The Ancient Craft of Gold Beating

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Transferable gold coatings, the manufacture and application of which were reviewed in Gold Bulletin a year ago, are now widely used for decorative purposes. True beaten gold leaf, however, remains the material of choice for prestige gilding in which durability is called for. Gold beating by hand has been practised for some five thousand years and the exponents of this ancient craft, to whom 'address is requisite', are justifiably proud of the traditions associated with it.

For many years past the holder of my appointment has been also privileged to hold the Royal Warrant as Supplier of Gold Leaf to the ruling monarch of Britain. It was only a few days after the receipt of my official confirmation as such supplier from the Lord Chamberlain to Her Majesty the Queen that I found myself in the very heart of our storehouse of gold reserves, the Bank of England, engaged upon a very delicate mission. Someone in that august establishment had adumbrated that gold leaf, consisting as it does of pure or at the least 23½ carat gold, was in fact 'gold bullion' within the meaning of the Exchange Control Act of 1947; a ruling which could involve considerable expense, delay in administration and shipments, and perhaps loss of orders. Furthermore, there could be uncharted seas of domestic trade to be crossed, if the decision were taken to its logical conclusion. A meeting was accordingly arranged with the department concerned,

whose officials freely admitted from the outset that their knowledge of the nature and history of gold leaf was probably as shallow as the product itself was thin, and it was in order to remedy this state of affairs that I related the essence of what follows to a small but select group of senior banking executives.

From Ancient Egypt to the Rest of the World

For at least five thousand years craftsmen have exploited the great malleability of gold by hammering it into leaf of extraordinary thinness which then, because of its beauty and durability, could be employed to ornament and protect that to which it was applied. The Egyptians appear to have been the earliest practitioners of the art and the illustrations on tombs at Saqqara and Thebes show their goldbeaters working together with gold founders and goldsmiths.

This illustration from an ancient Egyptian tomb at Saqqara (2500 B.C.) shows the melting of gold with the assistance of blowpipes and the beating of gold with a rounded stone held in the hand

The hieroglyph for gold showing a collar of beads indicates the most popular use of the metal. Thus, the hieroglyph for gold leaf is:

Many objects gilded by the Egyptians have survived to this day and the inner coffin case of Henutmehit, magnificently gilded, can be seen at the British Museum as one example of their skill. Indeed, samples of beaten gold leaf ready for application were found among the treasures of Tutankhamen's tomb at Luxor. Those who have also been fortunate to view some of these treasures during the Tutankhamen Exhibitions in Paris, London or, latterly, New York will have seen for themselves the numerous gilded objects of superb design discovered by Howard Carter and Lord Carnarvon's party.

It seems likely that the thickness of the leaf employed varied considerably as knowledge of the art increased. Marcellin Berthelot (1) produced the following analysis of the composition and thickness of Egyptian gold leaf for the period from the VIth to the XIIIth Dynasty:

Dynasty	VIth	XIIth	XIIth	XIIth	XIIIth
Gold, %	92.3	85.92	90.5	78.7	92.7
Silver, %	3.2	13.78	4.5	20.9	4.9
Copper, %	—	0.30	—	—	—
Others, %	4.5	—	5.0	0.4	2.4
Thickness, μm	—	—	—	1	1

while the Luxor samples (late XVIIIth Dynasty) were some 0.3 μm thick.

The Old Testament reveals in 'Exodus' that the Israelites learned the art of gold beating during their exile in Egypt (2). The boards and bars of the Tabernacle built by Moses in accordance with his covenant with God in Sinai were overlaid round about with gold (Ex., 35 and 36), as was the very ark of the covenant itself (Ex., 25). The Phoenicians probably acquired the technique from the same source and their workmen gilded the porch within King Solomon's House of the Lord in Jerusalem. In India gold beating must have been practised from the birth of Buddhism (Vth century B.C.) and to this very day the faithful purchase gold leaf in the streets near the temples and apply it to the great statues of Buddha that dominate the scene with a perpetual golden glow. The art then spread to Korea, Japan and China, where the use of gold leaf, in lacquer work particularly, abounds to the present day.

Numerous accounts of the use of gold leaf in antiquity have remained. Homer, whose works were later actually written in gold on purple vellum as a gift for Emperor Maximinus from his mother, makes reference in 'The Odyssey' to the gilding of the horns of sacrificial oxen. Persian officers are said to have slept in gilded beds before the battle of Plataea although whether this improved their performance during the fighting is not recorded.

When the Romans brought Phoenician captives to serve as slaves in Rome, they too acquired knowledge of gold beating. The 'Naturalis Historia' of Pliny the Elder records the gilding of the Capitol after the overthrow of Carthage and the adoption of such decoration afterwards on public and then private buildings. The Roman goldbeaters succeeded in beating out 750 leaves each four fingers (75 mm) square from one ounce of gold (3).

It is in illuminated manuscripts that the earliest evidence of the use of gold leaf is found in Great Britain. The Durham Book, the 'Lindisfarne Gospels' of about 700 A.D., in the British Museum is the oldest and best known extant example. Psalters and other sacred books using burnished gold appeared in the monasteries, particularly after the Norman conquest. Gold leaf was also in demand for decorating the stonework of churches and castles, as well as for

The golden arm and hammer traditionally distinguished the premises of 'goldbeaters'. This huge sign still projects, somewhat anachronistically, within the modern factory of George M. Whaley Limited at Livingston, and nearby modern vacuum metallizers and lacquering and coating machines, not to mention a computer installation, are in full operation. The firm, however, still manufactures beaten gold leaf, an activity it started in 1783

A skilled goldbeater can produce in several stages leaf to a thickness of $0.05\ \mu\text{m}$. It is so thin that the gold is transparent to light. Quite understandably, therefore, goldbeaters have always considered themselves superior to the other tradesmen and have been of an independent turn of mind. In 1612, for instance, upon its incorporation they joined the Worshipful Company of Gold and Silver Wyredrawers, but almost immediately stood for independent incorporation (4)

gilding oak furniture. As it spread from Egypt to the rest of the world, the technique of beating gold leaf improved, for the early English goldbeaters secured a thickness of less than $0.1\ \mu\text{m}$ and could each produce some 5000 leaves in a week.

Accounts of the Craft

It was in the XIIth century that the earliest comprehensive description of gold leaf beating techniques appeared in *'De Diversis Artibus'*, part of the 'Encyclopaedia of Christian Arts' by Theophilus. Thus:

Gold Leaf

'Take some Byzantine parchment, which is made from flax fiber, and rub it on both sides with the red pigment that is made by burning very finely ground and dried ocher. Then polish it very carefully with the tooth of a beaver, a bear or a boar, until it becomes bright and the pigment sticks fast as a result of the friction. Then cut this parchment with scissors into square pieces, four fingers wide and equally long.

After this make a sort of pouch of the same size out of calf vellum and sew it together firmly. Make it large enough to be able to put a lot of pieces of the reddened parchment into it. After doing this take pure gold and thin it out with a hammer on a smooth anvil, very carefully, so as not to let any break occur in it. Then cut it into square pieces, two fingers in size. Then put a piece of the reddened parchment into the pouch and in the middle on top of it a piece of gold, then another piece of parchment and again a piece of gold, and continue doing so until the pouch is filled and there is always a piece of gold interleaved in the center. Then you should have a hammer cast from brass, narrow near the handle and broad at the face. Hammer the pouch with it on a large flat smooth stone, lightly, not heavily. After frequent inspections you will decide whether you want to make the gold completely thin or moderately thick. If the gold spreads too much as it is thinned and projects out of the pouch, cut it off with small light scissors made for this purpose alone.

This is the recipe for making gold leaf.' (5)

This description of the methodology would be instantly recognizable by the goldbeaters of today; although the method of polishing the paper in which the beating is to take place has become otiose by modern paper-making techniques — even if the animal molars were easily obtainable.

Another valuable guide is contained in Dr. William Lewis's *'Commercium Philosophico-Technicum'* of

1763, whose description of the practice in France is particularly interesting for its recognition of how damp and cold weather adversely affects the process. Humidity and temperature control is still a pre-occupation of the modern goldbeater.

Indeed the methods of beating gold have not changed significantly since the days of the early Egyptians four to five thousand years ago. The rounded stone has been replaced by a cast iron hammer with a wooden shaft and some machinery has been introduced to reduce the effort of beating by hand but, in essence, the process remains the same.

The Beating of Gold Leaf

Modern batch production begins with the melting of approximately 1800 g of pure gold grain in a crucible where it is alloyed with a small quantity of copper and silver as the colour of the finished leaf requires. An ingot measuring approximately 280 x 40 x 13 mm is produced. After forging to the desired length or width, the thickness of the bar is reduced by passing through steel rollers with intermediate annealing or softening, resulting in a ribbon 25 μm thick and upwards of 40 m long, according to the issued mass. From the resultant ribbon some 300 g is then cut into squares of which 200 are inserted into a 'cutch' made up of sheets of vellum encased with bands of parchment. Many thousands of ancient deeds freed by land registration or the effluxion of time have been and indeed still are cut up to provide this invaluable material for which no adequate substitute capable of withstanding constant hammer blows has been found.

The tools of the goldbeating trade are displayed here with a few books of finished leaf. The heavy double-faced hammer is made of cast iron and is the only tool used by the beater himself. The cross-shaped weights are used to hold the 'cutches', 'shoders' and 'moulds' together between the various steps of manufacture. After the first stage of beating, gold foil and then leaf is not manipulated by hand but with boxwood pincers. Foil is placed on the calf leather cushions for cutting with the steel skewing knives while leaf, which readily adheres to steel, is quartered or cut into neat squares atop the cushions with a 'wagon', of which two are shown here. The hind feet of hares are used to evenly spread 'brime' on the goldbeater's skins. The small copper 'pennyweight' holds down the rouged tissues whilst the leaves of gold are inserted one by one into the books. Parchment is an essential accessory to the craft — the 'cutches', 'shoders' and 'moulds' are encased in it during beating. Obsolete legal records are now the main source of parchment

After thirty minutes' beating the gold extends to the edges of the cutch and the 100 mm square pieces are quartered and placed in a second cutch. This time the leaves of the square are supported by sheets of Montgolfier paper made by the same French firm whose owners developed the first practicable warm air balloon in 1783, but they are again bound together with parchment bands. After a further thirty minutes' beating, the now quite substantially thinner 100 mm squares which result are once again quartered and 800 pieces of these are placed in a 'shoder' made of goldbeaters' skins. The remainder is used for a second beating. The history and nature of the skins used by goldbeaters would merit an article in themselves, but suffice to say that in this area some technical progress has been made which avoids the complexity (and obnoxious effluvia) which used to attend their manufacture. The process for quartering

the leaves for the shoder is known as 'skewing' and the ladies who wield the steel skewing knives require a great delicacy of touch to handle the leaf which is now already less than 6 μ m thick. The leaf is manipulated with boxwood pincers, as even at this stage it would tend to stick to steel. After one hour of further hammering, the 50 mm squares have again been extended to 100 mm and are ready for further quartering and beating. It should be mentioned here that whether the beating is carried out by hand or by machine, the gold must be beaten evenly in a predetermined pattern to ensure that an unbroken leaf is formed.

Now there arises the most delicate stage of the whole operation and one calling for even greater dexterity and sureness of touch than have been necessary so far. This involves the transfer from the shoder to a 'mould' composed of 1200 very thin sheets of

goldbeaters' skins 130 mm square. It would now be quite impracticable to quarter the gold from the shoder by means of a steel skewing knife and the cutters make use of an ingenious implement known as a 'wagon' which resembles a small sledge made of a light boxwood frame carrying pieces of malacca sharpened to give a cutting edge. The smallest pressure cuts the leaf cleanly and without ragged edges. The preparation of the mould to receive the leaf before its final beating is of prime importance and for this the skins are cleaned on both sides with a calcined gypsum powder known as 'brime' and which is applied with the hind foot of a hare. It was traditionally thought that only the foot of an Arctic hare would achieve the necessary gentle cleaning action and even spread of the brime, but necessity and the lack of Arctic hares have revealed that the hind foot of a good Scottish hare can serve the purpose adequately. The skins in the mould are then placed in a hot press after which they undergo a manual 'flying' by the goldbeater flicking through the skins, very much as one fans the pages of a book, in order to remove damp accumulated throughout the process. The suitability of the mould to receive the leaves is wholly dependent on the skill of the goldbeater and it is upon his judgement that success or failure of the final beating relies. The mould then undergoes approximately four and a half hours of beating according to the caratage of the gold in it, following which it is returned to the lady cutters who, having removed them from the mould, cut the leaves to an even 80 mm square with their wagons. The cutting operation is performed on cushions of calf leather. The final cut leaf is then placed in a book of rouged tissues capable of holding 25 leaves of gold. The residue is weighed and calculated against 0.325 g per book of 25 leaves, returned to be melted and the process is repeated. The skill involved in handling the individual leaves can be best appreciated when it is realized that each is now thinner than the wavelength of visible light — $0.1\text{ }\mu\text{m}$ when machine beaten, and if beaten manually by a skilled operator as thin as $0.05\text{ }\mu\text{m}$ — sideways on they are quite invisible. The art of placing them down for cutting, employing a gentle breath of air, leaves one in no doubt that even in these days when discrimination of any kind is to be abjured, it must be admitted that such skills are more commonly found in the female of the species.

The Mechanization of Gold Beating

It is interesting to note that the desirability of a labour-saving machine to hammer gold preoccupied none other than Leonardo da Vinci (1452-1519) whose device like his flying machine was never actually constructed so far as we know. In Germany, Christian Reich of Fürth was the first to attempt to solve the problem, but a hammer designed by him in 1837

Leonardo da Vinci, and many others after him, tried... and failed to develop a mechanical goldbeater. It was only around 1928 that Cecil Whiley, after a detailed photographic and cinematographic study of the movements of the most skilled hand beaters in his employ, was able to develop a commercially viable machine. In essence, the complex assembly of cams and gears aims at reproducing as accurately as possible the traditional motions of hand beaters. Nevertheless, the mechanical hammer makes leaf twice as thick as that produced by expert hand beating

was not a marked success. He was followed by Michael Hoffman — also of Fürth — whose continuous hammer, although ingenious, did not seem to achieve worthwhile results.

Many others contributed later developments, notably T. H. Lauter of Nürnberg whose machine went some way towards solving the problem of unacceptable scrap involved in previous devices but still left much to be desired. In 1851 an American company, Vine & Ashmead, of Hartford in Connecticut, demonstrated an automatic hammer at the Great London Exhibition. Even this required considerable manual intervention during the process and it was not until Cecil Whiley designed a method of recording the movements of the hammer, arm and wrist of a skilled beater by a series of lights attached thereto and of plotting these photographically, that a wholly

satisfactory, fully automatic machine was constructed. Machines of this design are still in operation to this very day.

Current Applications of Gold Leaf

Whether hand or machine beaten, the gold leaf, its seven stages of manufacture complete and nowhere having been touched by hand, is ready to meet a worldwide demand, constrained only by the number of those gilders versed in the art of its application. 24 carat gold leaf is used for gilding statues, churches, public buildings, tombstones, weather vanes, bracket clocks, heraldic shields — indeed anywhere where other metals would quickly tarnish. Shop signs, business premises, furniture, handtooled leather, picture frames and other internal applications can utilize 23½ carat gold and these are but a few of the ways in which this fascinating product is employed.

Nor has the art of manuscript illumination died. In Britain, the Society of Scribes and Illuminators requires evidence of this skill to be shown by its candidates for election. Graily Hewitt, who taught lettering and illumination at the London Central School of Arts and Crafts for more than thirty years conducted many experiments in the art, in which he himself excelled, based on the directions and recipes of Cennino d'Andrea Cennini whose *Il Libro dell'Arte* describes the XVth century practice in Italy. In this materialistic age, it is still worth pondering on Cennini's advice in Chapter 96:

'I give you this urgent advice, to make an effort always to embellish with fine gold. And if you wish to reply that a poor person cannot make the outlay I answer that if you do your work well and spend time on your jobs you will get such a reputation that you will end by gaining your ambition. As the old saying goes, good work, good pay. And even if you were not adequately paid, God and Our Lady will reward you for it, body and soul.' (6)

Epilogue

This was the end of my story to the bankers and gesturing in the general direction of the Cross of St. Paul's Cathedral, Tower Bridge and Buckingham Palace, where my Company's gold leaf glistens, and thence downwards to where the nation's gold rests in heavy bars, I submitted that a substantial distinction existed between the two. For good measure I gently placed a leaf of gold from a book on the palm of the senior bank official and invited him to rub his hands together. As is its wont, the gold disappeared — absorbed into the skin! It needed no further illustration from me to indicate that this would not have occurred with one of his ingots!

I was graciously thanked for my visit and a few days later permission was given for George M. Whiley Limited to export gold leaf... 'as defined under the appropriate sections of Tariff 71.07 of the Customs Duties and Overseas Trade Descriptions Act without the need to provide a Certificate C.'

But gentle reader, beware lest you think this provides a loophole to deplete Britain's hardwon gold reserves by freeing the purchase of gold leaf in the U.K. for its indiscriminate export without the watchful eye of the Bank of England. It was made clear that 'the concession only applied to direct export by George M. Whiley and individual travellers will still require their Certificate C if they themselves wish to export.' What a mercy the ancient Egyptians did not require Certificate C for the export of their craft for how many building, books and objets d'art elsewhere in the world would have been diminished in their beauty for want of gold leaf!

Acknowledgements

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References

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THE great value which has at all times been fixed on gold, its beautiful colour, incorruptibility, and compactness, render its ductility an object of primary importance: on this depend sundry arts and manufactures, in which we see it extended to an amazing tenuity, and variously applied on the surface of other bodies, both for their ornament and preservation.

London 1768

WILLIAM LEWIS

Commercium Philosophico-Technicum