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A LOOK AT THE ORIGINS, HISTORICAL USES AND DEVELOPMENT OF THE CIRE PERDUE (Lost Wax) process of Metal Casting

by A.M. Turner

As some people possibly only know the 'Lost Wax' process as a name, a brief explanation of the principles of the process might be of help.

If it is desired to make a metal cast of an object, for example of a chess pawn, a wax replica is first made. To this will be added a wax sprue (or sprues according to the complexity of the design). This is a comparatively thin wax rod which connects the object with the crucible into which the metal will eventually be poured. If the object to be cast is large and/or complex, further wax sprues will be added as air vents to allow the air to escape when the metal is poured in.

If the final object is to be hollow then the wax is formed around a centre core of 'clay' which can be removed after casting. This core is held in place by metal pins through the wax into the investment. The whole is then invested in a one piece mould with the wax in the centre.

I do not intend to go into the chemistry of investments, but certain clays can be used. Essentially the first layer must be of a very fine grain, and thin, to allow it to be closely applied to the wax (even painted on). This is followed by a thicker, courser layer to give strength. This investment may be supported by a ring or external wires. It is then allowed to dry thoroughly and harden, before being slowly heated. This will melt the wax which can be poured off and re-used in larger casting or simply driven off as vapour, leaving a perfect replica of the original wax object in the middle of a one piece mould, hence 'Lost Wax'. (A two piece mould which can be opened and the wax taken out ceases to be Cire Perdue). When the investment has reached the correct temperature for the metal to be used this is poured (or forced) in through the crucible. After cooling the investment is broken away and the now metal object removed. The sprues are now metal air vents and are cut off and the object cleaned and finished.

The principal advantages of this method are that great detail can be carved onto the wax and hence exactly reproduced on the casting, very intricate work can be cast (see 'Oxford History of Technology Vol.11' for illustration of gilt-bronze candlestick presented to St. Peter's Gloucester by Peter, Abbot of Gloucester, 110-13), and also its extreme accuracy. Its principal disadvantage is that each mould can only be used once.

How and when did the method start? Unfortunately a clear cut answer cannot be given to this question; one can only attempt to trace back through history objects cast by this process. Even then, in the absence of discarded miscasts, and so far I have failed to find any written evidence of these, it is not always possibly to say with certainty whether a particular object was cast by this process or not (See later).

According to 'A Pictorial History of Invention' it is said to have been developed by Rhoecus and his sons Teleclus and Theodorus who belonged to the Samos school, (one of the famous metallurgical centres of Asia Minor with large deposits of good copper sulphate in the nearby mines), in the 7th Century B.C.

However this is much too easy a solution and this date is too late. There is in fact, in the National Museum of Wales in Cardiff, a bronze sword chape from the Guilsfield Hoard which is dated circa 900-700 B.C. It is the tip of the scabbard and has two opposite holes near the centre caused by the insertion of pins to keep the core and mould in the correct relative position. (See above). This is not to suggest that the process was discovered in this country. It certainly was not, but was presumably brought here by craftsmen travelling along the ancient trade routes. It does however indicate that by this date 'Cire Perdue' had spread over a very considerable area of the known world.

According to Henri Frankfurt (in 'The Art and Architecture of the Ancient Orient') six bronze statuettes – three female and three male – were found at Tell Teidel, a small hill in the plain of Antioch. These were found in layers contemporary with the first half of the Early Dynastic Period in Mesopotamia, thus giving a date of between 2,800 and 2,635 B.C. He says that these were cast by lost wax and that the process might have derived from Sumer.

Smelting of ores probably goes back to between 4,000 - 5,000 B.C. (Although naturally occurring copper had been beaten much earlier). However, firm evidence of smelting can be dated to round 4,000 B.C. at Tali Iblis in southern Iran, where smelting hearths, crucibles, slag and malachite ore have been found. (Dr. Andrew Sherrett, B.B.C, 'Origins').

G.M. Hallenback says that it is probably true that many of the Chinese bronzes made 5,000 or 6,000 years ago were made by lost wax but he does ask the question whether they were made in a multi-part mould and then hand finished to remove the flash resulting from the joins in the mould, so as to leave no visible trace of the mould. He goes on to suggest that this would be possible at a time when man hours didn't matter and Chinese patience would be capable of this.

However, in the catalogue to the Chinese exhibition at the Royal Academy in 1974, two very important points were made. One is that Lost Wax casting by its nature leaves no trace. Secondly, in discussing technology from the 15th Century to the 4th Century B.C., they point to the actual evidence of not only joint lines from the multi-part moulds on the finished castings but also to surviving fragments of the moulds themselves. This was apparently rapidly replaced by lost wax in the 5th Century B.C. It would therefore appear that the process probably spread to China from the Middle East rather than the other way round.

It would seem that Lost Wax as a process was discovered early in the history of metallurgy and that it spread from a Middle Eastern origin through the known world. Denis Williams claims that the method had been practised before that, perhaps as early as 3,500 B.C. He also says that the technique seems to have fallen out of use in Europe in the Middle Ages until an Italian revival in the 15th century.

It was used by Cellini (1500-1571), the Florentine artist, who describes in the 'Trattato della Scultura'. One amusing story told of Cellini concerns a bronze figure of a man that he was casting. Having melted the metal ready for casting he concluded that there was insufficient bronze. He therefore gathered together all the pewter ware, silver, pots, pans, plates, forks, spoons etc. and threw then into the melting pot!!!

The method was being used in Benin in Africa when the first Europeans arrived circa 1485. It was probably introduced there from Ife in the time of Oba Oguola, said to have been the sixth King of the present dynasty which gives a probable date of circa 1325, although dating is very difficult. It is generally assumed that it was introduced by possibly a single craftsman travelling along ancient trade routes through the Sudan to the south of the Sahara or across the Sahara from the Mediterranean.

A.E.J. Mackett-Beeson in 'Chessman' mentions and illustrates a set of bronze and enamelled chessmen, made in Madras in the 13th century, which are said to be cast by 'Cire Perdue'.

The method was introduced into dentistry by Dr. W.H. Taggard in 1907 and is still used for casting gold dentures, crowns, and inlays. Unfortunately he got involved in litigation over patent rights for its dental use.

A B.B.C. television programme 'The Gun' showed its use in mass production in modem industry for small parts for guns. Mass production for Lost Wax sounds like a contradiction but the waxes are mass produced in moulds and then invested in multiples along one long sprue. I believe that some parts of air-craft engines are made in a similar way.

When I set out to write this paper I had hoped to be able to find out where and when and possibly by who 'Cire Perdue' was discovered. The best date I can offer is that it appears to have been first used between 3,500 and 2,500 B.C., probably in the Middle East, a date which frankly astonishes me. It seems to have spread fairly rapidly through the known world and it is said that at the time of the Spanish Conquest reports were brought back of its use by the Incas and the Aztecs (Donaldson).

In a recent (Autumn 1978) 'Origins' programme a site which is at present being excavated in S.E. Asia was described. Metal-working dating to about 3,500 B.C. has been found there, including a socketed bronze spear head. It is thought that there may be a link with the Middle East about contemporary with Middle East metal work.

At present, work on this site is in its early stages, but it could be that further evidence of Lost Wax might come to light from this site.

In conclusion I would like to thank the Library Staff of Lowestoft Library. The Librarian of the British Dental Association and Mr. David Attenborough for their help in tracing written sources for me.

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EAST ANGLIAN FILM ARCHIVE

by David Cleveland

The Prince of Wales opening the Haven Bridge, Yarmouth on October 21st, 1930.

Last train run on the Southwold railway on April 11th, 1929

Stokesby 1942, a record of Charlie Wharton's farm.

Yarmouth Bus Station, 1960.

Sailing and steam drifters entering Yarmouth and unloading catch, 1902.

What have the above in common? The answer is they are all preserved on film - a unique record of the actual events collected together by the East Anglian Film Archive. The Archive, run jointly by the University of East Anglia at Norwich and the University of Essex at Colchester was set up in 1976 to search out, copy, preserve, and make available indigenous movie film of East Anglia. Through necessity our East Anglia consists of Norfolk, Suffolk, Essex and a thin slice of this side of Cambridgeshire. The sort of film we are looking for is not that which is already preserved in the London archives, but locally made films produced by East Anglian cameramen, amateurs and professionals. It is surprising how much locally made film there is. Nearly every town has had an amateur recording local events over the years, plus usually a professional as well. Take for example Southwold. Here the cinema owner had a camera, a 35mm. hand turned movie camera, with which he recorded events during the 1920's and 1930's in the town, showing them as soon as he could in the cinema as an extra draw. Some of this material has survived; thus we have a moving record of 1928 Trinity Fair, the 'Mary Scott' lifeboat, Southwold ferry, and other items.

The job of the Archive is to find this material and, with permission, borrow it from the present owner, copy it, and return the original. The film is then used for research and film shows throughout East Anglia. All film is of interest, either 8mm., 9.5mm., 16mm., or 35mm. We have almost 200 items in the catalogue, including a large selection of films dealing with farming and fishing in the region. Often young people have never seen certain machines at work, or at best, they have only seen tools in museums. With movie film you can actually see farming operations and how tools were used. Some defunct industries, such as the herring fisheries at Yarmouth and Lowestoft, are well covered, even including what went on at sea, both above and below decks.

The East Anglian Film Archive is run on voluntary lines, with an annual grant from the Eastern Arts Association to pay for the cost of film copying. We are always anxious to learn of films to copy them for the Archive. It does not matter how poor the film may seem, or how old or new it is, as long as it shows something of the way East Anglians worked, lived, played or transported themselves. Even shots of streets, an unusual thing to film, prove valuable when one is looking at the past.

Should you know of any film or possess any, we would be delighted to hear from you. Please do not hesitate to get in touch with us, either at Norwich University (Malcolm Freegard) or at Essex University (David Cleveland) or through Peter Stibbons at the Lowestoft Archaeological Society.

COMMODORE ROAD SMITHY AND COTTAGE

E. Marley

Outline Report

Blacksmith's Workshop, Commodore Road, Oulton Broad, Lowestoft (Marked on 6" O.S. map)

Classification:-

Farrier and General Smith. At one time Wheelwright.

Workshop and attached cottage.

Documentary evidence from 1859 to 1977.

Location:-

O.S. 1" sheet No.137 - Map reference: TM 522929

Local Authority: Waveney District Council

Address of site: Commodore Road, Oulton Broad

Present treatment of site: Demolished in 1978 for redevelopment.

Description of site at survey:

Cottage: Uninhabited. Brick built, roof heavily covered with dead ivy. Group floor boarded up.

Workshop: Main part only remaining. (See plans). Brick built. Main doors sliding. Large boarded-up doorway to storage area above main doors with crane beam above it. Trave no longer present, but line of lean-to roof in reported position of trave could be seen on front wall of workshop. Two forges still present. Flue of second very dilapidated. A single chimney appeared to serve both flues. No tools were present, these are known to have been stolen some years previously.

Owner of site: Hoseason Holidays.

Recorders: Miss E. Marley and G.A.M, Sims.

Date recorded: 1978.

History of the Smithy

In April 1978, men and machines began to demolish the blacksmith's shop and adjoining cottage in Commodore Road. It was sad to see them go, because they had been part of the road, and had been there a long time. Some of the records and events connected with the smithy are recorded below:

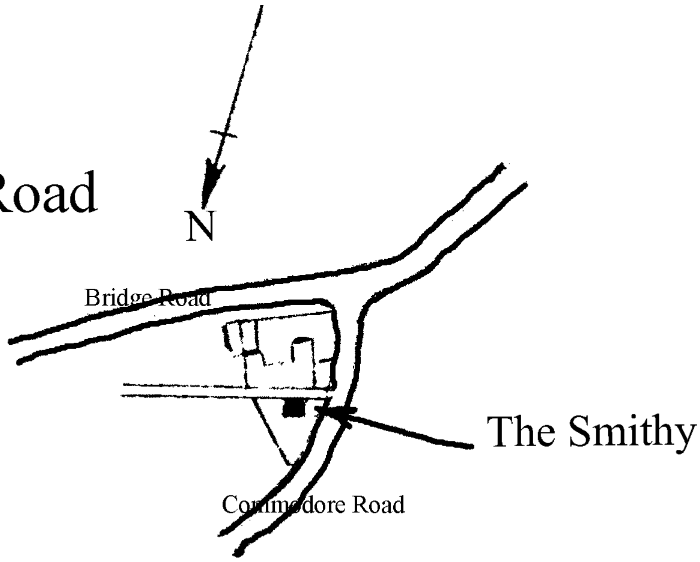
9. 7. 1859 The first mention of the cottage, when Cornelius Knights bought the property for £9. 4. 0d., free from encumbrances.

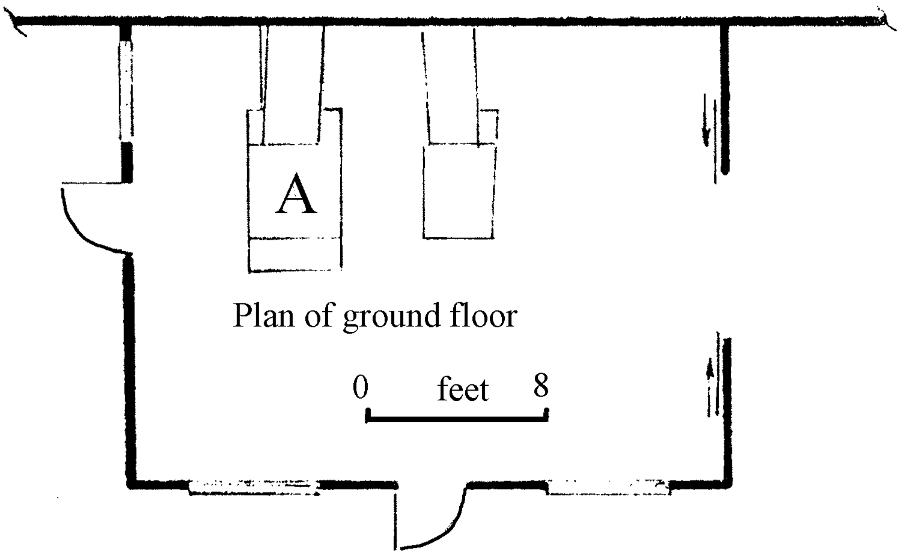
9. 5. 1867 The cottage and tenement garden land and hereditaments, 11½ rods or thereabouts, was on the only road from Mutford Bridge to the Railway Station West, and bounded by a private road on the east. It was sold to Isaac Beaumont, boat proprietor, for £130.

1873 Isaac Beaumont died, and left to his brother Edward his freehold cottage and land wheresoever, household furniture, linen and wearing apparel, books, plate and pictures, churd, horses and carts, carriages, and all boats rowing and sailing; and also all moneys which might be due, owing or belonging. Also all stocks, funds and securities.

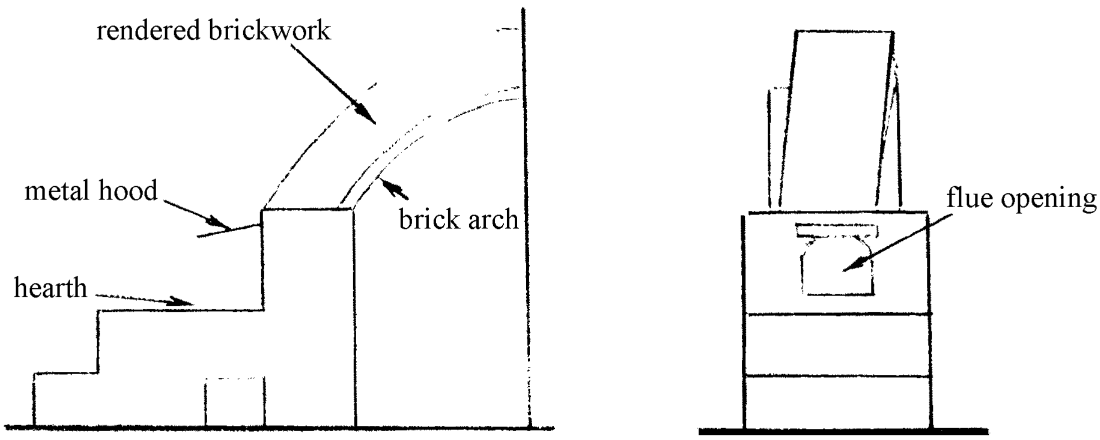
The Smithy
Commodore Road
Oulton Broad

scales indicated are
only approximate





Plan of ground floor



End & Front Elevation of Forge

0 feet 4

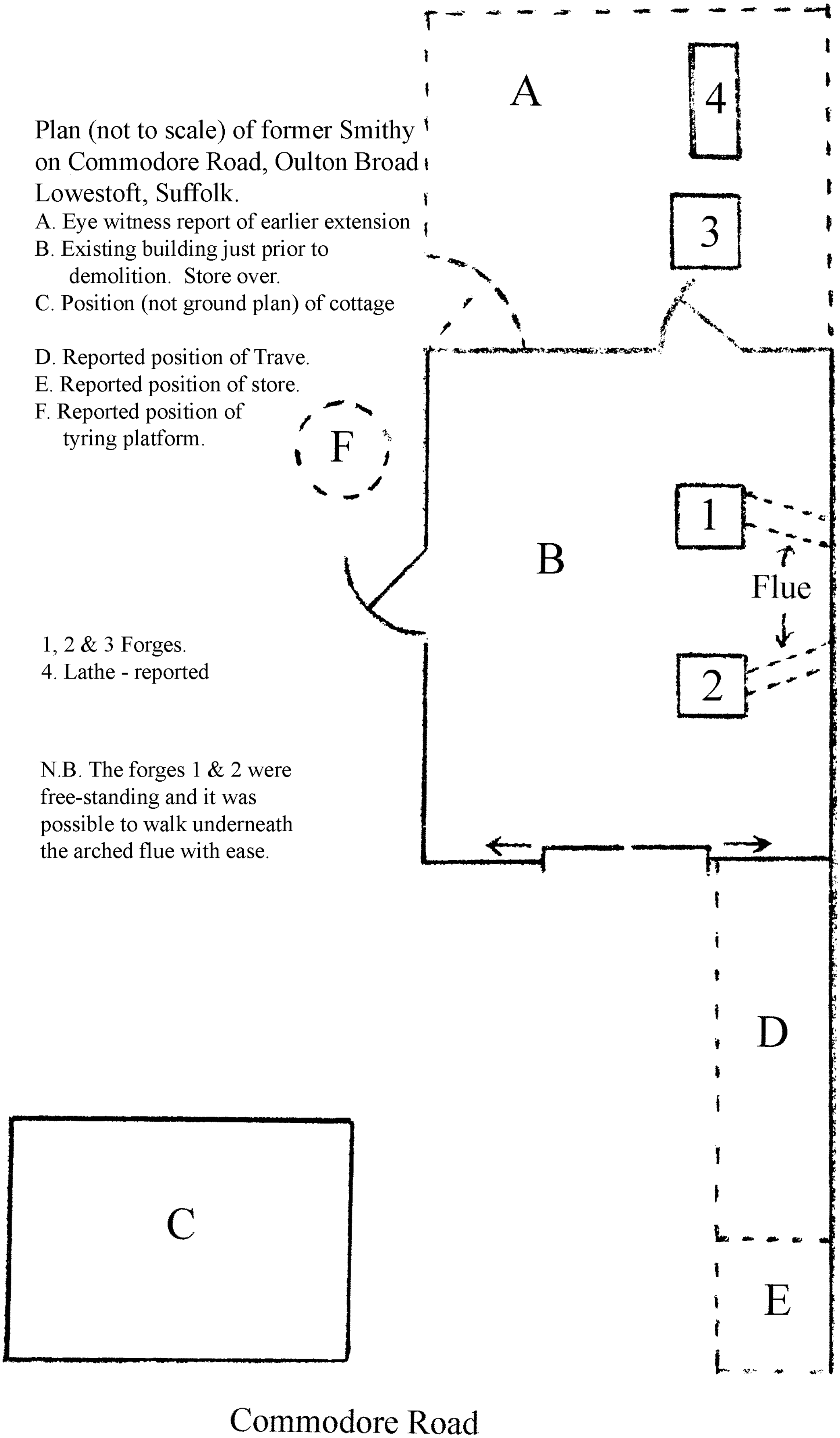
Plan (not to scale) of former Smithy on Commodore Road, Oulton Broad Lowestoft, Suffolk.

A. Eye witness report of earlier extension
B. Existing building just prior to demolition. Store over.
C. Position (not ground plan) of cottage

D. Reported position of Trave.
E. Reported position of store.
F. Reported position of tyring platform.

1, 2 & 3 Forges.
4. Lathe - reported

N.B. The forges 1 & 2 were free-standing and it was possible to walk underneath the arched flue with ease.



The Smithy at Oulton Broad prior to demolition. A.M. Turner 1978

A glowing fire and row of tools at a Smithy in Commercial Road serve as a reminder of the need to record industrial premises and the skills practised there, before they give way to more modern techniques.

1886 Edgar Darby of Oulton agreed to buy the property for £200, for the use of the said Edgar Darby in fee simple subject to an annual land tax" (as assessed in 1885) of one shilling and ten pence halfpenny, and to the tithe commutation rent charge payable to the Rector of Oulton. A mortgage was arranged, £120 to be paid on 8.1.87 and interest at the rate of 5% per annum in half yearly payments. The buildings were to be insured against loss or damage by fire in the sum of £120 at the least in the Sun Fire Insurance Office, or some other insurance office approved by Edward Beaumont.

1899 The mortgage was repaid.

28. 1. 1926 Edgar Darby died, the estate being worth £1056. 17. 9d., duty being paid £18. 17. 7d. The property comprised of a dwelling house and blacksmith's shop. The vendors as personal representatives of Edgar Darby agreed to sell the property and fee simple in possession for the price of £400. The land frontage was 96' 9" or thereabouts, and a depth of 99' 6" on south-east by private road, together with cottage, smithy and other buildings standing. It was arranged that Herbert Olding Darby would carry on business as the firm of Darby Bros. The two other partners died in 1940 and 1941.

1951 Herbert Olding Darby died, and left the property to his widow and two other people. A Mr. Moyse became the only blacksmith left.

1965 Swannells Maltings closed, and so the last horses were shod by the smith.

Mr. Cooper, boat owner, says that in the past horses queued up, and that there were three forges in use at one time. There was a cropping machine for cutting steel, and a lathe. There was also a metal circle on the ground outside the building, where cart wheels were made. The wood was put in position first, and the hot metal rim put round and fastened. When it cooled down, it was a tight fit.

There had been a publicity drive round the country by the Atora Beef Suet people in a van driven by two oxen. These oxen were shod at the smithy.

After this, different work was carried out by the smith. He repaired machinery and farm implements. It was possible to see the glow of the fire from the road, and also to hear the clang of hammer on anvil.

1974 Mr. Moyse died, following his retirement. A search was carried out by Mr. A.A. Taylor. There was a possibility of the front garden of the property being affected by a future road widening scheme.

21. 1. 74 The use of the cottage as a chemist's shop was approved, with the use of a front room as a betting shop.

7. 11. 74 The property was bought by Mr. Hoseason.

9. 3. 77 The property was bought by Hoseason Holidays.

With thanks for Mr. Hoseason for making the deeds to the property available.

THE SIZE OF A BRICK

M.G. Reeder

During a recent visit to COVE BOTTOM brickworks in Suffolk, a remark about 'small' bricks which were being made for fireplaces etc., set me thinking about why a brick is the size that it is. A simple question, with an obvious answer. Let us see.

All the references I could find[(1)] either implied, or stated plainly, that the size of the bricklayer's hand was always the determining factor.

Only JANE WIGHT hints at another reason, viz: the amount of clay it is easy to drop down in a mould.[(2)]

What size is a brick? Smallest are the hard pale 'Dutch dinkers', supposed to have been brought in by Dutch ships in the 17th century. The smallest I have seen is $6^1/_8$" *x* $2^5/_8$" *x* 1¼" weighing 1 lb. 6 ozs. and it came from one of the towers on Great Yarmouth town wall. Another one in my collection is $6^7/_8$" *x* 3¼" *x* $1^{11}/_{16}$ weighing 1 lb.14 ozs. and came from the Middlegate area of Great Yarmouth.

The largest is more difficult to determine. At St. Margaret's House, King's Lynn[(3)] a brick 15" *x* 5½" *x* 2¼" has been recorded and at Caversham near Reading are some late 17th century bricks 22" long by 6" broad[(4)]. Roman bricks range from 6" x 3" x 1" to 24" x 24" x 2"[(5)]. These are the two extremes, which surely illustrate that there is more to the size of a brick than the size of a bricklayers' hand.

How a brick is made and the material it is made from may provide some clues. The Romans brought their technique with them, found the materials which would produce what they wanted, and with suitable modifications for our climate produced excellent bricks. With their military organisation they were able to transport bricks to where they were required. We know little of their methods, but the thinness of their bricks was partly dictated by the difficulty of drying and firing thick sections. More of this later.

When ‘we’ began to make bricks, possibly around 1180, at Little Coggeshall, Essex, everything went right and some remarkably good bricks were produced. Sizes varied, but all were large, 13" to 14" long, 6" wide and 1¼" to 2" thick, and many moulded specials. The technique then seems to have been lost. Several reasons could be involved. Until the 16th or 17th centuries transporting bricks would have been very difficult, very time consuming and very expensive. Therefore bricks had to be made as close as possible to the site of the building and material on site had to be used. To make consistently good bricks requires a good fuel for firing them. Wood and turves can suffice for inferior clay, but a good clay mix may need coal[(6)] and this was not available to many. Records show that coal was in use for royal works in 1437[(7)]. Until the 17th century clay used for brickmaking would invariably be soft weathered, glacial, and recent deposits, either on or near the surface[(8)]. Most contained harmful salts which needed to be leached out. Most needed the addition of sand and fluxes. Until the 17th century it was not common to mix sand with clay[(9)], not necessarily through ignorance but because suitable machinery was not available, and if it had been available could not have been used for temporary on site work. Usually the potential brickmaker set to work with fine grained, sticky unconsolidated mud and clay. His problems were just beginning. How to shape this into any sort of brick? He could not use a mould, unless he were prepared to allow his sticky substance to partly dry out in the mould. This was obviously impractical as he would need thousands of moulds. A method which is proposed by many is the pastry board method. A large sheet of clay is prepared and trodden out with the feet[(10)] on a layer of straw to prevent sticking, and then cut into bricks. If anyone believes this method to be practical, I would suggest they try it. Firstly, how do you get a fairly even sheet? It’s too sticky to roll out and too stiff to tamp, but both would be very time consuming. Next you need to set up some sort of cutting guide and get on the sheet to cut it in two directions. Now if you leave it, it will tend to fuse together again and will take ages to dry. If you attempt to separate the bricks they are not only stuck to each other, but have a mat of straw embedded in them. It may be possible, and have been the method used for a very short time, probably only until 1350[(11)]. Then I suggest a far more efficient method was used.

Bricks are still made in some countries by using a frame, and this is the obvious method used by our medieval brickmakers. One man places dollops of clay at intervals on a bed of straw and another man follows with a simple wooden frame and small container of water with a brush and stick in it. He brushes water on the inside of his frame, places it over the lump of clay, presses this into the corners of the frame, strikes off any surplus with his stick, lifts off his frame and moves onto the next brick. The brick stays where it is to partly dry[(12)]. Each brick is separated by at least the thickness of the frame, say 1" to 2", so there is fairly even drying and no sticking together. Some will argue that cutting from a sheet is the only method which can give the size variation found in early bricks. JANE WIGHT[(13)] refers to NORWICH COW TOWER where the length of bricks vary by up to 4" and width by 2" as proof of the cutting method. But these bricks are also of varying colour, texture and made of unevenly mixed clays[(14)]. These size variations are due to several causes, different clay or mixtures of clays, different firing temperatures, even made at different sites with different sized frames. Frame made bricks have size variations as a result of the above plus sagging and damage whilst the clay is still wet, i.e. wider and thinner at one end.

Now we come back to size. This sticky clay is very difficult to dry, therefore the brick had to be made thin to aid drying. When making in a frame, as much weight of clay as possible is required in the frame, with as little vertical area of contact with the frame as possible. This all lessens the chance of sticking and lifting the brick up with the frame. Also the thinner the brick the less the chance of the clay creeping and spoiling the vertical edges. As in all things a compromise has to be reached because too thin and uneven drying will warp the brick. 1½" to 2" seems about right.

Still two more dimensions to find. It is useful if the length is slightly greater than twice the breadth, not only in the final building but when stacking and firing. We have to consider the weight of the raw clay lump required to be placed for the making and also the weight of the half dry green brick and the final fired brick. Much of this stacking and moving was done by the women and children. Also very important is the thickness of the final wall to be built from the bricks. A 9" to 10" thick wall can be built any length without strengthening piers or buttresses, and to a height of 12 to 15 feet[(15)], even by today’s standards suitable for most purposes. Bricks 10" *x* 20" would be too heavy, so all of this makes the 10" *x* 5" *x* 1½" brick a logical outcome. With the added bonus of being able to build 15" thick walls when required, still using these standard bricks. A 10" *x* 5" *x* 1½" in my collection has a dry weight of 5½ lbs. and needs about 10 lbs. of clay to make it.

Our next stage is drying and firing. This appears to be the least understood part of the process. Some writers on bricks seem convinced it is the same process as baking bread! Here again we find size of bricks a critical factor. Bear in mind that these early bricks were made from unsuitable material, with almost no tradition to act as a guide, no machinery and on temporary sites. This fine grained sticky clay in 1½" to 2" slabs requires a long time to dry especially in our climate. It may be several weeks before the brick is suitably leather hard on the surface to enable it to be stored or stacked. At this point we ought to consider how drying works.

Clay contains a considerably quantity of water, about 50% by weight of our fine ground clay. This water is divided into three types, water of plasticity, pore water and bound water. Water of plasticity is required to lubricate the particles and make the clay workable and accounts for about 25-30% of the weight of the clay. This quantity of water is required in any type of clay when it is to be worked by hand, oven with the addition of sand. When this water has dried out the clay is called leather hard, the particles are touching each other. It can be handled without damage but still has some resilience. Pore water is that which is trapped within the clay when the particles touch. About 10% of the weight of the clay, this water is very difficult to remove. Clay can only dry by evaporation from the surface and needs a constantly moving air flow, very obvious statements, but often forgotten by those who assume these bricks were stacked to dry. I have not noticed stacking marks on this type of brick, but it is obvious many of these bricks were turned on their side, on a straw bed just before they were leather hard. This exposes the maximum surface area, and done at the right moment prevents warping. Even so drying down to the moisture content of the atmosphere, which is the most one can hope for, would take many weeks (one month[16] is a quoted time related to 1644 when techniques had been refined). A large space is required, and constant supervision, with some sort of portable covering. Here again size is critical, the thinner the brick the faster and more even is the drying. In the 17th century, when it became general to add sand to open up the clay, drying and shrinkage becomes less of a problem. Sand stiffens the clay, while still retaining a high percentage of water. This enables the bricks to be handled directly from the mould, allows them to be stacked, and drying can be faster because the sand keeps passages clear for the water to reach the outer surface. By keeping the clay particles apart, shrinkage is loss and more consistent.

Now we come to firing and troubles multiply. If we had some of these bricks to fire today, we would almost certainly use a pottery kiln, with slow energy input and precise control, placing the bricks on shelves, not stacking them. Heat would be applied very slowly with plenty of ventilation, up to about 120°C when all pore water will have evaporated. We have arrived at bound water; this is chemically combined water and could account for up to 15% of the original weight of our bricks. To drive out this water requires at least red heat,. About 450°C is required to begin the process, reaching a peak up to 600°C and finishing about 700°C. At this point the clay has changed its chemical composition and cannot revert back to clay simply by the addition of water. We still need to continue heating up to 900-1000°C to obtain a useable brick. All this heat must be applied very slowly and evenly, a top temperature must be held long enough for the whole brick to reach this temperature, cooling must be equally slow and controlled. Even with this treatment many bricks would fail, mainly due to the uncertain nature of the clay. Shrinkage of this type of clay is large, and some is erratic due to its lime rich nature[17]. Even small stones cannot be tolerated and will cause the brick to split. Any air trapped during making of the brick may well cause a dramatic explosion in the kiln. This danger was not overcome until powered pug mills were used, probably in the 17th century[18]. When we now contemplate stacking our unfired bricks in a long heap, with layers of faggots, bundles of brushwood, tree toppings, hedge slashings and undergrowth generally[19], covering it with clay and earth, and setting fire to it – firing was very slow and uneven, a matter of weeks[20] (a month or more for 1644[21]). I wonder how many useable bricks we would expect to result? Some idea, though from a later period, may be deduced from a load of bricks delivered in 1530 to the King's new Whitehall Palace. It comprised 65,000 'sand' soft under fired bricks; 24,000 hard bricks; 32,000 broken bricks[22]. If these are the proportions achieved in a clamp firing of that period, only one good brick out of five, and that for a prestige customer, then in our beginnings 300 years earlier, one in ten might be a good ratio. Here a brief return to size, because the heat would be insufficient to penetrate bricks of today's thickness[23]. This seemingly archaic method of firing in a clamp, but using coal, was still in use in Kent in the 1930's. Now we come to the point where the size of a brick has always been determined by the size of a man's hand[25], building the wall. Lime mortar was the bonding agent. Nowadays we would consider this to be composed of finely ground lime and well washed and graded sand. Six hundred years ago the lime would be very coarse, and the sand would vary from loamy subsoil to road dust[26]; the mixture would have a long setting time. Mortar joints were very thick occupying about ¼ of the wall surface[27]. With this large quantity of mortar required for each brick, continued one hand laying would be very difficult, also it is almost impossible to keep a thick mortar wedge on the end of thin bricks while laying. Also let us not forget that the medieval hand was smaller than ours[28]. It would seem logical to have one man shovelling on a layer of mortar, and filling the vertical .joints of the course below, with another man placing the bricks two handed. There would be very little incentive to work too fast because with the very slow set of the mortar the height of the wall could only rise slowly. Our medieval wall is now built with bricks whose size has been determined by several constraints, but little influenced by the size of a hand. Although early bricks varied considerably in size from site; to site, our 'chosen' site is typical and I happen to have several in my collection and I can assure you that anyone with a 'small medieval hand' would not be able to continually handle these bricks one handed. These bricks were no fleeting freaks, the methods outlined above continued almost unchanged through to the 17th century, some 500 years! The bricks from this period which survive today are the successes. Then more suitable clays began to be used, no doubt great pressure was building up for a higher quality product. Permanent brickyards grew up close to the material, and finished bricks had to be transported. The size varied very little from previous centuries although the techniques of manufacture change. Better clay blended with sand allowed bricks to be moulded and stacked straight out of the mould, less shrinkage and distortion. Permanent kilns fuelled by coal with better control all led to a more consistent product. The brick tax imposed in 1784, then increased in 1794, led to one of the biggest changes in size, the thickness being increased to 3" to 3¼". In the 1803 increase in tax, the tax on bricks over 150 cu. in. (10" x 5" x 3") was doubled. This effectively sealed the size of our bricks; the weight was reduced by the introduction of the frog. Slightly smaller, more consistent bricks allowed thinner mortar joints, and with quicker setting cement, larger hands, and the demand for faster building following the industrial revolution, one hand brick laying. It would seem that the size of bricks we use today originated because of the limitations of materials and methods during the period from approximately 1100 to 1600 to be slightly modified by the brick tax and standardisation. The brick reduced to meet the hand, and the hand increased to meet the brick. Too often the result to deemed to be the cause.

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