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The Bronze Sculpture Studies of the Swedish Central Board of National Antiquities

Background

From 1987 funds were provided by the Swedish Central Board of National Antiquities for repairing damaged bronze sculptures and at the same time investigating the effects on outdoor sculptures of bronze to see whether their character and extent are such as to justify a major remedial programme. The work was carried out until 1994 through the former institute RIK, which was part of the Central Board of National Antiquities and the National Historical Museums.

For this work it was considered to be of utmost importance for the corrosion specialist, the technician, the conservator and the restorer to know the viewpoints of art historians, antiquarians and aesthetic experts as to what a sculpture should look like and why. Accordingly, ethical and aesthetical discussions are a highly essential part of the development process, and the choice of methods and materials to be included in the tests entailed by the research side of the project have been guided and sometimes decided by considerations of this kind.

It is appropriate here to mention a fundamental difficulty connected with the improvement of conditions in the conservation field. Conservators, art experts, material chemists, technicians and traditional craftsmen all have very different ways of looking at things. As a result, very different interpretations can sometimes be put on objective, direct observations, due to this very difference in frames of reference. One is greatly tempted to infer that representatives of the different competencies tone down other specialists' perspectives as irrelevant or perhaps fail to understand the true nature of the problem.

These difficulties should not be regarded as an embarrassment to be avoided but as central core issues which can only be tackled head on. For this work, the aim has always been to achieve a constructive partnership between the different competencies. Happily it has proved possible to find competent representatives of different fields who are actively interested in working towards a common goal. It is thanks to their efforts that essential parts of the work have been made possible.

Aims

The overriding aim of this project has been to make it possible for owners of public sculptures to give them adequate care and maintenance. Work under the project was made to focus on four partial objectives, viz:

1. Investigating how harmful air pollution is to the bronze material in the instances and environments investigated.
2. Devising methods for ascertaining whether and if so to what extent a bronze sculpture has been damaged.
3. Investigating the suitability of existing methods of restoration.
4. Testing serviceable materials for the conservation, maintenance and corrosion protection of bronze sculptures in the outdoor environment.

Structure of the Project

Work proceeded both within the co–ordinating institute, RIK, in the form of project management and compilation of results, and in the form of contracted work comprising both research, inventory and remedial measures. The internal work also included a certain amount of research and the compilation of input documentation for an inventory.

The contracted restoration work was undertaken in association with Gunnar Petterssons Konstgjuteri, Stockholm.

Most of the research was contracted out and undertaken in association with the Department of Inorganic Chemistry, Chalmers Institute of Technology and the University of Göteborg, and with the Swedish Corrosion Institute. In connection with restoration work material studies were carried out in RIK. An in-depth inventory of 14 selected bronze sculptures in Göteborg was undertaken by the Heritage Conservation Department of Göteborg University. This work also involved co-ordination with the Eurocare project COPAL.

Co-operation has also taken place with representatives of the sculpture conservation workshop at the Nationalmuseum, Stockholm, with representatives of the Stockholm City Museum and with the sculptor Liss Eriksson. These persons served as an advisory working party in connection with sculpture restorations and took part in a field trip to Paris. Field trips were also undertaken to Germany and Czechoslovakia.

Studies under the Project

Research

In 1987 R&D began with a study of literature aimed at updating the research situation on the corrosion and surface protection of bronze material.

Some of the R&D work within the project was concerned with improving our understanding of the patination process and of the composition of patina, especially patina which is of variable appearance, e.g. patchy or streaked.

A special study was made of the layer structure of patina coatings in differently coloured and structured areas. The purpose of these studies was, if possible, to find connections between the outward appearance of the patina and the state of the underlying metal.

Special studies were also made of various cleaning methods and of methods for surface treatment and protection. It was not the aim of this project to devise a universal method of bronze sculpture restoration.

The treatment of works of art as if they were standardized industrial products is quite inappropriate. Instead the idea was to utilise existing knowledge, above all that possessed by bronze founders and patinators, and to investigate the effects and consequences of different treatments from an art–theoretical, aesthetic and technical viewpoint.

The studies in technology and material science undertaken as part of this work were intended to broaden and deepen our understanding of various topics and to establish a foundation of material technology and material science.

R&D at the Swedish Corrosion Institute

Various methods for cleaning corroded bronze were studied at the Swedish Corrosion Institute (SCI). Chemical and mechanical methods used both in corrosion protection and in conservation were investigated in order to establish their cleaning efficacy and to gauge the degree of metal removal which cleaning involves. In connection with this work, a number of the blasting agents were also tested under craft conditions at the Pettersson art foundry.

The conclusion arrived at is that all cleaning methods which to any extent dissolve or remove the corrosion products also attack the underlying metal to a greater or lesser extent. The degree of attack depends very much on the skill of the person who does the cleaning. Blasting has been widely criticized, but, competently performed, it has proved to entail less metal removal than, for example, the method preferred by conservators, namely treatment with the complex former EDTA.

SCI's tasks also included investigations of the various types of patination that occur and of the ways in which they attack the metallic surface patinated. The findings show that the patinations tested have a metal consumption equalling no more than between two and five years' corrosion of unprotected bronze in Swedish urban atmospheres of the 1980s. The traditional artists' patinations consume slightly more material than the industrial ones, but the latter are generally ruled out by aesthetic and/or craft-related considerations.

SCI, acting in collaboration with RIK, has inaugurated an extensive exposure of patinated and surface–treated bronze material. This will continue for eight years at three field stations, two of them in Sweden and one in the Czech Republic. The exposure involves unpatinated bronze and two kinds of brown-patinated and green-patinated material, one of them patinated by a patinator, the other in a laboratory using industrial recipes. These materials are being exposed both uncoated and with the following coatings: microcrystalline wax, beeswax, acrylic varnish and INCRA varnish, i. e. acrylic varnish with corrosion inhibitor. An industrial method for green-patinating copper roofing is also included in the exposure, but only without organic coating.

Laboratory Study of the Impact of Corrosive Substances

Some years ago a great deal of interest came to focus on the possible influence of nitrogen dioxide on various degradation processes, above all as regards the interaction of nitrogen dioxide and sulphur dioxide. After the concentration of sulphur dioxide in Swedish urban atmospheres had been considerably reduced from the 1960s onwards, whereas no such reduction of nitrogen oxides had been achieved at all, a certain amount of attention came to focus on the harmful effects of these gases.

The Department of Inorganic Chemistry, Göteborg, was engaged to investigate reactive mechanisms for these corrosive gases and statue bronze. That work was conducted by Peter Eriksson in close collaboration with the project at the Central Board of National Antiquities and formed part of his doctoral thesis.

The results of the experiment show that the atmospheric corrosion chemistry of a technical alloy like that under consideration involves several parallel reactions. The situation is further complicated in the case of a traditionally patinated and waxed statue bronze in an outdoor atmosphere during changeable weather.

The results obtained in the study convey a deeper insight into the reactions which can be expected in outdoor bronzes, but they are not to be used as a basis for in-depth conclusions as to which factors determine the corrosion of real objects in outdoor surroundings, especially not as regards more long–term processes. There are two main reasons for this reservation:

1. the impact of rain–flushing of parts of sculptures is considerable and was not simulated in the laboratory studies;
2. the study concentrates on short–term and initial processes, the longest exposure time was four weeks.

It may be appropriate to ponder the results obtained in the light of our knowledge that, normally speaking, copper oxide and brochantite can be identified on bronze sculptures and, in chloride-containing environments, atacamite and paratacamite as well, among other substances. These solids are thermodynamically stable in contact with aqueous solutions containing divalent copper ions in fairly low concentrations and sulphate and/or chloride.

The study confers new insight into the existence of several reactive paths for corrosion processes which can include both nitrogen compounds and sulphur compounds. In the light of this new knowledge there seems little point now in pursuing the studies in much greater depth, because the relative proportions of the different parallel reactions can be expected to vary a great deal, depending on the ambient conditions of real outdoor sculptures. In such conditions there is probably little point in defining a number of model systems for different conditions, unless there is found to be reason for devoting very large sums of money to research in this field.

Results are now available showing that there are several possible chemical reactive paths for the formation of the constantly recurring corrosion product components. It is reasonable to suppose that these compounds are formed under conditions which could be termed quasi–equilibrium between the solid phases and aqueous solutions containing copper (II) ions, sulphate ions, chloride ions, nitrations and so on. With varying wetness on the surfaces, no doubt both dissolution in and precipitation from aqueous solution occur.

Surface Cleaning at Restoration

When restoring sculptures one is sometimes forced to remove both old patina and perhaps other solid precipitations on the surface. It is very important to be able to do this with the least possible removal of the underlying metal and with a reasonable work input. There are several divergent opinions as to how this should be achieved. Apparently the only consensus opinion is that, in chemical cleaning, one must not use acids for this kind of work. In this study very careful and competent sandblasting was mostly used.

The Structure of the Patina Layers

Studies of material specimens from remediated sculptures have been performed at RIK on scraped corrosion specimens, on

ground sections of drilling cores and on drilled metal chips. The metal analyses, performed with ICP, show that all the alloys used have a copper content of about 85-90%, with varying proportions of tin, zinc and lead. The analyses of corrosion products, performed using XRD (Debye–Scherrer and Guinier-Hägg), mainly indicate the presence of copper oxide and brochantite, and in one or two exceptional cases also of antlerite, a basic copper sulphate with a higher sulphur content than brochantite. The latter apparently occurs on well–protected surfaces which are not flushed by water. Studies of material from Göteborg have also revealed atacamite.

The metallographically polished sections of the patina layers were examined in an optical metal microscope and a scanning electron microscope, and were analyzed with energy-dispersive X-ray fluorescence in SEM. These analyses show that black zones on the surface of the sculpture next to the metal have a thin layer of copper oxide, over which there is a layer consisting of a mixture of brochantite, various airborne solid contaminants like quartz, soot etc., and a tin compound which is not crystalline, probably SnO_2. An outermost layer contains brochantite only, together with the solid impurities. Under green surfaces, i. e. the water–flushed upward–facing surfaces and in green streaks, copper oxide was observed nearest the metal and, in an outer layer, a mixture of brochantite and the tin compound which recurs all the way to the outer surface. Thus in the green zones there is an accumulation of tin caused by leeching of the water-soluble copper sulphate from the patina. At the same time the impurities making the patina black are washed away.

Inventory

Limited inventories have been compiled as a basis for practical work and to gauge the extent and type of existing damage. This work was restricted to a total inventory of bronze sculptures in the Municipality of Sundsvall, which was formerly known for its extremely polluted air, and an indepth inventory of 14 sculptures in Göteborg. The latter describes and documents type and extent of damage. The composition of the patina, in terms of its constituent chemical compounds, is an essential part of this account. That work was done by Helena Strandberg of the Heritage Conservation Department, Göteborg University.

Within the Municipality of Stockholm, a general inventory of older sculpture in the inner city was compiled by RIK. It was on the basis of that inventory that sculptures were selected for the remediation measures carried out as part of this project.

Inventory work has shown that most of the outdoor bronzes require curative treatment in the form of washing and waxing but are not in need of any more extensive restoration. In Sundsvall, reputed to have had the worst air in Sweden, only the two oldest sculptures have developed a patina which can be considered to indicate damage to the bronze. Those sculptures were erected in 1911 and 1935 respectively. The other bronze sculptures, the oldest of which dates from the 1940s, are in satisfactory condition.

In nearly all known cases, including other towns and cities besides those mentioned here, the care and maintenance of outdoor sculptures is a practically unknown concept. There are occasional exceptions, e. g. when a sculpture is covered over for the winter and washed down and polished in the spring. Such exceptions are salutary and show that even regular care of a very simple kind will keep a sculpture in extraordinarily good condition and presumably eliminate entirely the need for expensive restoration measures at some later date. Besides, works of art which are looked after are aesthetically more attractive. It should be vigorously emphasized that works of art which are placed outdoors require regular attention.

Restoration Measures

The purpose of remediation work was to deal with outdoor bronze sculptures which are in acute need of attention. Another purpose was to provide knowledge and information concerning bronze sculptures and their properties and states, as a basis for directions concerning inventory work and future remediation. Altogether nine objects, of different ages and sizes and in different conditions, have been dealt with.

Four of them were treated in order to investigate the reversibility of a new method of treatment. The other five objects were treated due to their having developed various kinds of patina indicative of different types of damage. The youngest of them has been exposed to the elements since 1949, the oldest since 1867. All the sculptures are located, and always have been, in the inner city of Stockholm, where the situation of air pollution has varied both geographically and historically. In all five cases it proved impossible to obtain any information about the surface treatment and appearance of the sculpture at the time of its erection.

In connection with restoration work, samples were taken from some of the sculptures in the form of drilled metal chips for the determination of their alloy composition. A number of drill cores were also taken in order to study cross-sections of metal and patina, as well as scrape specimens for phase analysis of corrosion products.

The Sculpture Restoration Working Party

All treatment of sculptures within this project was discussed by a working party recruited in such a way that various interests and specialists had an opportunity of communicating their viewpoints. The members of the working party were:

Liss Eriksson, sculptor,

Jan Gullman, inorganic chemist, corrosion specialist, the Central Board of National Antiquities,

Gunnar Pettersson, artware master founder,

Elisabet Tebelius-Murén, sculpture conservator, Nationalmuseum,

Mille Törnblom, metallurgist and project leader, the Central Board of National Antiquities,

Bo Wingren, art historian, the Stockholm City Museum.

All remediation measures were discussed within this working party, and before action was decided on it was established what would be suitable and, above all, what end result was being aimed for. On this basis it was decided what would be technically permissible. Clear reasons were given for physical interference with the objects restored, and in such cases no more was done than was judged to be necessary.

Corrosion Status of Selected Sculptures

Four of the five objects treated seemed at first sight to be in much the same condition. They all had the typical spread of up-

ward-facing green zones, with a black patina on the vertical and protected zones, and green streaks running down from the green zones over black surfaces. Closer inspection, however, revealed essential differences.

Restoration of Selected Sculptures

Sampling

Sampling was undertaken when considered justifiable, as described in the reports on each individual sculpture restoration. All samples were archived. Insofar as the samples have been analysed, the analytical findings are presented in the report concerned.

Cleaning

For the remedial work, which was done at Gunnar Pettersson's artware foundry in Stockholm, careful blasting was the principal method used.

To achieve the aim of understanding and assessing the extent of damage beneath different kinds of patina, two of the sculptures were blasted clean. Blasting yielded important information concerning the extent of the corrosion process. The older of the two sculptures had a heavily corroded surface with pitting up to 0,5 mm deep. The metal under the green streaks was deeply furrowed. The later sculpture had quite an extensive streaking pattern but no visible attacks in the metal after cleaning.

The other two sculptures which were blasted were not cleaned right down to a purely metallic surface. The aim here was to make a full-scale study of using blasting to remove only the outer patina layer which had to be removed for cleaning – that is the glotchy, uneven outer layer stained with soot and grime – so as to leave the bottom layer of copper oxide and parts of the green brochantite layer above it in situ as an underlay for patination.

Patination and Surface Protection

The repatination work was done by a professional patinator, Karin Wassberg, just as all the previous operations were performed by a professional artware founder and chaser. Above all, patination serves an aesthetic purpose, but together with surface treatment afterwards, it can also provide a corrosion-retarding coating.

The sculptures which were blasted absolutely clean were first given a dark basic patination to which a green patina was applied, and they were then waxed. On some sculptures beeswax was used, on others microcrystalline wax.

One sculpture was not blasted at all, but only cleaned by washing and grafitti were removed by organic solvents. Then it was given a slight retouching of facial patina after cleaning, and was than waxed with beeswax.

Conclusions

The studies commissioned from the Swedish Corrosion Institute and the Chalmers Institute of Technology yielded the following main results:

The Corrosion Institute Study showed the cleaning of a corroded metal surface involved metal removal, in the sense of the surface being stripped of metal not converted into patina. If cleaning is carried out properly, no appreciable further removal of the remaining material need happen. Blasting has proved especially suitable as a means of achieving controlled partial cleaning where it is not the intention to remove all patina.

Patination on a purely metallic surface always consumes parent material, even if a great deal of the patina is added in the form of copper salts. The extent of metal removal was of the same order as with between two and five years' outdoor exposure of unprotected bronze. A rawness or chasing of the surface does not appear to have any substantial effect on the subsequent course. The formation of a moderately sized working party of this kind is recommended for all restoration work, i. e. for measures extending beyond rudimentary washing, waxing etc. In this way it is easier to obtain a solid basis for deciding the measures to be taken and also to deal with the criticism which anyone who has completed a restoration will invariably have to face. The main conclusion drawn from the investigations and restoration work carried out is that most of the outdoor bronzes in Sweden, whatever they may look like, are not seriously damaged and are not in need of extensive restoration.

On the other hand, virtually all the objects inspected are in a state of neglect. With very few exceptions indeed, they have never been cleaned since they were put up. If these sculptures, which are valuable works of art and for the most part were purchased with public money, are not maintained, it is to be expected that eventually they will incur damage requiring very expensive repairs.

Literature

A. Gullman/M. Törnblom, *Bronze Sculpture – Its Making and Unmaking*, 1994