ENGLISH HERITAGE
PRACTICAL BUILDING CONSERVATION

# METALS

ENGLISH HERITAGE

ASHGATE

## TABLE OF ARCHITECTURAL METAL USE: FERROUS METALS

| CHARACTERISTICS | APPEARANCE (CUT SECTION) | OXIDISED COLOUR | CORROSION RESISTANCE | OTHER COMMENTS | ARCHITECTURAL APPLICATIONS | IN COMMON USE |
|---|---|---|---|---|---|---|
| **WROUGHT IRON** | | | | | | |
| Manufactured by smithing, giving a characteristic layered and fibrous appearance | Fibrous<br>Grey | Reddish-brown | Low<br>Needs coating | | Fastenings<br>Small fittings such as locks, chains, and hinges<br>Railings and gates<br>Beams and tie bars | 2500 BC to late 19th century<br>Large components from 18th century onwards |
| **CAST IRON: COMMON OR GREY** | | | | | | |
| Contains flakes of graphite: broken surfaces appear greyish, and form planes of weakness | Granular<br>Grey | Reddish-brown | Much more resistant than steel | Can be cast into intricate shapes | Fireplaces, railings<br>Load-bearing structures (panels, columns, beams) | 15th century to present |
| **CAST IRON: SPHEROIDAL GRAPHITE OR DUCTILE** | | | | | | |
| Malleable metal produced by melting grey cast iron with magnesium: graphite forms spheres rather than flakes | Granular<br>Grey | Reddish-brown | Much more resistant than steel | Can be the same strength as grey cast iron for half the weight | Water pipes, grids, and other types of fittings at risk of breakage | 20th century to present |
| **CAST IRON: WHITE** | | | | | | |
| Extremely hard and resistant to abrasion, but also very brittle | Grey-white | Reddish-brown | Much more resistant than steel | Extremely hard and abrasion-resistant | Crankshafts | 20th century to present |
| **CAST IRON: MALLEABLE** | | | | | | |
| Produced by heating and treating white cast iron | Grey | Reddish-brown | Much more resistant than steel | Good ductility | Locks and other fittings<br>Small components for water systems | 20th century to present |

**1878**

In England, Sir William Siemens patents electric furnaces of the arc type.

**1880**

**1881**

In Russia, Nikolai Benardos creates the first electric arc welding method, using carbon electrodes and known as 'carbon arc welding'.

**1886**

In England, Paul Héroult discovers the electrolytic aluminium process (aluminium oxide is dissolved in molten cryolite and reduced to the pure metal). Discovered the same year by Charles Martin Hall in the USA, therefore called the 'Hall-Héroult' process.

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|---|---|---|---|---|---|---|
| **PURE IRON (SWEDISH IRON, BUTTER IRON, ARMCO IRON)** | | | | | | |
| Workability and strength similar to wrought iron, but homogeneous | | | Poor<br>Needs coating | | | Early 20th century and up to present |
| **STEEL: CARBON STEEL** | | | | | | |
| Contains carbon, manganese and silicon, and possibly other elements<br>Strong, malleable, easy to weld, excellent rigidity<br>Can be cast, machined and extruded | Granular<br>Shiny grey | Reddish-brown | Poor<br>Needs coating | Most important commercial form of iron<br>Different qualities available: rimming steel fully-killed and semi-killed steel (deoxidized with elements such as aluminium or silicon, so there is less gas evolution during solidification) | Used extensively for structural applications | 1880 to present |
| **STEEL: LOW ALLOY** | | | | | | |
| Alloying improves tensile strength, but also resistance to corrosion | Grey | Fine and sandy, darkens with time | Poor<br>Needs coating | Can be cast into intricate shapes | Cladding<br>Roofing | Early 19th century to present |
| **STEEL: STAINLESS** | | | | | | |
| Many different alloys<br>May be cast or machined | Grey | Reddish-brown | Good to very good | Stronger than carbon steel<br>Ferritic stainless steel is alloyed with chromium<br>Austenitic stainless steel is alloyed with chromium and nickel | Cladding<br>Roofing<br>Decorative finishes | Early 20th century to present |

**1890**

In Germany, Hans Goldschmidt develops an aluminothermic process for producing carbon-free chromium, paving the way for the production of stainless steel.

**1900**

Paul Héroult develops the first electric arc furnaces. These gradually replace large smelters for the production of a variety of steels.

**1901**

Standardisation of wrought-iron and mild-steel sections reduces production costs, and simplifies design and construction.

**1904–11**

Leon Guillet of France (amongst others) prepares stainless-steel alloys.

# ASSESSING METALWORK

Before any works are planned, commissioned or undertaken, it is important to allow some time to understand the problems, assess their importance to the conservation of the building or structure, and develop a picture of the ways they might be resolved.

Deterioration and damage will often be obvious, but their causes and their long-term implications may be very much less clear. For effective conservation, it is necessary to really understand the underlying problems: no matter how good any treatment or repair might be, it will not be enough to preserve the metalwork if these are not resolved first.

Conservation assessment aims to investigate the causes of problems, and determine wise courses of action for the future: deciding, for example, whether there is any pressing need for treatment or repair, and if so what needs to be done and how. Assessment must take into account the future not only of the metalwork, but of the structure as a whole. For example, it must consider the possible outcomes of new maintenance regimes, and of any changes of use that might be proposed. This demands a good understanding of:

- the history of the metalwork (including both the original materials and construction methods, and any materials added later)
- the problems and failures besetting it, past and present
- its current condition.

For effective assessment, it is necessary to weave together information from many different sources, which can be roughly summed up under three categories:

### 1. Background Research

Information from existing sources about the history and significance of the structure, and past deterioration and intervention. The historic significance of the metalwork will usually be critical when deciding how best to conserve it. Background research can also make it possible to identify which areas have persistently caused problems, and sometimes even to determine the rate of decay.

### 2. Condition Surveying

Assessment of the current condition not only of the metalwork, but of the structure as a whole. In the hands of experienced specialists, condition surveys are the best and fastest way of building up a picture of past and present causes of deterioration, and predicting what may happen in the future.

### 3. Special Investigations

Detailed research designed to answer questions raised by the preliminary research or the condition surveys; may be conducted by the metal specialist, or by other specialists brought in specifically. Typical investigations include structural assessments, identification and analysis of materials, and long-term studies of the environment.

Crossness Pumping Station, in Bexley, London

*Facing page*: Since even functional architectural metalwork was often highly decorated, aesthetic considerations will usually form part of assessment.

In the Victorian period, railings were most often painted green (as here on the Wellington Arch in London).

'Bronze green' was another family of colours extensively used throughout the 19th century. As the landscape designer Humphry Repton wrote: *"...when painted of a slate colour [cast iron] resembles lead, which is an inferior metal to iron; and if white or green, it resembles wood; but if we wish it to resemble metal, and not appear of an inferior kind, a powdering of copper or gold dust on a green ground, makes a bronze, and perhaps it is the best colour of all for ornamental rails of iron."* A recipe from 1926 indicates how this 'bronzing' would have been done: *"If desired, gold bronze may be put on the prominent parts, as on the tips or edges of iron railings. When the paint is not quite dry, use a piece of velvet or plush with which to rub on the bronze."*

Early specifications do sometimes refer to a bronze green that was to be dusted with metallic powder, though usually a plain mixed bronze green was used. Specifications from the 1850s show both options: at the Clothworkers' Hall in London, the iron railings were to be finished in bronze green, whereas iron shutters and an ornamental iron railing for the Bloomsbury Branch Banking-House were *"to be finished bronze green, bronzed and twice varnished".*

Greens of various kinds were often used on the increasingly popular verandahs, and indeed these were sometimes striped, in imitation of fabric canopies. Since the 18th century a common undercoat for green paints has been grey, which is thought to bring out the green.

Meanwhile, lead colour remained a cheap staple. An 1865 specification for the Athenaeum Club in Pall Mall reveals that all the external ironwork was to be painted in lead colour, except for that next to the street, which was to be *"finished Bronze green as at present"*. As ever, price must have been an important factor: we know that a few years earlier, rainwater pipes were being charged at threepence per foot run in lead colour, but threepence halfpenny in green.

By the middle of the 19th century, specifications began to demand red-lead primers, often coated by a layer or two of iron-oxide paint. Earthy red finishes soon became popular. At the beginning of the 20th century, Paul Hasluck, a prolific writer on all matters concerning paint, summed up the thinking of his day: *"Such colours as indian red, venetian red, and red-lead... are the best for outside work. A red-lead priming, with a finishing colour formed of a pigment mixed with varnish, is the best for ironwork."*

It is very often said that the painting of ironwork with the now ubiquitous black began at the death of Prince Albert in 1861, but in truth it is rarely encountered before the 1960s. Fast-drying black paints became a possibility only with the introduction of alkyd binders in the 1930s, and the disruption caused by the Second World War meant it was adopted only slowly, with dark greens continuing to see great use. Nonetheless, in some circles black became highly desirable, with Basil Ionides in the 1930s insisting: *"…all ornamental ironwork on the outside of a house should be black, or as nearly black as it can be."*

Victorian awnings and railings in London and elsewhere in England are now commonly painted black.

## EXAMPLES OF WHAT TO LOOK FOR WHEN SURVEYING FERROUS METALS

| | DESCRIPTION | COMMENTS |
|---|---|---|
| CORROSION | | |
|  | Corrosion at footings and bases | Common position for water to pool, and maintenance to be poor |
|  | Corrosion of base of metal window frame | Common position for water to pool, and maintenance to be poor |
|  | Crevice corrosion: rusting where water is trapped in small cracks and cavities | Common position for water to pool, and maintenance to be poor |

| EXAMPLES OF WHAT TO LOOK FOR WHEN SURVEYING FERROUS METALS | | |
|---|---|---|
| | DESCRIPTION | COMMENTS |
| CORROSION | | |
|  | Corrosion in areas where paint is not well maintained | Common at the back of downpipes, especially those that are inset into the wall |
|  | Corrosion in areas not washed by rain | Salts, pollutants and other dirt can attract enough moisture to initiate corrosion |
|  | Failure of working parts; for example:<br>• Corroded locks and hinges on gates<br>• Gates unable to open or close correctly<br>• Windows or doors that do not open or close correctly | Failed locks and hinges can lead to distortion as the gates are used<br>Often locks are replaced by chains and padlocks, but these can strip paint from the gate, leading to more corrosion<br>Raising of ground levels and seizing of quadrant wheels are both common reasons for gates to be unable to operate correctly<br>Complicated moving parts such as hinges and locks have many crevices in which water can be trapped; if maintenance is not meticulous, rusting can soon cause these to seize |

## STORAGE

Dismantled ironwork is vulnerable to theft or loss, so insecure loose components must not be left unsupervised.

As well as being clean and secure, the storage must be as dry as possible: ironwork can deteriorate in damp conditions.

Components must not be stacked, and may require some support to prevent bending, as well as protection from abrasion with padding, and a covering to exclude dust. As a general rule, to minimise stress it is advisable to store ironwork, particularly cast iron, in the plane in which it was designed to serve in the building. Panels, window-frames, doors and the like should be stored upright. For long-term storage, regular inspections are needed to ensure the ironwork remains in good condition.

**Parts from the Albert Memorial in London, being stored during conservation works**

Storage can be an important issue, particularly when dealing with extensive architectural metalwork such as railings. Here, these dismantled sections of the Albert Memorial have been labelled with robust metal tags, and stored flat on wooden palettes.

# PREVENTING CORROSION

Preventing corrosion is critical to conserving architectural iron and steel. Two options are possible: to stop water and oxygen reaching the surface; or else to stop the flow of electrons from the anodic to the cathodic element.

## STOPPING WATER ENTRY

The most effective approach is to cut off the supply of water at its source. This can mean something as simple as fixing a leaking gutter, or as complex as adjusting ventilation to prevent condensation. This is only possible for well-protected metalwork, such as elements in building interiors.

In some extreme cases, it may be necessary to consider moving important metalwork indoors or changing its location within the building. ➲ENVIRONMENT

## BARRIER COATINGS

The most common means of preventing corrosion is to apply a coating which can serve as a barrier between the metal surface and the environment, preventing water and oxygen reaching the metal. Paints and other coatings have been applied to architectural ironwork since antiquity, but they are not always successful, and even the best have finite lifespans.

The effectiveness of a coating depends on:

- the condition of the substrate
- the preparation of the surface
- the choice of coating system
- the thickness of the coating
- the environmental conditions
- the ongoing care and maintenance.

Coatings applied to prevent corrosion of ironwork typically include paints (both with and without additional corrosion inhibitors), high-viscosity greases, protective wraps, and conversion coatings. In some very difficult cases it may be necessary to consider electroplating, hot-dip galvanising or metal spraying, but these are all irreversible, and so should be used only where the corrosion problem is severe and intractable and no other coating technique is suitable.

The greatest difficulty with patching may be finding sheet that matches the original profiles, thicknesses and sheet sizes. Wherever the fixing points will be visible, the original fixings should be reused if possible, or else these should be matched as closely as possible.

### Replacement

Decorative elements should be retained and repaired wherever possible, rather than replaced, especially where building is of an unusual type. Corrugated wrought iron is now very rare, and so should be retained if at all possible. Ideally, all characteristic details such as sheet sizes and fastenings should also be kept the same wherever they are visible, although this can be difficult to achieve.

Accumulated weathering – a combination of alterations in surface reflectivity, multiple layers of painting, minor distortions and dents, patterns due to sheet positioning and fixing, and the soft colours of rust – often lends old corrugated iron a special charm, especially in rural settings. Early sheet was thick and soft, and the zinc coating was much thicker as well. Modern sheets are not only thinner but longer, and although long lengths do have the advantage of reducing the number of joints (and hence the risks of leaking and corrosion), repairs made with long sheets will appear very different.

## Sourcing Replacement Materials

Modern corrugated steel is protected with a coating based on aluminium and zinc, comes in very long lengths (and so needs very few joints), and is extremely robust, but it is very different in appearance, being much more evenly coloured and highly reflective, and having a very different texture. Behaviour is different as well: the aluminium means that modern galvanised steel will tend to corrode if it is used in contact with old galvanised sheet. For the same reason, old gutters and downpipes will have to be replaced if modern sheets are being used. Modern sheet cannot be soldered or welded, so replacement gutter sections must be pop-riveted together and sealed with silicon.

Use of modern sheet causes particular problems for old lead flashing, unless great care is taken to prevent the development of galvanic corrosion cells (which will quickly destroy the lead).

Luckily, traditional galvanised sheet is still produced in the UK, not least because of demand from rural areas, where it is commonly used for farm buildings.

Where new galvanised iron cannot be found with the correct profile or thickness, it may be necessary to use second-hand materials. One option is to move the sheets from the building around so that the most visible walls or pitches can be repaired with original material, the remaining areas being replaced with new sheet. ➲ROOFING

## CARE & MAINTENANCE

In adverse conditions, decay can be very rapid. It is important to keep all gutters, drains, roof surfaces and so forth clean, especially where they are not frequently washed thoroughly by rainwater. This is as true for protected areas as it is for low-pitched roofs; such surfaces should be swept down regularly (though the benefits of cleaning must always be weighed against the dangers of foot traffic).

Fastenings should be checked for tightness, and adjusted if necessary: if wind is able to lift the sheet, any problems with fastenings will steadily worsen.

The checker-board patterns that resulted from using small sheets with uneven coatings cannot be replicated with modern corrugated-iron sheet.

# OTHER FACTORS

## WEAR & TEAR

Copper-based metals are often used for moving parts such as handles and hinges, and are also common for architectural elements that are both decorative and functional, such as floor grilles and name plates. To retain their bright finish, brass fittings may be polished frequently with abrasive cleaners. This makes them susceptible to gradual loss of surface detail, and eventually the thinner components may wear away to the point of structural failure.

Polishing can also cause problems for surrounding materials: it is very common to see that the stone around a brass plaque has been stained by metal polish.

Wear and tear on architectural elements made from metals such as brass often incorporates damage to the metal and its surroundings from repeated polishing.

# Monumental Brasses

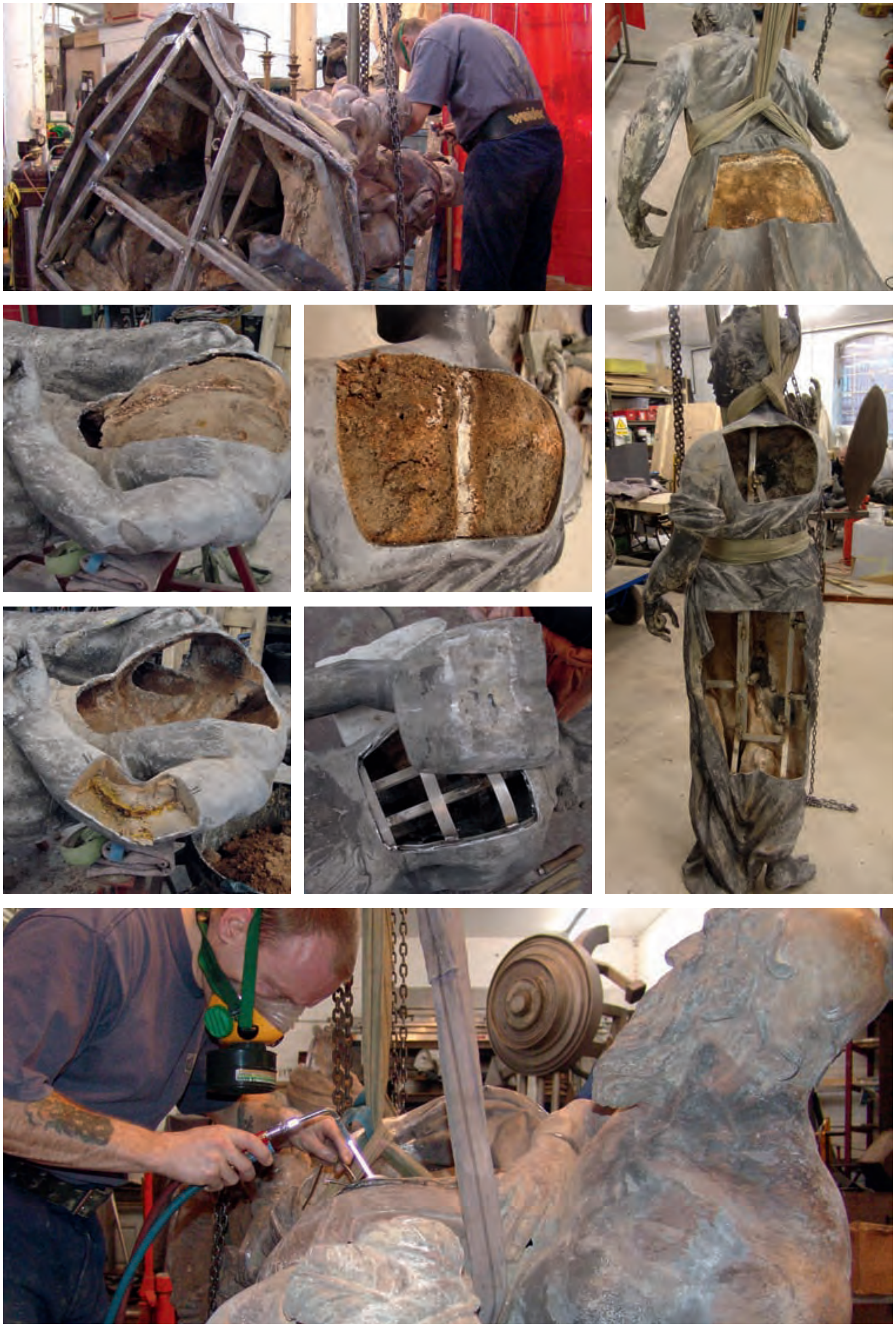
For four centuries, monumental brasses were the most important form of tomb decoration in English churches, and the practice was briefly resurrected in the 19th century. Most seem to have been made by a handful of specialised workshops, and their manufacture survived not just the Black Death but the Reformation.

*"A good many of our bodies*
*shall no doubt*
*Find native graves;*
*upon the which, I trust,*
*Shall witness live in brass*
*of this day's work."*
William Shakespeare (*Henry V*)

Incised brasses set into floor slabs were the most common memorials in England from the early 14th century until the late 17th century, and provide an unmatched picture of how ordinary people wished to be remembered for posterity. Many are depicted in their finest clothing, but others wear shrouds, perhaps to remind passers-by of their own mortality.

'Brasses' were made from sheet metal, decorated and shaped to fit into recesses cut in the stone, mostly in the form of standing or kneeling figures, sometimes cut out around their silhouettes, at other times incised into frames like pictures. The brasses were held in place by brass rivets set in lead caulking in the stone, and were bedded in pitch.

Many Victorian examples had coloured infills, and were protected with lacquer; they were often fixed in place with rivets soldered to the reverse.



Replacing an armature

The core material is removed, so the new armature must be able to provide the support once given by the combination of core and original armature, as well as giving extra support where needed.

# ZINC STATUARY

# CASTING BELLS

Bell founding began in Great Britain as early as the 10th century, and proved a prosperous industry: at one time there were up to 170 known bell foundries. By 1900 this had dropped to eight, and at the time of writing only two remained. 'Bell metal' is traditionally a bronze made up of 77 % copper and 23 % tin; there was a brief period from 1854 to the late 1870s when cheaper steel bells were marketed, but these were not successful.

Early casting used the 'false bell' method, a variant of lost-wax casting, but using either wax or loam. For wax casting, the inside profile of the bell (the 'core') was modelled in an organic-tempered clay, and this was then overlaid with wax, which was shaped using a revolving outer 'strickle board'. The wax was then covered with more clay to make the outer shell (or 'cope'). The whole mould was then baked to harden it, and to melt out the wax. The loam system was probably more used; for this, the core was modelled in the same way, but it was then covered with loam to form the profile for the outer mould. The outer cope made as before, but once dry it was removed, the loam was cut away, and the core and cope re-assembled to leave a void between them in the shape of the bell. In the 1850s, a way was developed to use an inner strickle; this allowed the outer mould to be constructed independently inside a perforated cast-iron moulding flask.

Casting bells, in an undated antiquarian image.

To cast the bell, the assembled mould was lowered into a casting pit mouth downwards, packed round with sand, and the molten metal was poured into the void using a header box. Before transport systems improved, large bells were sometimes cast in the ground near the church for which the bell was destined.

Up until 1850, a wrought-iron staple was cast in to take a clapper (this was also wrought-iron, and was often fixed by means of a leather loop (or 'baldrick'). Until the 20th century, six loops were also cast onto the crown, to be used with strapwork to hang the bell. These loops were known as 'canons', the central canon being the 'argent'. By contrast, modern bells have flat tops and are suspended from bell bolts, and they have a large hole in the centre of the crown to take an independent 'crown staple'. Modern clappers are made from spheroidal-graphite iron.

The belfry of St John the Baptist at Stokesay in Shropshire, where the bell frame is wooden, but the bells have been suspended in the modern manner with bell bolts.

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