issues with application, creating numerous bubbles in the surface that were difficult to remove. The process was also time and labour intensive.

5- Lascaux Gesso

Lascaux gesso was moderately successful as a fill for gilding. While there were no bubbles in the material, it only ranked fourth for oil gilding and seventh for water gilding, averaging fifth overall. Burnishing tended to abrade the surface, most likely because of the soft and flexible nature of Lascaux. This quality also attributed to difficulty during sanding as well as carving. The only benefit that the cast maintained was that it was flexible enough to be removed in one piece. However, the cast was riddled with bubbles and had formed a shell during drying, cracking down the back. Despite averaging well, this material would only be recommended for oil-gilded materials.

6- Ronseal Epoxy Putty

This material was excellent for casting and performed the best out of the synthetic materials. However, it consistently fell into the lower half of the rankings for surface finishes. While it was difficult to apply, its other working properties were highly advantageous, being easy to carve and to sand. The use of a fume hood or good ventilation is an absolute must with this material, making it less convenient for general use. It most likely should only be used for cast elements and would be a good candidate for further mechanical tests to assess its compression in comparison to that of wood.

7- Paraloid B-67

B-67 performed poorly in comparison to previous assumptions. It was easy to mix and apply, and appeared to go on very evenly. However, large bubbles formed in the surface and it was a difficult material to sand flat. Lastly, it only averaged in the middle of the sample range. This material has potential to be successful, but modification to the application and consistency is necessary before it can be recommended for use.

8- Paraloid B-72

The main issue with this material was its choice of solvent. The quick evaporation rate of acetone led to an uneven bubbled surface. However, the use of stronger solvents as a replacement has health concerns similar to those of Ronseal. Despite performing moderately poorly in this research, B-72 gesso has been applied successfully to gilding conservation previously using toluene as a solvent (Wilson 1998). This material using a different solvent should be reconsidered for future applications.

9- Butvar B-98

While B-98 was easy to mix and apply, it is inherently brittle and had poor adhesion to the substrate. It is not recommended for any burnishing applications, but may be suitable for flat oil gilding where increased pressure is not required. It is not recommended for casting or carved elements, particularly as reworking the surface caused cleavage and fracture.

10- Klucel G

Klucel G was unsuccessful in almost every aspect of this study. It was a difficult solution to mix and apply, severe cracking of the surface and bubbles created a bad surface for gilding, and it shrinks and slumps when applied thickly. It is not recommended for any application.

Observations

Surface Finishes

Materials appeared to have varied success when comparing the matte samples for both water and oil gilding. For example, PVOH ranked third for matte water gilding but eighth for oil gilding. A similar trend is found in the B-98 samples, ranking fifth in oil gilding but ninth in matte water gilding. It is possible that these two materials were negatively affected by the rapid absorption of the oil size (see *Oil Gilding* in *Results*). However, Modostuc also absorbed the size quickly, but ranked the best sample for oil gilding, implying that the sample application may have varied between boards and affected the outcomes. Additionally, it implies that there is greater inconsistency in results within the lab-mixed materials versus premixed.

There was also inconsistency within individual boards. This was noted when comparing burnished to matte surfaces on the water gilded samples. Gesso, Flügger, Ronseal, B-72, and PVOH rated more than one deviation away between their matte and burnished rankings (see *Table 14).* Application of the materials over a large surface area potentially created dissimilar surfaces that affected the overall appearance. These dissimilarities were amplified once burnished.

Table 14: Materials with Varying Ranks between Burnished and Matte Water Gilding

Materials	**Burnished**	**Matte**
Gesso	1	4
Flügger	3	1
Ronseal	6	8
B-72	8	5
PVOH	4	2

What was particularly interesting was that materials that appear smoother on a microscopic level are not necessarily the best performers. Lascaux gesso appeared very smooth both when examining the surface of both samples and their silicone casts. However, it performed consistently worse than gesso, ranking 7th twice (both water gilding) and 4th for oil. This is also true of the Ronseal, which ranked 6th for both oil and burnished water gilding, and 8th for matte water gilding. Ronseal had pinhole bubbles in its surface similar to those of gesso and PVOH, yet consistently scored worse than both. This implies that the consistency and hardness of the material has a greater impact on the overall finish appearance for gilding than microscopic smoothness of the surface. The Lascaux gesso retains its flexibility even weeks after drying (as evidenced by the cast sample), which translates to a streaky finish on the burnished sample. Conversely, too hard of a surface can have the same effect (as seen on the Ronseal sample).

Additionally, photomicrography at such high magnification made the gilded surfaces more unreadable than standard photography. The unevenness of the surface read more clearly and comprehensively when observed as a complete surface rather than as a 250x magnified image. Reflection off of the surface further disrupted the interpretation of the images, making analysis at this level very difficult (see *Figures 87-89*).

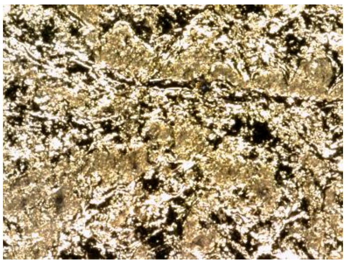


Figure 88: Gesso oil sample at 250x magnification

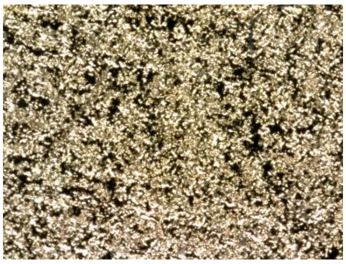


Figure 89: Modostuc oil sample at 250x magnification

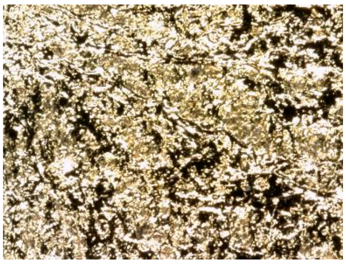


Figure 90: B-98 oil sample at 250x magnification

Casting on the whole was unsuccessful for all of the materials with the exception of Ronseal and composition. This means that despite obtaining a satisfactory surface, Modostuc, Flügger, and PVOH were unsuitable for cast applications. However, they were unsuccessful in this specific concentration and consistency, and may improve with modification. Different consistencies, such as a thicker putty for PVOH or thinning the Flügger, may aid improvements in surface detail and prevent the collapse and cracking due to shrinkage.

The Right Material for the Right Application

Some materials tested may be better for different applications than others. While Ronseal was not very successful for a flat surface, it was highly successful for cast details. It may be best used as a substrate for casting lost appliqué elements. Conversely, materials that were fairly poor when casting, such as Flügger, were very successful as fills for flat surfaces. A combination of different fill materials may produce the best results depending on the piece and treatment. These fill material tests all focus on the use of fills in a superficial or aesthetic context rather than for structural support. Research on the mechanical properties of the materials to determine their suitability for structural fill purposes should be undertaken.

Premixed Versus Lab-mixed

The premixed materials had an advantage over the lab-mixed materials in that they were consistent every time during application. They were easy to apply either by spatula or with a brush and dried fairly quickly between layers, allowing bulk to be added rapidly. While their premixed composition may make them less manipulable, they have a base consistency and bulk specific to their manufacture.

The lab-mixed materials have more freedom to alter consistency, but this freedom can lead to arbitrary decisions. Solutions can be made more or less viscous by either altering the quantity of filler, or by creating a higher or lower concentration solution. Each modification alters the physical properties of the end product (a higher concentration solution is harder than a lower concentration, as seen with the two concentrations of B-72) and can lead to results that are difficult to repeat. While giving a general idea of the consistency, descriptors such as 'heavy cream' or 'size of a golfball' are not as accurate or repeatable as weight measurements.

Both the premixed and lab-mixed materials have an advantage over traditional gesso: they do not require heating before application. Practically speaking, that makes *in situ* work much easier. Materials can be applied without needing additional equipment. Of these, the premixed fills are the easier to work with, requiring just the opening of a jar or tube. While store-bought materials may be easier to apply and quick to obtain, the composition of the material can change without any notice. Additionally, it is very difficult to know exactly what each material is made of as the compositions are kept as trade secrets.

Survey Results

While the survey was used as a tool to neutralise author bias, there was an interesting range in opinion. There were a few general consensus opinions, such as Klucel G being the worst sample for (9 of 10 responses for oil gilding, 9 of 10 for matte water and 8 of 10 for burnished). However, while it was easy to identify unsuccessful materials, it was more difficult to determine the general order for the rest. The range of responses implies that multiple materials may provide a satisfactory surface depending on the desired outcome. However, it may more accurately reflect that there is no genuine consensus between survey participants as each person sees and interprets the data set in their own way.

Traditional versus Synthetics

It has been shown in the results that there are synthetic materials that can perform as well as traditional gesso. However, it does not mean that traditional materials should never be used. The advances made by Cox 2013 and Salimnejad (2002 & 2005) resolve some of the issues with documenting areas of loss and replacement on gilded objects. On particularly water-sensitive materials such as water gilding, it may be best to use synthetic materials that have solubilities that will not affect the gilt surface. It is important to have options when making conservation decisions, providing a variety of materials with different solubilities allows conservators to select the best material for each specific treatment. Additionally, as mentioned in the *Preface,* gilding requires skill and practice. Synthetic materials, particularly the premixed materials, may provide better results for conservators who are unfamiliar with traditional gesso or gilding. If a conservator is familiar with Paraloid B-72 or PVOH and has never used traditional gesso before, they will most likely be able to obtain a more satisfactory surface using synthetic materials.

Conclusions and Future Research

Potential Issues

There are a few areas which may have negatively impacted the results and potentially skewed the findings listed above. These fall within three categories: application, sample board size, and the survey results.

Application Issues

The application issues refer to both the application of the materials to the substrate as well as the application of the gold leaf. Improper tools, such as brushes that were too soft or the lack of a good spatula for pressing down on the pre-mixed materials, may have led to the formation of the bubbles within the surfaces. These issues can be attributed to limited experience, and would be rectified if the experiment were to be undertaken again.

Sample Boards

The sample boards were too large and the thickness of each fill too difficult to establish consistently. A smaller board size would have also cut down on the finishing time as the surface area would be reduced. Additionally, most fills to be performed on gilded objects will not be of such a large surface area.

For a more accurate reflection of the degradation and reversibility of the materials, the samples should be artificially aged. While the reversibility tests offers a rough approximation of how the materials will react, i.e. materials that are already difficult to remove will not become easier to remove with time, ageing the samples may provide more insight into the degradation of these materials.

Survey Results

The survey group itself provided a relatively small quantity of answers, therefore the responses given can only represent a small sample of the community as a whole. Additionally, while the majority of the participants had either arts or conservation training, very few had any experience with gilding prior to this study. Combining inexperience with the application issues outlined above, many of the participants found the survey difficult and assessed the samples based on their own criteria and definition of ‘smooth and even.’ This ranged from one participant judging each sample by touch versus visual appearance to one that arranged them based on whichever they ‘liked’ the most. If the experiment were to be repeated, perfect controls for oil, matte and burnished water gilding should be given for comparison. Additionally, instead of ranking them from best to worst, a point system such as 10 for perfect surface to 1 for uneven surface might allow for a more accurate assessment and more clearly reflect how the materials behaved. For example, where Flügger, Modostuc, and Gesso were frequently ranked within the top 3, they may have all scored the same if ranked individually instead of as a group. Additionally, two materials may have been ranked consecutively (fourth and fifth) but may have scored drastically differently (7 versus 3 on surface). The gap in score is more telling than arbitrary rankings.

Conclusions

Modostuc, PVOH, and Flügger are all good alternatives to traditional gesso for filling losses in gilded materials. Additionally, Paraloid B-72 and Paraloid B-67 have potential to be successful with modification, either through application or solvents. This range of materials provide a variety of options, from quick, premixed solutions to more variable lab-mixed fills. However, as the field advances with new materials, new materials should be investigated to see if they can be applied to gilding conservation. There may be materials yet to be developed that are more stable, easier to work with, and dissolve in solvents that are non-harmful to both gilded surfaces and conservators. Ideally, a material that can be applied without any bubbles in the surface that also casts well would be particularly beneficial for gilding applications.

Synthetic materials have made immense progress in gilding conservation. However, as mentioned in both the AIC and ICON code of ethics (AIC 2015, ICON 2015a, 2015b), the ultimate decision to use a synthetic versus a more traditional material is left to the conservator. Synthetics are not meant to completely replace traditional materials and techniques, but to supplement them when the working properties and longevity of traditional methods are inappropriate or damaging to the substrate. If traditional materials are to be used, modifications such as bismuth oxide for x-ray opaque fills or the UV fluorescent pigments should be made to make the fills identifiable by future researchers and conservators.

Future Reasearch

A more thorough investigation into the ideal combination and application of Paraloid B-72 should be undertaken to best understand how this material will behave for gilding applications. Revisiting the cast materials section to find what combination and consistency provides the best result would also provide useful information for future applications. As synthetic materials have proven successful as alternatives for gesso fills, investigation into the use of synthetics as mordants and sizes for gilding should also be considered. This would help identify fills in the future and allow for reversible treatment. Additionally, aged samples for the materials that were successful should be tested to understand the long term effects on the stability of the fills over time.

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Appendix 1: Hide Glue

Hide Glue as an Adhesive

The glue pearls must be soaked overnight. Place the pearls and the water (ratio 3:2) in a heat resistant container. The water should just cover the pearls. The next morning, place the container into a double boiler with the water hot (approx. 140 F) but not boiling. The glue should melt in a few minutes and should run from the brush in a continuous stream. If it runs in droplets, it is too thin and needs to be stirred to evaporate off any excess water. If it clumps to the brush, it needs to be thinned with hot water until the appropriate consistency has been achieved.

Hide Glue for Bole

Rabbit skin glue is the preferred adhesive for this application. The ratio is 1:14 w/v hide glue:water. The pearls can be soaked for an hour, then heated in the bain marie as above. When making bole, scoop out a small amount of the clay into a container. Add the glue a few drops at a time until a heavy cream consistency is achieved. The bole can then be painted onto the surface of the gesso.

Making Gesso

Rabbit skin glue is the preferred adhesive for this application. An approximately 5% solution should be made (1 pint of water [568 ml] to 1 ounce [28g] of animal glue pearls). Allow the pearls to soak overnight, then place in the bain marie and heat until it melts. Once it has melted, add the whiting (approximately 620 g chalk to 280ml glue) until the gesso is the consistency of thin cream. The whiting is added and allowed to soak before stirring gently. If stirred to vigorously or stirred before allowing it to soak, bubbles will form and they are virtually impossible to remove later without the aid of a vacuum. The mixture can be sieved to remove any clumps from the gesso. Gesso is always applied at room temperature, never hot. It should only be reheated if it begins to gel. Gesso should be applied with a firm bristle brush, allowing each layer to dry matte before applying the next coat. if bubbles do appear, a small amount of alcohol (IMS or ethanol) can be applied to surface of the next gesso layer and worked in with the fingers.

Please note, after the gesso has dried completely (more than 24 hours) the surface MUST be wetted again before applying any more layers. Otherwise, the lower layers will draw the moisture out of the later layers and not bond strongly. This will cause splitting and fissures when burnishing later on.

Appendix 2: Composition

How to Mix Composition

Followed a ½ recipe of the one from the Tate

Heat hide glue and water in a bain marie after soaking for 12 hours/overnight to allow the dehydrated hide glue to swell. The hide glue becomes very jelly-like (similar to the tapioca in bubble tea). The top layer went whiter and softer than the rest of the beads, but the others were still sticky. When heated it all melts together. It needs to be stirred to dissolve completely. It will have a cream-like consistency and smell very strongly of wet dog or wet wool. At this point the glycerol was added and stirred.

In a separate container, heat the linseed oil and rosin mixture in a bain marie (also after allowing to soak overnight/12 hours). The rosin normally only partially dissolves in the linseed oil overnight. It looks like very thick molasses. After heating, it will become translucent gold but takes a long time to melt. After 45 minutes it was only partially melted, some was very liquid, the rest was like cool honey. Even after additional time and stirring, the resin did not fully dissolve, some stuck to the stick and it was decided to just move forward with the recipe. At this point, turpentine was added.

Once both solutions are liquid consistency, the animal glue was poured into the rosin over heat. Normally, one would pour the rosin/oil into the animal glue, but due to the sizes of the containers, it made the most sense to do it this way. The new mixture was thoroughly stirred for approximately 10 minutes over heat. It became a yellow/tan colour & thick like chocolate or caramel sauce. At this point, a handful of whiting was added and mixed in.

Approximately 500g of whiting was used in this recipe. The actual amount varies due to the consistency of the oil/glue mixture, as well as how much chalk is absorbed off of the board during kneading.

Most of the whiting was added to a plastic bowl and a well was made in the middle for the adhesive mixture. It is better to start with not enough chalk and add it than to add to much as too much chalk makes the composition brittle and prone to breakage.

Pour the hot adhesive mix into the well and mix, incorporating more chalk with stirring. It may be advisable to wear gloves because this part is really sticky and messy. Once it is a thick mixture, the consistency of loose biscuit dough, get in with your hands and mix the rest. Once all the chalk in the bowl has been incorporated, turn the dough onto a chalked board or surface to knead. It will be VERY sticky at the beginning. Knead until it is velvety/silky smooth and sticks to hands but releases. Roll out to about ¼" then cut into strips and place into baggies. The compo will set to non-sticky within about 15 minutes.

Freshly made compo will reactivate with heat from hands (within the first hour of making it). Compo should be smooth and pliable when worked and tacky without being sticky.

Compo that is not going to be used that day should be stored in sealed bags in the refrigerator for up to a week, or in the freezer for up to 3 weeks.

To Mould/Press Composition

First take a mould of the area you would like to press. Compo does well with long runs of moulding instead of small bits, so it's best to get a longer (8-10cm) run. Obtain the mould using dental putty (2 part non-toxic mixture that sets hard but flexible). Press the putty and try to keep a flat, parallel surface for its back. Once the putty has set, peel it carefully from the surface. Create a small box around the mould to make sure the mould is level and square.

Mix Plaster of Paris using the manufacturer's guide. This can be adapted either thinner or thicker depending on what you aim to achieve. Pour this into the mould and allow to set. I left mine over a long weekend, but it can set much quicker/overnight. Carefully remove the plaster casts from the mould and clean up the surface as best as possible. Make sure the plaster is the appropriate thickness for the area you are filling. If not, this will be more work later to get the compo down to the correct level. Glue the plaster cast onto a flat surface (EVA should be good enough). Screw down two pieces of plywood on either side of the plaster casts, leaving approximately 1 cm between them. A flat piece of wood the same width as the gap should fit snuggly into the gap without requiring force to remove it. Block the two ends with pieces of ply. Place a thin (3mm) spacer on top of the plaster cast, then rest the flat wood on top of it. Mark a line on each side or the wood at this point. This will be where you stop pushing down, ensuring that the mould will not be too thin at its high points.

Mix the moulding material, and generally mix more than you think you will need. The blank spaces at the ends of the mould will take more moulding material than you think. Place the putty into the box then press down to the line with the flat piece of wood. Leave it to set.

Once the mould has set, carefully remove it from the plaster. It is not uncommon for the plaster to break inside the mould, just pick it out. Once the mould has been cleared of plaster, create a box for it using two pieces of ply. This adds structure to the sides and, if aligned correctly, will allow you to scrape the compo level with a knife.

To soften the compo, place a piece of cotton muslin or other loose weave cloth over a pot of boiling water. Secure the cloth with a rubber band or have it fixed to a frame like a screen. Place the compo strip on the screen for about 10 seconds a side, keeping your hands chalked to prevent sticking. The compo is ready when it is malleable and gooey (it will be very sticky). Roll the compo into a sausage between your fingers, then lay into the mould. Keeping your hands chalked, press the compo in as best as possible. Take a flat piece of wood or Teflon board, chalk the surface of the compo, then press hard to get the compo flat and fully into the mould. Remove the board, smooth over the surface with a chalked finger, and let set for at least 10 minutes or until firm. Once the compo is firm, it can be gently removed from the mould to prevent distortion, the excess can be trimmed off, and the compo mould set to cool and dry.

Before applying it to the surface, compo can be quickly softened on the bain marie. Keep the temperature low and only put the moulding over the heat for a few seconds at a time. Hide glue applied hot and fluid is an effective adhesive for attaching composition.

Appendix 3: Synthetic Recipes

Paraloid B-72 in Acetone

As mentioned in the essay, only one consistency was mixed as it thickened quickly from a thin ‘gesso’ state to a thicker putty as the acetone evaporated. 50 ml of 20%w/v Paraloid B-72 in acetone was placed into a small cup. 100g of whiting was measured out into a separate cup. Whiting was added in small quantities and mixed into the B-72 until a syrup consistency was formed: capable of pouring but not so thin that it ran in drips. Once the whiting was mixed in and the sample was coated, the remaining whiting was measured, showing 84g were used.

Paraloid B-67 in IMS

Gesso consistency:
50ml of 20% w/v B-67 in IMS was placed into a small cup. As above, a pre-measured quantity of whiting was then added in small quantities and mixed until a gesso or heavy cream consistency was formed. This was then brushed onto the boards in multiple coats. 54g of whiting was used.

Putty consistency:
25ml of 20% w/v B-67 in IMS was placed into a small cup then slowly bulked with whiting (67.5g). The solution was bulked until it formed a loose putty or spackle that could be spread into the losses.

Butvar B-98 in IMS

Gesso consistency:
50ml of 5% w/v B-98 in IMS was placed in a small cup. It was then slowly bulked until a gesso or heavy cream consistency and painted onto the sample boards. 77g of whiting was used.

Putty consistency:
25ml of the 5% B-98 in IMS was slowly bulked until a putty or sparkle consistency capable of being spread with a spatula was formed.

Klucel G in IMS

Gesso consistency:

50 ml of 5% Klucel G was placed in a small cup. It was then slowly bulked with calcium carbonate until a gesso or heavy cream consistency was formed. This was difficult because the 5% Klucel G was already very thick before being bulked. 25.18g of whiting was used. The same process was used for the 2% concentration, but 31.1g of whiting was used instead.

Putty consistency:

25 ml of 2% Klucel G was placed into a cup then bulked to a putty consistency with calcium carbonate. 27.22g of whiting was used (approximately double the ratio for the gesso).

Polyvinyl Alcohol in Deionised Water

Gesso consistency:

There was a bit of confusion when revisiting my notes from this past summer. The gesso consistency was listed as 3:1 bulking agent : PVOH and the putty as 2:1 bulking : PVOH, which seems backwards. Instead, the PVOH was mixed 1:2 PVOH:bulking agent (10%kaolin : 90% whiting).

Putty consistency:

25ml of 6% PVOH was placed into a small cup then bulked with a 1:9 Kaolin : whiting combination. 77.25 grams of the bulking agent was used.

Appendix 4: Detailed Results of the Surface Rankings

A questionnaire consisting of six questions were handed out to 10 participants. They were asked to choose a favourite sample for each of the three categories: oil gilded, water gilded matte, and water gilded burnished as well as to describe their choices. After, they were asked to rank the samples from best to worst for both water and oil gilding. The following are the answers to these questions.

Participant 1

Favourite Oil: 9 - gesso. Smooth areas look really good and I like the effect created when light hits it (like a Fererro Roche).

Ranking -
7 (Modostuc) - Very good smooth surface and brightness
13 (Flügger) - Good smooth area, most light reflectance
9 (Gesso) - Good smooth areas
18 (Lascaux Gesso) - Not very smooth, light reflects better than 14 (Ronseal)
14 (Ronseal) - Not very smooth, light doesn't reflect as well
3 (PVOH) - Good smooth areas, good brightness
10 (B67) - Very 'dotted' surface, brightness ok, not great
16 (B72) - Not great, surface isn't very smooth
6 (B98) - Areas that are smooth are good
8 (Klucel G) - Not great, very uneven surface

Favourite Burnished: 12 - Modostuc. Nice finish and good smoothness.
Favourite Matte: 4 - Gesso. Good smoothness

Ranking-
17 (PVOH) - Very good surface and brightness for both matte and burnished
19 (B67) - Very good surface and brightness for both matte and burnished
12 (Modostuc) - Nice finish and smoothness is good. Burnishing is not very bright.

1 (Lascaux) - Not the very smooth surface. Good brightness overall.

4 (Gesso) - Both sides are very smooth and good brightness overall.

2 (Flügger) - Good smoothness, some dips in the surface. Matte side seems not smooth.

5 (B72) - Good brightness, surface is okay. Matte side is not very smooth.

11 (Ronseal) - Very uneven surface for burnished side. Matte side was smooth and bright.

20 (B98) - Good smoothness but some 'dips'. Matte side seems smooth

15 (Klucel G)- Not a very good surface, no clear distinction between burnished and unburnished sides.

Participant 2

Favourite Oil: 9 (Gesso) because of its evenness of surface texture, smoothness, reflecting quality. And this has the appearance that I would expect as 'gilding' in general.

Ranking -

Rank	Smoothness	Overall
1	7 (Modostuc)	7 (Modostuc)
2	13 (Flügger)	13 (Flügger)
3	6 (B98)	9 (Gesso)
4	9 (Gesso)	6 (B98)
5	14 (Ronseal)	18 (Lascaux)
6	18 (Lascaux)	14 (Ronseal)
7	10 (B67)	10 (B67)
8	8 (Klucel G)	3 (PVOH)
9	3 (PVOH)	16 (B72)
10	16 (B72)	8 (Klucel G)

Comments: Tried to accommodate a feel of 'evenness.'

Favourite Burnished: 15 (Klucel G) because it shows the 'metal' quality of gold and weight.

Favourite Matte: 15 (Klucel G) because the gilded surface appears to have been gently pressed rather than stretched out

Ranking Burnished -

Rank	Smoothness	Reflectance	Overall
1	17 (PVOH)	2 (Flügger)	4 (Gesso)
2	2 (Flügger)	17 (PVOH)	12 (Modostuc)
3	4 (Gesso)	12 (Modostuc)	2 (Flügger)
4	12 (Modostuc)	5 (B72)	17 (PVOH)
5	11 (Ronseal)	4 (Gesso)	5 (B72)
6	19 (B67)	19 (B67)	19 (B67)
7	5 (B72)	11 (Ronseal)	11 (Ronseal)
8	1 (Lascaux)	1 (Lascaux)	1 (Lascaux)
9	20 (B98)	15 (Klucel G)	15 (Klucel G)
10	15 (Klucel G)	20 (B98)	20 (B98)

Comments: 1-3 had the least obvious ‘scratch’ marks and soft roundness of reflecting light. 4-8 a bit ‘harsh’ on the surface due to ‘scratch’ marks and sharp reflecting light. 9&10 lack of smoothness on surface.

Ranking Matte -

Rank	Smoothness	Reflectance	Overall
1	17 (PVOH)	12 (Modostuc)	17 (PVOH)
2	1 (Lascaux)	2 (Flügger)	5 (B72)
3	4 (Gesso)	4 (Gesso)	12 (Modostuc)
4	2 (Flügger)	5 (B72)	2 (Flügger)
5	12 (Modostuc)	17 (PVOH)	4 (Gesso)
6	5 (B72)	19 (B67)	1 (Lascaux)
7	19 (B67)	20 (B98)	19 (B67)
8	20 (B98)	11 (Ronseal)	20 (B98)
9	11 (Ronseal)	1 (Lascaux)	11 Ronseal)
10	15 (Klucel G)	15 (Klucel G)	15 (Klucel G)

Comments: Smoothness weighs more than reflectance, as seeing reflecting images on unfurnished surfaces are a bit difficult.

Survey Comments: Very interesting to see various quality of gilded surface created by different methods underneath the surface. Thank you.

Participant 3

Favourite Oil: 7 (Modostuc). It stood out from the others

Ranking -

7 Modostuc

13 Flügger

6 B98

14 Ronseal

9 Gesso

10 B67

18 Lascaux

16 B72

3 PVOH

8 Klucel G

Favourite Burnished: 4 (Gesso) - I wasn’t distracted by the scratches

Favourite Matte: Tied between 2 (Flügger) and 4 (Gesso). This was very difficult to rank they were more about the same consistently.

Ranking-

4 Gesso

17 PVOH

11 Ronseal

2 Flügger

5 B72

19 B67

1 Lascaux

12 Modostuc

15 Klucel G

20 B98

Ranking was done by by touch (moved finger over vertically, horizontally, and clockwise). For burnished, lined up the blocks and tried to see face in reflection.

Participant 4

Favourite Oil: 18 (Lascaux) Good tone, pretty texture, glowing

Ranking -

18 (Lascaux)

9 (Gesso)
7 (Modostuc)
10 (B67)
13 (Flügger)
6 (B98)
14 (Ronseal)
3 (PVOH)
16 (B72)
8 (Klucel G)

Favourite Burnished: 2 (Flügger) even surface, neatness, even level of shine, smooth
Favourite Matte: 17 (PVOH). even, smooth, nice edges, few flaws

Ranking Burnished-
2 (Flügger)
12 (Modostuc)
17 (PVOH)
19 (B67)
1 (Lascaux)
4 (Gesso)
11 (Ronseal)
5 (B72)
20 (B98)
15 (Klucel G)

Ranking Matte:
17 (PVOH)
2 (Flügger)
19 (B67)
12 (Modostuc)
4 (Gesso)
1 (Lascaux)
5 (B72)

11 (Ronseal)
15 (Klucel G)
20 (B98)

Participant 5

Favourite Oil: 9 (Gesso) - I think the surface only has some wrinkles that are I guess application errors or the denote some divots but I like the surface appearance.

Ranking -
9 (Gesso)
18 (Lascaux Gesso) - Assume wrinkles are application not material
7 (Modostuc) - High cause smooth and shiny but hate the darkening & if based on not smooth & reflection I would have this lower
14 (Ronseal) - Tough between this and next but more pinhole and divots in 13
13 (Flügger)
3 (PVOH) -a bit wobbly and uneven
6 (B-98) - more of the radiate more obscuring
10 (B-67)
16 (B-72)
8 (Klucel G)

Favourite Burnished: 12 (Modostuc) - it's very shiny
Favourite Matte: 2 (Flügger) pretty uniform surface, just calls to me

Ranking Burnished-
4 (Gesso) - good combo of reflecting and smooth
12 (Modostuc) - Shiniest but some divots so not smooth
2 (Flügger) - Some pinholes and streaky (very close tie with next one)
17 (PVOH) - More pinholes than 2, streaks are less
1 (Lascaux Gesso) - streaky losses
11 (Ronseal) - Some losses, streaky
19 (B-67) - streaky
5 (B-72)

20 (B-98)

15 (Klucel G) - really bumpy

Ranking Matte-

2 (Flügger) - Think surfaces are smoother which makes it shiny

17 (PVOH) - think surfaces are smoother which makes it shiny

4 (Gesso) - not counting gold loss

12 (Modostuc)

19 (B-67) - Really close to 12, dark smudge on 19 is distracting

1 (Lascaux) - Found pinholes and losses more distracting. Smooth and reflectance then wrinkles

11 (Ronseal)

20 (B-98) - Found lost gesso under pretty gilding distracting and gunsmith

5 (Paraloid B-72) - really shiny but not smooth though

15 (Klucel G) - surface losses and uneven

Participant 6

Favourite Oil: 18 (Lascaux Gesso) - the gilding is smooth and shiny but it also has some small bumpy featrues that are seen throughout and reminds me of gilded objects I have seen in the past

Ranking -

18 (Lascaux Gesso)

9 (Gesso) - smooth and shiny

7 (Modostuc) - Very smooth but not as shiny as 6, 14, or 13

6 (B-98) - Shiny, very very shiny, this was my second favourite appearance wise

14 (Ronseal) - Again shiny but not as smooth

13 (Flügger) - less shiny but still smooth (similar to 6)

8 (Klucel G) - smooth but not as shiny

3 (PVOH) - shiny but lacks smoothness

10 (B-67) - shiny but lacks smoothness

16 (B-72) - shiny but lacks smoothness

Favourite Burnished: 12 (Modostuc) - I felt this was very shiny and smooth in most places although there were marks (bumps) on the surface which did not bother me

Favourite Matte: 17 (PVOH) - I really like the surface finish on this sample, it is also quite shiny and smooth

Ranking Burnished-
12 (Modostuc)
19 (B-67) - very shiny
17 (PVOH) - many imperfection sin the surface but really shiny
4 (Gesso) - smoother than 19 or 17 but not as shiny, this was a close second favourite but there were bubbles in the surface finish
11 (Ronseal) - Shiny but not smooth
5 (B-72) - Shiny but not smooth
15 (Klucel G) - very shiny but really not smooth
2 (Flügger) - smoothish (there are heavy stroke marks) but dull
1 (Lascaux Gesso) - Smoothish (there are heavy stroke marks) but dull
20 (B-98) - Worst surface finish - bumpy and has weird waterline stains

RankingMatte-
17 (PVOH)
12 (Modostuc)
5 (B-72) - not as smooth
20 (B-98)
15 (Klucel G) - worst surface finish but really shiny
1 (Lascaux Gesso)
19 (B-67)
2 (Flügger)
4 (Gesso)
11 (Ronseal) - many imperfections and very dull

Participant 7

Favourite Oil: 18 (Lascaux) - Not the smoothest sample, but the rough texture makes it shinier than the smoothes sample (7- Modostuc) thus more visually appealing.

Ranking -

7 (Modostuc) - centre is very smooth and reflective

13 (Flügger) - The sections are pretty reflective and smooth

6 (B-98) - slight surface pitting, no surface loss

9 (Gesso) - one section of surface loss at top corner, couple of pitting more matte texture

14 (Ronseal) - Increasingly matte, very small areas of surface loss at bottom

18 (Lascaux) - Matte

3 (PVOH) - Pitting, matte, some surface loss

16 (B-72) - some pitting and surface loss

10 (B-67) - 2nd most textured surface, pitting, surface loss

8 (Klucel G) - Most matte, peeling, surface loss, least reflective

Favourite Burnished: 4 (Gesso) - Least tearing or missing chunks or fragments (see 1-Lascaux, 20-B-98). Very smooth burnished surface compared to others (19-B-67)

Favourite Matte: 12 (Modostuc) - Smoothes, fullest coverage, with only one minor flake lost.

Ranking Burnished-

4 (Gesso) - flattest, smoothest surface, burnished, not scratched

12 (Modostuc) - Burnished, yet slightly scratched

15 (Klucel G) - Very smooth finish, slightly indentations, may be due to original surface?

17 (PVOH) - Smooth, but scratched

2 (Flügger) - minor flaking and scratches

11 (Ronseal) - deeper scratches

5 (B-72)

19 (B-67)

1 (Lascaux Gesso)

20 (B-98) - evidence of lifting/cracking, though admittedly less roughly polished

Ranking Matte-

12 (Modostuc)

5 (B-72) - very smooth and reflective, slight loss on bottom

2 (Flügger) - Slight surface loss, very smooth

4 (Gesso) - almost uniform surface

20 (B-98) - variable quality - towards centre lower quality, centre edges very high quality.

17 (PVOH) - duller shine

19 (B-67) - Slight loss and less smooth

11 (Ronseal) - surface less smooth

1 (Lascaux Gesso) - Poor reflectance

15 (Klucel G) - poor surface, affects smoothness & reflectance

N.B. Less difference between these samples than the burnished.

Participant 8

Favourite Oil: 9 (Gesso) - not the shiniest or smoothest but fairly goo balance of both, nice texture.

Ranking -

13 (Flügger)

6 (B-98)

18 (Lascaux)

9 (Gesso)

14 (Ronseal)

7 (Modostuc)

3 (PVOH)

10 (B-67)

16 (B-72)

8 (Klucel G)

Favourite Burnished: 2 (Flügger) - Smooth, shiny. Clearest reflection, evenly distributed.

Favourite Matte: 2 (Flügger) - Smooth with a little texture

Ranking Burnished-

2 (Flügger)

12 (Modostuc)

4 (Gesso)

19 (B-67)

17 (PVOH)

1 (Lascaux Gesso)

11 (Ronseal)

5 (B-72)

20 (B-98)

15 (Klucel G)

Ranking Matte-

2 (Flügger)

17 (PVOH)

19 (B-67)

1 (Lascaux)

11 (Ronseal)

4 (Gesso)

12 (Modostuc)

5 (B-72)

15 (Klucel G)

20 (B-98)

Participant 9

Favourite Oil: 9 (Gesso) prettiest :) just like it. uniform I guess?

Ranking -

13 (Flügger) - the areas that were done properly look really good

7 (Modostuc) some pits but smooth

6 (B-98) - same as 13

14 (Ronseal) - some areas that are really shiny in-between the more wrinkly bits

9 (Gesso) - on the left it is really fairly smooth but kinda wrinkly

18 (Lascaux) - wrinkly but alright, similar to 9 but not quite as good in my opinion

10 (B-67) - obvious pocks- relatively smooth otherwise though

3 (PVOH) - Some large pocks and some wrinkling

16 (B-72) - large pocks in surface and overall just looks kinda messy

8 (Klucel G) - flaking off, uneven surface. Just the worst!

Favourite Burnished:20 (B-98) I like the quality of the parts that are burnished sans the cracked missing bits.

Favourite Matte: 20 (B-98) same as above

Ranking Burnished-

4 (gesso) - very nice

2 (Flügger) - very nice only one imperfection

12 (Modostuc) - a small pit in bole

1 (Lascaux) - can see some bole

5 (B-72) The base has large pits in it

11 (Ronseal) - you can see some bole through

17 (PVOH) - you can see some bole through

19 (B-67) - you can see even more bole through

20 (B-98) large parts of gilding missing

15 (Klucel G) - Uneven pitted base

Ranking Matte-

2 (Flügger) - really nice

5 (B-72) - really nice

4 (Gesso) - really nice but a few missing bits

12 (Modostuc) - A few missing bits and cracks

19 (B-67) - a few missing bits and cracks and a little bubbly

17 (PVOH) - can see bole

20 (B-98) missing bits/can see bole and wrinkled

1 (Lascaux Gesso) - cracks and missing bits

11 (Ronseal) - missing bits and cracks

15 (Klucel G) - uneven base

Participant 10

Favourite Oil: 9 (gesso) very sparkly

Ranking -

18 (Lascaux)

7 (Modostuc)

9 (Gesso)

14 (Ronseal)

6 (B-98)

13 (Flügger)

3 (PVOH)

10 (B-67)

16 (B-72)

8 (Klucel G)

Favourite Burnished: 4 (Gesso) - smoothest surface & most even glow

Favourite Matte: 20 (B-98) - mellowest tone/flattest

Ranking Burnished-

4 (gesso)

12 (Modostuc)

2 (Flügger)

17 (PVOH)

11 (Ronseal)

1 (Lascaux Gesso)

19 (B-67)

5 (B-72)

15 (Klucel G)

20 (B-98)

Ranking Matte-

2 (Flügger)

5 (B-72)

4 (Gesso)

12 (Modostuc)

17 (PVOH)

1 (Lascaux Gesso)

19 (B-67)

11 (Ronseal)

15 (Klucel G)

20 (B-98)

Appendix 5: List of Materials Used

	Materials for Gilding	
Name	**Provider**	**Use**
Calcium Carbonate	Gold Leaf Suppliers UK	Bulking agent
Gold Leaf (loose and Transfer)	Gold Leaf Suppliers UK	Gilding
Double Weight Gold Leaf	Cornelissen's	Gilding
Bole Clay	Gold Leaf Suppliers UK	Bole
Oil size	Gold Leaf Suppliers UK	Mordant
	Miscellaneous Materials	
Name	**Provider**	**Use**
Silicon Rubber	Cornelissen's	Casting Moulds
Kaolin	Amazon	Bulking agent
Sandpaper	Robert Dyas	Surface Finishing
Cork sanding block	Robert Dyas	Surface Finishing