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Introduction

Bronze is a common material found on many war memorials as sculpture or inscription plaques and its design is often decorative and intricate. Notable sculptors such as Albert Toft, George Frampton, Charles Sargeant Jagger and Ferdinand Victor Blundstone designed a number of war memorial bronze sculptures. Therefore, as well as being war memorials they have an important role in the architectural and artistic heritage of the UK; this should inform any treatment of the memorial. The use of bronze in a memorial would not have been a cheap option for those commissioning it so it is almost always executed to a high standard and has an important artistic role, often to convey symbolism. This means its protection is particularly important in maintaining the aesthetics and sentiment of a memorial.



Bronze sculpture can evoke the meaning and sentiment of a memorial © War Memorials Trust, 2010

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conservation and repair of bronze is a specialist subject so the aim of this guidance is to highlight the different considerations involved. This will mean informed decisions can be made about options for conservation and repair and that custodians can approach specialist conservators with a brief for the type of work they want undertaken. Further advice on commissioning contractors can be found in the Trust's guidance 'Tendering and obtaining quotes'.

All helpsheets mentioned in this guidance are available from War Memorials Trust's website: www.warmemorials.org/a-z.

Conservation principles

This helpsheet should be read in conjunction with the Trust's 'Conservation: Principles' helpsheet as many of the decisions regarding treatment of bronze raise conservation issues and should be in line with current conservation best practice as far as possible. It is important to remember that we are all custodians of these memorials for only a

part of their life so decisions and actions should always be based on careful consideration of the artistic and commemorative function of the memorial, its history and previous treatment as well as its current condition so it can be maintained for future generations.

All treatment should aim to repair any damage so as to protect the memorial and increase its longevity, whilst maintaining its historic and artistic integrity and allowing the memorial to reflect its age. This will allow future generations to appreciate the memorial in the best condition possible and as close as possible to the original design and materials. We should respect the design decisions made by those who erected war memorials and remember that a memorial is a piece of history that will age so there need to be realistic expectations about what can be achieved. Any inappropriate methods, materials and alterations undertaken can have long-term implications and potentially damage a memorial. In the case of bronze, this damage can be difficult and costly to rectify.

It is important to remember that freestanding memorials containing bronze features, particularly when there are sculptural elements, may be a designated heritage asset, such as statutorily listed. Therefore, before starting a project the planning department at the local planning authority should be contacted to discuss the project and establish whether any consents are required for the work.

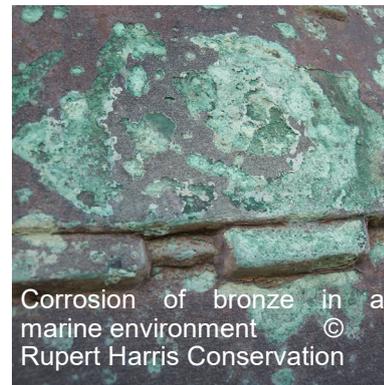
The Trust strongly recommends that a metals conservator with suitable experience should always be employed on conservation and repair projects due to the complex chemistry of bronze and associated treatments, as well as to inform decisions based on the artistic features of the memorial. Details of how to find relevant contacts for metal conservation can be found in the Trust's helpsheet 'Conservation contractors'.

Properties and decay

Bronze is a copper alloy made from roughly 90% copper and 10% tin usually with small amounts of other metals such as lead, nickel or iron; referred to as trace elements. Brass is an alloy of copper and zinc; it is the presence of zinc as the main element after copper that defines the difference between bronzes and brasses. Both these types of copper alloy have been used for the casting of sculpture and decorative elements for war memorials, however they are traditionally generically referred to using the term 'bronze' but have different properties based on their

composition. The main causes of damage or deterioration of bronze are:

- Faults in the casting process
- Structural failure of joints in the casting when the bronze was assembled in the foundry
- Corrosion caused by environmental factors such as pollution, rain, high humidity and salt from marine locations
- Lack of regular maintenance
- Inappropriate past treatments



Problems resulting from past inappropriate action or inaction can result in current condition problems, some of which are very difficult to address. This is why we should be mindful of our actions today to avoid causing problems for tomorrow's custodians.

Structural failure

Bronzes can suffer structural failure as a result of several factors:

- Failure of construction joints in the casting that may be formed by brazing, welding, pinning or occasionally bolts or screws
- Cracking can occur due to casting faults, such as shrinkage or gas porosity formed when the metal is cast, resulting in the production of unsound and weak areas
- Failure can also result if the sculpture has a supporting armature or fixings made of iron; corrosion of the iron can lead to cracking and structural damage

Corrosion

Bronze is generally fairly resistant to corrosion as long as it is regularly maintained, particularly with a protective coating such as a microcrystalline wax. If the protective coating is not maintained then it exposes the bronze to oxygen, pollutants, acid rain and bird droppings which all react with the bronze and corrode it. The wax protective coating will break down, thus requiring maintenance in the form of washing and the reapplication of wax every year to two years. When the bronze corrodes it initially displays a deep brown colour (copper oxide); this develops over many years to a light green, compact surface colouring, often called 'verdigris'. This type of corrosion is slow forming

and fairly stable and can itself afford some protection to the bronze; as long as a protective coating is applied and maintained it is not a cause for concern. The green formed on copper roofs is a typical example of this form of stable copper corrosion. This green surface is also referred to as 'naturally formed patina' and has aesthetic and historic value and is discussed in more detail below.



Bronze naturally patinates to a green finish © Rupert Harris Conservation

However, if the corrosion is 'active' then it is important that it is removed and the cause of corrosion addressed as it actively damages the bronze. Unlike the green patina described above, active corrosion is typified by pitting, pustules, powdering and holes and is bright green in colour. This is normally found in areas that are not washed by the rain so the damaging material can build up and attack the bronze. Although bronze appears solid and substantial from the exterior, due to how it is cast it is usually only thin and hollow so corrosion can eat through the metal and expose the internal structure to more damage as water enters. It is important when considering any treatment of bronze the differentiation between active corrosion and stable green patina is made as they require different treatment.



Active corrosion is typified by bright green pustules © Rupert Harris Conservation

In addition to the green corrosion products of copper in either stable or active form, black deposits of copper sulphide can form on the surface of bronzes particularly in polluted environments, in addition carbon based particulate pollutants can adhere and combine with the copper corrosion often feeling rough to the touch. The action of rain over a bronze surface often results in the formation of a black / green streaked effect on poorly maintained bronzes. These black, crusty and porous accumulations will

hold damaging pollutants and will need to be either removed or reduced to a thin residue to prevent on-going corrosion of the base metal.

Iron fixings

The corrosion of iron can sometimes cause a problem for bronze. Iron will normally feature in the form of fixings if the bronze is fixed to stone, or may also feature as internal supports (armatures) either as part of the original foundry process or later added to try and provide additional structural support. If water is able to reach these iron elements then they will corrode. When iron corrodes it expands and may result in cracking of the bronze due to the exerted force and may also feature as orange staining visible on the exterior.

Depending on the location and damage caused it may be necessary to remove the iron and, if applicable, replace with a more suitable product such as stainless steel or bronze. Any damage which has allowed water to enter the structure will also need to be repaired either by welding (if the damage is severe) or cosmetically using hard wax or tinted inert fillers to stop it re-occurring.



This staining has probably been caused by a rusting internal armature © War Memorials Trust, 2011

Repair options

Depending on the specific circumstances, sometimes a 'less is more' approach is suitable. All repairs undertaken should ideally be reversible and not hinder future repair and treatment options. Structural failure and active corrosion need to be repaired as a matter of urgency by a metals conservator. The cause of the problem should be identified and addressed such as ensuring maintenance or removal of iron fixings.

Repair should in most cases be like-for-like and with the maximum retention of original fabric as possible. This may include patch repairs or reinstatement of lost features, which can be welded or pinned to the original. It is important that traditional materials and methods are used so they are compatible with the original as the use of other

metals (or the same metal of a different



Untreated damage can speed up deterioration due to water ingress © War Memorials Trust, 2010

composition) can cause corrosion as they react with one another (bimetallic / galvanic corrosion). It may be necessary to analyse the composition of the bronze alloy to ensure any new elements are as close a match as practicable.

Small holes and / or pustules will usually require no more intervention once they have been cleaned than the application of the microcrystalline wax. When the bronze has wax applied it is heated up first to allow the wax to adhere better and penetrate more deeply into the naturally porous bronze patina - a process known as 'Hot Waxing'. This also has the added benefit of filling any fine pitting which may have resulted from corrosion and therefore protecting them from water or pollutant ingress. Where there are larger holes or pits it may be necessary to fill them with a hard wax following the application of the microcrystalline wax. Where substantial holes or cracks are evident it may be necessary to use a tinted epoxy filler, however, in outside situations this is likely to shrink over time. Therefore it should only be used where necessary and monitored as part of the maintenance programme so that it can be renewed as required. The root cause of cracks and holes should be identified before a repair method is chosen.



Larger holes can be filled with hard wax © War Memorials Trust, 2013

Depending on the nature of the works and condition of the bronze, it may be required for the bronze to be treated in the conservator's workshop rather than in-situ. This is so that the environmental factors can be controlled and also ensures that surrounding masonry is not affected by the products used on the bronze or by any expansion of the bronze when heated up for wax application which could crack surrounding

stonework. With larger sculptural pieces this may not always be possible.

Cleaning

Cleaning (particularly with abrasive methods) should not be the first port of call; there should be careful consideration of whether cleaning is required, and if so, what the appropriate method is. If you are unsure you should seek specialist advice.

In general it is recommended a metal conservator undertakes all cleaning of bronze but more interventionist methods and those using chemicals should only be undertaken by conservation professionals to ensure that they do not react with the metal and also to ensure the appropriate level of cleaning is achieved. Over-cleaning can be damaging and visually undesirable. Cleaning trials in discreet locations should always be used to identify the appropriate method in each case, starting with the least aggressive.

The following are examples of acceptable methods of cleaning bronze but there are other methods available depending on the soiling which needs to be removed and the condition of the bronze.

- To remove corrosion products and bird droppings wooden spatulas can be used in the first instance (droppings are toxic and must be wetted first, to avoid inhaling dry particulates)
- To remove dirt and pollution clean with de-ionised or distilled water and pH neutral soap using a lint-free cloth or natural soft bristle brush. Rinse and dry with another lint-free cloth. This can be used for general maintenance or prior to re-waxing. In general, cleaning methods more aggressive than this should not be required
- To remove greasy deposits use the same methods as above but the soap may be diluted 1:1 with white spirit to help remove the grease
- To remove paint use non-caustic methylene chloride-based gel. Steam cleaning, such as the DOFF system, may also be used. This should only be undertaken by a professional
- Generally steam cleaning can be used on bronze to remove corrosion, dirt deposits and degraded wax or lacquer coatings if the less interventionist methods do not prove successful. This should only be undertaken by a professional
- In extreme circumstances where there is active corrosion more abrasive methods such as TORC / Jos or bronze / stainless steel wool may be used. This type of cleaning should only be undertaken by a professional and after

eliminating all other options. Abrasive techniques should be localised to areas of active corrosion only and use the softest abrasive material possible to achieve corrosion removal. Significant and irreversible damage to the bronze surface can result from the misuse of air abrasive techniques

Do not use:

- Metal brushes as they can damage the surface and leave deposits which react with the bronze (bimetallic / galvanic corrosion). In some cases the use of phosphor bronze brushes may be required but these should not be used for general cleaning and should only be specified and used by conservators
- Air abrasive or blast cleaning, unless the condition of the bronze is such that no other alternative is available; uninformed use will damage the bronze surface. It is important to be aware that the removal of stable green patina is not advised and the client should seek clarification and justification from the specialist should abrasive cleaning techniques be suggested
- Abrasive papers and cloths as these can be severely damaging, however, if used by specialist conservators carefully and locally they may have use on areas of black crusty copper sulphide streaking to reduce their visual impact
- Acid or alkali-based cleaning products as these can etch the surface and enter the casting through joints and casting flaws where they are unable to be removed; if this happens the chemicals will promote further corrosion
- Laser cleaning is not recommended for use on bronze as it is not possible to accurately remove only the corrosion products and therefore may affect sound patina
- High pressure or jet wash cleaning as it can damage the surface or any weak area and encourage water into the structure
- Commercially available or household cleaning products such as 'Brasso' as they can damage the bronze or leave damaging salts and deposits

Cleaning using any abrasive methods should be a last resort and the benefit of undertaking the work would have to clearly outweigh the potential damage caused to the memorial by its implementation as it can result in the loss of historic patina. This type of cleaning should only ever be undertaken by a metals conservator. More abrasive methods such as TORC / Jos should only be used in exceptional circumstances where there is active corrosion present and should be limited to these areas as they will clean the bronze back to the bare metal, thus removing any evidence of the

historic surface developed over the years. If abrasive cleaning is used these areas may need to be re-patinated after cleaning so they match the surrounding bronze. It is important that active corrosion is treated urgently by a metal conservator as if left un-treated it will continue to deteriorate and corrode the bronze.

It is important to remember that war memorials are historic structures and will therefore have imperfections and show signs of ageing and deterioration, but this is part of their intrinsic value. It is important to balance this consideration with treating any damage and ensuring any future potential damage is minimised. The choice of cleaning method and its impact on the appearance of the memorial should always be carefully considered, ideally with the input of a conservator.

Re-patination

Patina is the surface coating of the bronze and can either be natural, resulting from the reaction of the material with the environment, or it can be artificially applied by use of chemicals.

Traditionally, when the bronze was originally cast, an artificial patina would have been applied to create a particular surface colour. A protective coating (commonly wax, and sometimes lacquer in an internal environment) was then applied over the patinated surface. Bronze will commonly display a green verdigris patination on the surface. This can be artificially applied, but is more likely to have naturally occurred as a result of lack of maintenance and is widespread across bronze memorials.

Some consider this green surface as undesirable or unsightly, however it is now commonly considered aesthetically acceptable and a part of the history and story of the memorial, its original fabric and reflection of its age. Although this natural patina is essentially evidence of corrosion of the surface of the bronze due to oxidation, once this patina is formed it actually slows down the rate of corrosion, protects the bronze and can be considered stable i.e. not active.

As long as it is maintained regularly in



Natural formation of patina © Rupert Harris Conservation

the future by cleaning and application of a protective wax coating this finish may be considered as contributing to the visual appearance of the memorial. However, if the corrosion is active as discussed above, then it will need to be removed to protect the bronze.

Particularly in the case of statuary, bronze can be very evocative and integral in expressing the sentiment of the memorial and the patination of the sculpture is an essential element of this. Likewise, inappropriate patination can make a sculpture or plaque appear dull and lifeless and in some cases can be distracting and remove any reference that the original material was bronze. Carefully considered patination can bring sculpture to life through the use of light and shade and therefore aid in telling the story of the memorial and what it illustrates.

Many different colours can be used for artificial patination and this is achieved through the application of specific chemicals. However, the typical colours used on memorials are black, brown and green in varying shades. Traditionally, a mid to dark brown was used and this is probably still the most common colour and the least contentious. It is very difficult to determine the original patination from the material itself. Without this physical evidence, documentary or photographic evidence is very important. Research should take place to try and identify the original patination of the memorial and in some cases the original intention of the sculptor can be uncovered; see the Trust's helpsheet on 'Researching the history of a war memorial' for guidance. Unless evidence can be found of the original patination colour it is not possible to knowingly return the memorial to its original patina colour. It is contrary to conservation best practice to reinstate a patina where there is no historic evidence for such work. In some cases it may be appropriate to adopt a local precedence used on other bronze sculpture or a finish used in other sculptures by the same sculptor if they are well-known.

If re-patination is undertaken this should be done by patinating over the existing naturally formed patina rather than removing it first, as this removes the need for more abrasive methods such as the TORC or Jos systems. As discussed, re-patination should be sensitively applied, respecting the design of the sculpture. If appropriate, the underlying green patina can be incorporated in the visual surface finish. Paint should never be used as a coating on bronze.

The re-patination of bronze is a contentious area of conservation and therefore needs to be carefully considered on a case-by-case basis. If you are

planning to apply to the Trust for grant funding and re-patination may be included in the project you should contact the Trust's Conservation Officers to discuss this element. The local community should also be consulted on re-patination as it can dramatically alter the appearance of a memorial and they may react to the change. Due to the commemorative function of war memorials there is generally a more flexible attitude towards their re-patination compared to other historic monuments.

Bronze staining of masonry

Bronze will often be combined with stone, such as a plinth for statuary or bronze plaques on a stone memorial.

If the surface protective coating on bronze is not maintained, not only will the bronze turn green, but also this colour (copper sulphate) will be transferred onto surrounding masonry by rainwater. Although some metallic salts will be deposited onto the stonework it does not cause significant harm and is essentially an aesthetic issue which can be unsightly and distracting. The options available in these cases are limited. It is unlikely to be possible to completely remove this staining, although it can be reduced. The older the staining is the more difficult it is to remove. Simple cleaning will not remove the staining as it penetrates deep into the pore structure of the stone so the most effective method of removal is by ammonium chloride or EDTA-based poultice, the appropriate poultice will be dependent on the type of stone. Poultices draw out staining by capillary action, which is required for this type of staining. Porous stones such as limestone or sandstone are far more susceptible to copper salt staining than a more compact stone such as granite.

Although poultices can be employed it needs to be carefully considered whether their application is



Bronze is typically chemically re-patinated to a mid-dark brown © Friends of Spa Gardens, 2011

suitable for what is essentially a cosmetic issue and which cannot be completely resolved, only alleviated. This decision will be based on the extent of staining and condition of the stonework. If the stone is in poor condition, unnecessary treatments can accelerate the decay of the stone. In cases where the stone affected is limestone a limewash can be applied to cover the staining, but this will need to be re-applied periodically. If the microcrystalline wax coating is maintained on the bronze it will prevent further staining.

Theft

Unfortunately bronze is subject to theft and vandalism, whether opportune, for scrap value or art theft. Therefore, it is important to protect the memorial as much as feasibly possible against this. The Trust, in collaboration with English Heritage and Historic Scotland, has produced guidance on 'War memorial theft: Prevention and solutions'; it is strongly recommended the relevant guidance from this is implemented. This type of protection will often not involve the memorial itself but its surroundings and recording of the memorial. It is also recommended that insurance of the memorial is considered; please see the Trust's helpsheet on 'Insurance for war memorials' for further guidance.



To repair damaged or stolen bronze, in the first instance ideally like-for-like repair and replacement should be adopted along with additional anti-theft measures such as additional fixings (ferrous fixings should never be used). If there is persistent theft of bronze then an alternative material may need to be considered but it is important to ensure any replacement is appropriate both aesthetically and in terms of its relationship with the existing materials as they could accelerate decay. The Trust recommends that where an alternative material is required this should be traditional and in-keeping with the rest of the memorial (for example, stone indent or plaques). The Trust does not recommend or support the use of resin or imitation metal plaques.

The Trust strongly recommends that all custodians of memorials with metal elements apply for the In Memoriam 2014 project. This is a partnership between War Memorials Trust and the SmartWater Foundation which protects memorials at risk of theft or damage by marking them with a forensic liquid called SmartWater. The crime prevention fluid, which is being made available at no charge, will not only make memorials uniquely identifiable, it also offers robust traceability should a theft occur. This will act as a significant deterrent to those considering desecrating our war memorials by massively increasing their chances of detection and subsequent arrest. Further details and how to apply are available on the project's website: www.inmemoriam2014.org.



War memorials can be victims of theft © Wolverhampton City Council, 2011

Maintenance of bronze

Maintenance of bronze is essential to its long-term protection and should be of prime importance to all custodians. Although maintenance needs to be undertaken regularly, it is low-level. Maintenance will help to protect the bronze as well as the surrounding stonework from staining and will identify any potential damage and failure early to reduce the likelihood of more severe damage occurring, which can be destructive as well as costly to repair.

Maintenance should comprise annual inspections of the bronze to monitor condition and to identify corrosion, damage or any signs of structural failure at an early stage; the Trust's 'Condition survey' can be used to assist with this. If the bronze is in good condition then the protective microcrystalline wax will need to be cleaned off and re-applied roughly every couple of years following the recommendation of a metal specialist. It is important the wax is regularly removed and re-applied to ensure it adequately protects the bronze. Paint should not be used as a protective coating as it is difficult to remove and causes problems when it begins to break down as it allows water, pollutants and air to come into contact with the bronze which can cause decay. Paint also does

not create a visually acceptable finish for bronze. Lacquer should also be avoided as this will crack causing differential weathering and is much harder to remove and re-apply than a wax coating.

The patina does not need to be removed before applying the wax but it will need to be cleaned to make sure no pollutants are left which can attack the bronze underneath the wax. Depending on the circumstances, suitable cleaning methods include water and pH neutral soap or steam cleaning as outlined above.

Maintenance of stone

As with bronze, regular inspection of the stonework is advisable, in particular the mortar joints. Water penetration through failed mortar joints into the structure of the monument can cause significant damage if left unattended for long periods. Frost damage such as spalling of the stone or in extreme cases the dislodging of the stone itself may result. If mortar repairs are required, they should be undertaken by qualified conservators or stonemasons using the correct techniques and materials.

Please see the Trust's stone conservation helpsheet for further guidance.

External sources of information

Historic England, *Practical Building Conservation: Metals* (Surrey: Ashgate Publishing Limited, 2012). <https://historicengland.org.uk/images-books/publications/metals-conservation/>

Historic Environment Scotland, *Inform Guide – Bronze* (2005). www.engineshed.org/publications/publication/?publicationId=ab4370d9-d0a6-4e44-b63a-a59500abeab6

Historic Environment Scotland, *Short Guide – The repair and maintenance of war memorials* (2012). <https://www.engineshed.org/publications/publication/?publicationId=abea0f18-bd2b-43f3-9b60-a59101039dc0>

Rupert Harris, 'Conserving Outdoor Metal Sculpture' in *The Building Conservation Directory* (2006). www.buildingconservation.com/articles/conservingsculp/conservingsculp.htm

Please note that this helpsheet is intended to offer informal advice and is a distillation of experience. The information contained in this helpsheet is not exhaustive and other sources of information are available. War Memorials Trust is not responsible for the content of external sources.

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