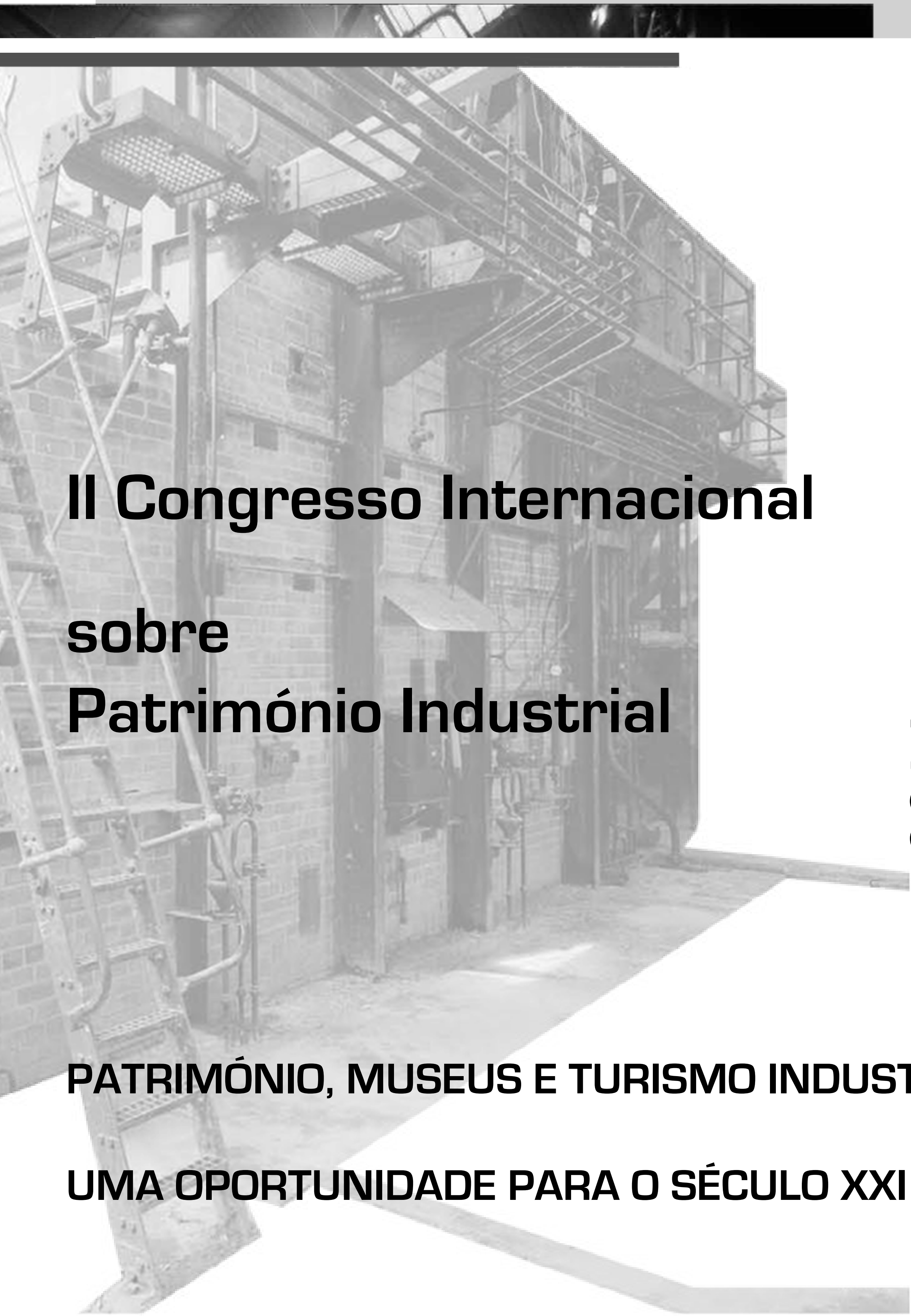

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INTERVENTION PROPOSAL FOR TRAM 177 FROM OPORTO'S (PORTUGAL) TRAMWAY MUSEUM COLLECTION. CONSERVATION AS AN ALTERNATIVE TO RESTITUTION OR RECONSTRUCTION

Diego Lois[1], Eduarda Vieira[2], Carmen Lorenzo[1]
[1]School of Conservation and Restoration of Cultural Goods of Galicia
[2]School of Arts - CITAR - Portuguese Catholic University

ABSTRACT

This paper aims to discuss the intervention proposal for the conservation of the Tram 177 from Oporto´s Tramway Museum Collection. We want to highlight a new approach that permits a different result from the one usually obtained in the Museum´s practice, where reconstruction and restitution became more important than conservation. Framed within minimal intervention guidelines, our proposal has as goals both the preservation of the vehicle original layout as well as its technical and historical values.

Keywords: Industrial heritage, trams, conservation, minimal intervention, technical value, historical value.

INTRODUCTION

Most institutions with vehicle collections are obliged to deal with their preservation and restoration on a regular basis. Often, the conservation of original elements is not considered as a priority (Fernandez; Rodriguez, 2010), while strictly cosmetic and functional refurbishment are preferred. To worsen this reality even further, many of such interventions are seldom documented.

This paper presents a different proposal and highlights an alternative beyond reconstruction and reuse. The main idea is to stand up to the concept of minimal intervention, emphasizing conservation criteria in order to ensure the vehicle's integrity and safeguard its originality.

As case study, we chose tram no. 177 (Pacheco, 1995) from Oporto's Tramway Museum collection (Dias, 1998), because it still retains all its original elements and values. Furthermore, it is one of the few vehicles in the collection devoid of any added parts since it was manufactured.

HISTORICAL CONTEXT

Public transportation has been essential in the development of towns in our age, with direct effects on all urbanization-related issues and population distribution, to the point of influencing real estate prices and therefore contribute to the modify its value in the real estate market.

In 1832 John Stephenson tried to create a network road between New York and Haarlem to be used by a steam car. Unfortunately, the authorities did not welcome the novel ideal and Stephenson was forced to use horses for traction. Nevertheless, Americans promoters decided to export these new vehicles to Europe, inaugurating their exploitation in major towns, like Paris in 1853, Birkenhead in 1860, London in 1861 or Copenhagen in 1863.

The first railway in Oporto was laid in 1871 (Fernandes, 2000). The first tour was settled from the Rua Nova da Alfándega to the Passeio Alegre, reaching later the Foz neighborhood and Matosinhos, in the immediate outskirts. Once the line was completed, a concession for its exploration was awarded to *Companhia Carril Americano do Porto* à Foz *e Matosinhos*. In 1873, another company - *Companhia Carris de Ferro do Porto* - emerged. From this moment onwards, the relationship between both companies was marred by some differences.

Steam traction was introduced in Oporto in 1878, replacing animal traction, by the *Companhia Carris de Ferro do Porto*. This technical innovation cheapened the lines' maintenance costs by comparison to animal traction. The company acquired locomotives in Germany and France; although their existence was not very long-lived due to excessive emission of smoke they produced.

Siemens & Halske, a German company, was the first to offer a public service by electric tram in Berlin, in 1881. This kind of transport rapidly spread to other countries like the United Kingdom, where the Volks line was founded

in Brighton in 1883 and which still stands today.
In September 1895, the first electric line in Oporto, between Carmo and Massarelos known as *Linha Restauração*, was inaugurated. Soon, new lines were laid and formed a complex network connecting the city. The tram became the most important public transportation since the end of 1910s until well into the mid-century years. In its heyday, back in the 1950s, the *Companhia Carris de Ferro do Porto* had a sizeable fleet, totaling 192 trams.

Trolleybuses started operating in Oporto in 1959 (Monterey, 1971), cornering trams to a secondary role, in part due to a steady increase of automobile traffic and also because the amount of energy needed could hardly be supplied by the Massarelos power station. In 1967, trams would be permanently replaced by trolleybuses since these vehicles could carry more passengers in longer routes.

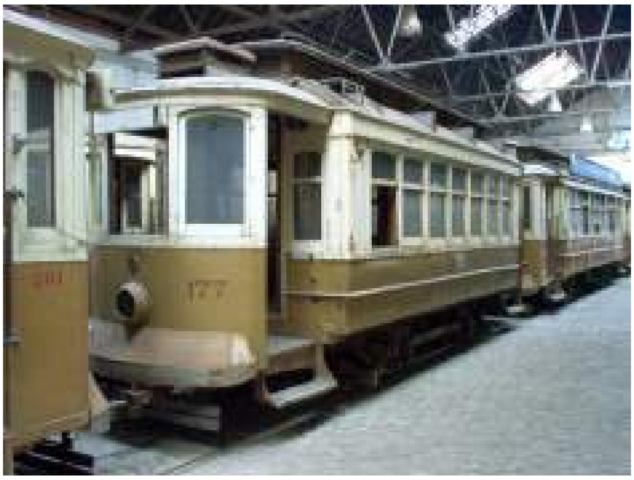


Fig.1 - Tram 177.

THE TRAM 177

The tram no. 177 belongs to a set of eleven vehicles kept in storage at Oporto's Tramway Museum. Its main interest lies in the way original attributes were preserved, without any elements added throughout its career.
This specific vehicle was built by the *Oficinas Gerais of the Companhia Carris de Ferro do Porto*. Its manufacture began in 1938 and only ended in 1945, according to the *Oficinas Gerais da Estação da Boavista* records, during the existence of the *Companhia Carris de Ferro do Porto.* Its Art Deco lines are directly influenced by trams built in the United States between 1925 and 1938. In 1988 the vehicle was withdrawn from service and carried to the Museum storage.

Fig. 2 - Serviços de Transporte Colectivo do Porto company logo.

The bodywork is painted in the proprietary *Serviço de Transportes Colectivos do Porto* color scheme, used between 1946 and 1974. During this period, the company belonged to the local municipality. The logo of the company displays Oporto's coat of arms combined with the old logo of *Companhia Carris de Ferro do Porto*. The STCP acronym is present in capital letters framed by the CCFP lettering, topped by a five towered mural crown. The vehicle is owned by the company *Sociedade de Transportes Colectivos do Porto S.A.* and its incorporation to the museum collection became effective on July 22, 2004, through transfer from the *Sociedade de Transportes Colectivos do Porto S.A*. The vehicle had an original capacity of 23 seated passengers and 19 standing.

RECONSTRUCTION/RESTITUTION VS. CONSERVATION

Usually the staff of *Sociedade de Transportes Colectivos do Porto* have worked in the reconstruction (adding new elements or components cannibalized from other disabled trams) and maintenance of old trams with their reuse in mind. Such work was crucial to prevent their loss and reuse and enabled their conservation, a practice in accordance with the principles embodied in several international heritage conservation letters and heritage protection documents. According to Nizhny Tajil Letter, section 5 paragraph IV: *"The adaptation of an industrial site to a new use to ensure its conservation is usually acceptable except in the case of sites of especial historical significance. New uses should respect the significant material and maintain original patterns of circulation and activity, and should be compatible as much as possible with the original or principal use. An area that interprets the former use is recommended".*
Nevertheless, despite the attractive finish, the company technicians' did not intend to refurbish vehicles back to their fully original configuration; their main goal was to keep them in running condition, even at the expense of other standards. The lack of a specific methodology and the absence of comprehensive documentation on the different stages of these overhauls is what make them controversial and questionable. Adding up new parts alters original historic, technical and symbolic values and contributes to the subtraction of its significance.

Therefore, the main motivation behind this proposal is to safeguard each value still present, which all added comprise the authenticity of the tram's structure, especially in the cases of vehicles that were not subjected to any addition throughout its functional history (when this condition can be proved by documental sources). Accordingly, consolidations are of paramount importance in order to restore consistency to frail parts, as well gaps reintegration towards to facilitate the vehicle´s functional reading/understanding and to improve its aesthetic impact. Once the treatment is completed and to ensure further preservation (Prytulac, 1998), the tram should be integrated in the museum's collection and exhibited in a sub-area specially adapted for such purpose, where the public would experience a less idyllic and more Ruskinian vision of the vehicle, more adequate to the renewed awareness for this kind of recent heritage.

This is a twofold intervention approach: on one hand, we face the usual reconstruction method that prioritizes functionality, sacrificing originality via the cannibalization of other vehicles whenever necessary; on the other hand, a minimal conservation proposal, intended to safeguard inherent values above all, preserving at the same time the integrity of other vehicles, but without any operating possibility (i. e., the vehicle is not supposed to be restored back to running condition). We believe both solutions to be complementary, despite the different end results. Both have the same goal: the vehicles' maintenance. Nevertheless, it is crucial to list meticulously every new part fitted at some point during reconstruction jobs, charting its exact spot in the vehicle. Therefore, reconstructions must be abandoned since they rely upon the removal of parts from other historical vehicles.

INTERVENTION PROPOSAL

Nowadays there is still a lack of studies dedicated to the preservation of industrial collections, especially those which include large objects (Industrial Museums Scotland, 2014; CCI, 1993), in danger of being lost because they are not protected by an inventory or through dedicated conservation and diffusion policies.

CONSERVATION CONDITION

Deterioration of materials is a natural process that results from aging and the action of deterioration agents that cause physiochemical alterations in their structure, loss of functionality and often a relevant cosmetic outcome. Alterations are caused by variations in the supports and frequently the damages change the object's original values. The paint is in good condition, especially in the brown areas (over metal). However, the cream areas (over wood) show gaps with some losses, both at paint and primer layers. An overall darkening layer is present on the vehicle's surface (fatty deposits and suspended particles) due to its extended life and to the aggressive environment (low pH, high humidity and water leaks which favoured the appearance of mould and accelerated oxidation processes), in which it is currently kept. Frequent moisture and temperature variations are probably the origin of several points where the paint is peeling, hardening the film and decreasing its strength.

Fig. 3 - Loss of tram side paint and primer layer.

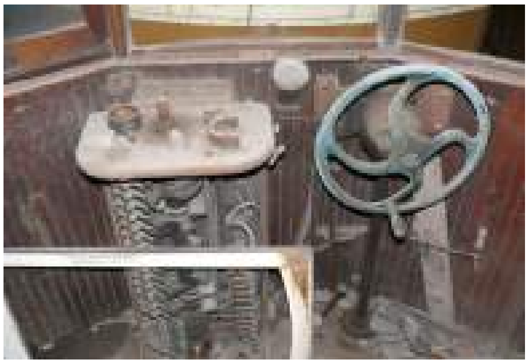


Fig. 4 - Detail of one controller.

The side body panels and deck are in good condition while doors, windows and flags show more damage.
The wooden vehicles' bumpers show specific paint and primer uprisings. Not surprisingly, chassis sub-assemblies (axles, engine, compressor and brakes), except springs and some electrical parts (resistors, trolley, wiring, switches and controllers), are the most damaged, with dirt, grease stains and severe corrosion of the surfaces by pitting.

In the two driver cabins, the controller units have lost most of its elements. Both cabins still keep the controllers, but the command reverse key and the air brake handle are missing. Only one of the cabins still retains the hand brake wheel, made from a copper-based alloy altered by salts (sulphates and/or copper acetates).
The controllers' surfaces show superficial deposits of dust and grease. The mudguard reset lever, which was operated when something fell on the rails, is conserved, as well as two small holes in the floor where the claxon and sand switches were located. Both spaces also show on the control platform, the circuit breakers.
The wooden parts of the cabins show dirt, bio-deterioration and in some cases paint wear and detachment, especially on the roof. On the other hand, some windows have lost their original glasses, many of them fallen and fragmented on the floor. Due to rainwater leakage, a portion of the wooden floor becomes periodically wet. However, the condition of the passengers' area is good. The wooden floor is quite well preserved, despite being covered by dust and trash bags. The engine cover is not attached.

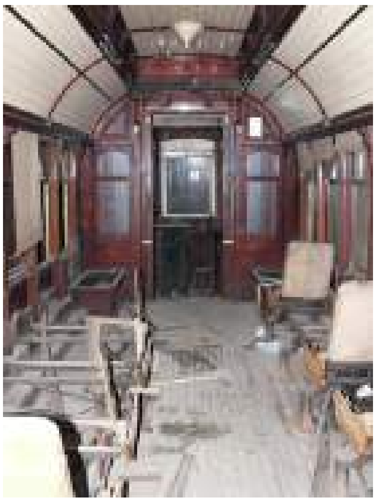


Fig. 5 - Current condition of the tram's interior.

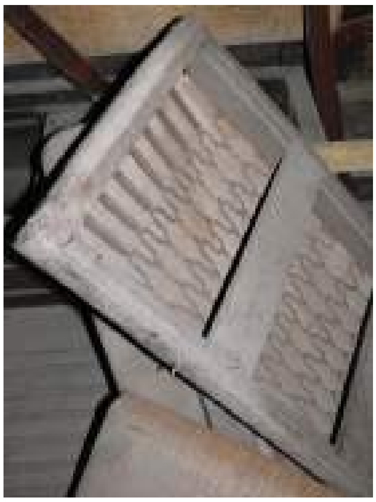


Fig. 6 - Obverse condition on the burlap seats.

The tram still has the sandboxes, whereas the burlap seats have signs of severe deterioration. Only a few are preserved, because many have been relocated to other vehicles during reconstruction procedures. The few remaining seats are dusty, with water stains and alteration induced by photo degradation (UV light). As a result, fading causes an aesthetic effect through colour loss and the stiffness of the material has increased. The seats' corners are roughened by use while springs are corroded.
Access between the driver and the passengers' cabins was done through a sliding door that still works. The windows' frames are still in good condition, as well as the curtains, despite being dirty and stained with grease from use.
Over the windows there are some alloy based copper elements. These parts were originally connected by a cord so that passengers could request the driver to stop along the route. Such parts display a green-blue coloured salt efflorescence, probably sulphates over an oxidation layer (red-black colour) and/or acetates (blue green).
The surviving leather grab straps are incomplete and show wear from continued use and minor rust staining around the screws which fasten them to the vehicle roof.

PREVIOUS ANALYSIS

Fortunately, all information about the vehicle history (manufacture) is preserved in archival documents, whereby analytical tests will only complete information already very wide-ranging.
However, it will be interesting to consider the possibility of monitoring the environmental pollution of the exhibition space on an annual basis (Industrial Museums Scotland, 2014; La Fuente, 2011). With this purpose in mind, different metal samples (iron, lead, copper...) with commercial purity and known composition would be taken in order to relate corrosion and samples damage with recorded environmental values. It will thus be feasible to identify the sequential appearance of different changes on the materials and their propagation speed. Minimal exposure time would be two months, so that corrosion by-products can build up and therefore be detected. Corrosion is subsequently evaluated by gravimetric testing (qualitative), weighing the samples before and after exposure. The corrosion products may then be characterized by instrumental techniques such as X-Ray Fluorescence (multi-element and qualitative analysis) and X-ray Diffraction (requires sampling and provides a qualitative and semi-quantitative analysis of compounds). This study and subsequent interpretation of results will be essential to outline a suitable preventive conservation strategy (environmental control measures, maintenance) of the exhibition area intended for the vehicle.

TREATMENTS OF METAL SUPPORTS

CLEANING

Cleaning is a critical treatment process that requires caution and experience (Prytulac, 2007) due to its irreversible nature.
Before the cleaning process is started, all items stacked inside and which belong to the vehicle (loose seats, wooden slats from the seats) will be removed and stored in a reserved area to prevent their loss.

Subsequently, dry mechanical cleaning by aspiration will be performed inside the vehicle to remove dirt (dust, earth, and solid particles). The deposits which appear in the window frames, roof, doors or chairs will be removed with a damp cloth or cotton swab soaked in a solution of demineralised water and ethanol 50%. If mould persists, a biocide sodium hypochlorite (NaClO), based at low concentration in demineralised water, can be used.
The blinds can be taken apart and cleaned with a solution of warm demineralised water and neutral detergent or ammonia (NH3), in the case of the more difficult stains.
The burlap seats show rainwater staining on the obverse, probably as consequence of water filtered from the roof. As they still have moisture, it will be necessary to enact progressive drying to remove humidity, which will alter cellulose dimensions, weight and resistance. Besides, a wet mechanical cleaning with demineralised water and neutral detergent is required on 5% of the spots.

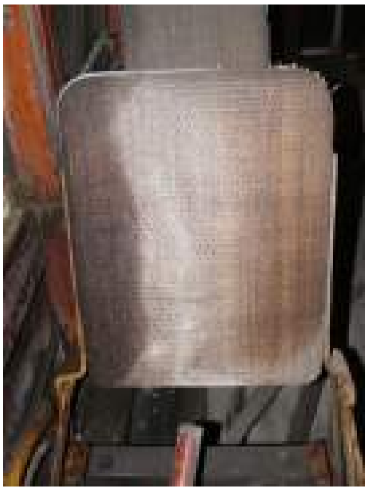


Fig.7 - Detail of the stain on the seat.

The degreasing of metal components can be performed initially through the use of organic solvents followed by alkaline heat bleaches (at about 65º C). Surfactants or complexing agents can also be added at this stage. The goal is to dissolve the fat and to achieve the flocculation[1] of mineral and metal particles as well.

[1] Deflocculant: conversion of a material that cannot flow (high-density doughy mass) into a fluid liquid which can flow without adding other liquids.

Corrosion products visible at the paint layer can be dissolved by the complexing action of EDTA tetra sodium salts (Boucard *et al*, 1995) [$C_{10}H_{12}N_2O_8Na_4$] in demineralised water 3% in weight, since this formula provides good results in ferrous alloys, copper or aluminium provided that the solution is applied for short periods only. The method is based on the application of buffers on metallic surfaces with an absorbent tissue paper, ending with a cleaning operation with demineralised water.

DESALINATION

Chlorides could be considered the main responsible for metal degradation morphologies. Desalination is an important process which always should be considered to reach the metal stabilization. The elimination or stabilization of chlorine ions is an essential procedure to achieve this goal.
Alkaline solutions (Fernandez, 2003) are an effective treatment to remove chlorine ions from iron supports, while the use of removing and sealing systems are common procedures in case of copper alloys.

INHIBITION

The metal corrosion process can be stopped or slowed with chemical inhibitors (Diaz; Garcia, 2011) which react with metal surfaces, offering some degree of protection.

To stabilize (Logan; Selwyn, 2007) the surfaces and the iron elements, tannic acid ($C_{76}H_{52}O_{46}$) can be used as an anodic inhibitor; it helps passivation of anodes on iron surfaces, converting iron oxides (more stable) into iron tannate, for the temporary protection of areas more susceptible to react with water vapour. It is used due to its low toxicity and the uniform finish that improves the final appearance of the object. The product must be warmed in order to be applied with compresses on previously brushed surfaces, to remove adhered oxide particles.

In the case of alloy copper-based elements, the suitable inhibitor is benzotriazole (Cano; La Fuente, 2013) ($C_6H_5N_3$) as it affords long term protection against other inhibitors such as 2-amino-1,3,4-thiadiazole 5-mercapto (AMT). The BTA may act as a cathodic inhibitor or as anodic, bonding with metal and corrosion products and establishing a physical-chemical protection barrier, although it has the drawback of causing a slight surface darkening.
In what regards all the alloy copper-based elements which can be disassembled (wheel brakes and passengers' ringer supports), we purpose a vacuum application of the inhibitor to allow the product to penetrate deeper.

CONSOLIDATION

Consolidants are essential to restore cohesion in the most vulnerable substrates. The selection of an appropriate product is determined by each case specific needs' (substrate type, condition or environment where the object is to be kept).

In order to consolidate metal parts, acrylic resins will be used in different concentrations since they provide the desirable qualities of stability and transparency, despite their fast deterioration through ultraviolet radiation. Afterwards, successive layers - raising the concentration on each application - will be applied by impregnation to ensure a better penetration and enhance the effectiveness of the process. The last layer should be diluted in a volatile solvent so that upon its quick evaporation a protective film will be formed on the metal surface. Synthetic resins in an aromatic hydrocarbon solution such as Xylene, will also be used in the case of the wooden parts.

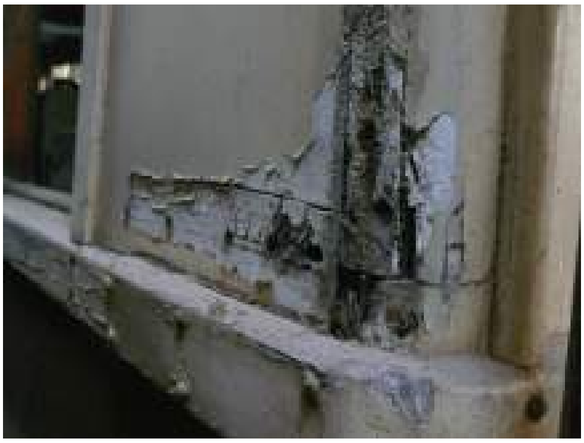


Fig. 8 - A gap on the wooden support which must be consolidated.

ADHESION OF WOOD AND METAL ELEMENTS

Broken wooden elements will be glued with HMG or polyvinyl acetates, because these are reversible products with good adhesion, flexibility, light stability and non-yellowing properties.
If the need to glue metal parts arises, acrylic polymers such as Paraloid B48N (methyl methacrylate and butyl acrylate copolymer) will be used, as they are easily soluble in organic solvents. The finish is flexible and stable on the outside; however, it is necessary to consider the glass resin transition temperature in the presence of heat.

REINTEGRATION

When reintegration is undertaken on heritage of this sort, it aims to ease the reading and interpretation of the artifact as a unit, for its proper display. Reintegration operations are restricted just to well-documented areas, supported by pre-extant well-preserved areas, while added elements are also slightly recognizable on the whole.
On the other hand, reintegrations should be limited to a minimum in order to preserve the cohesion, strength and readability of the object.

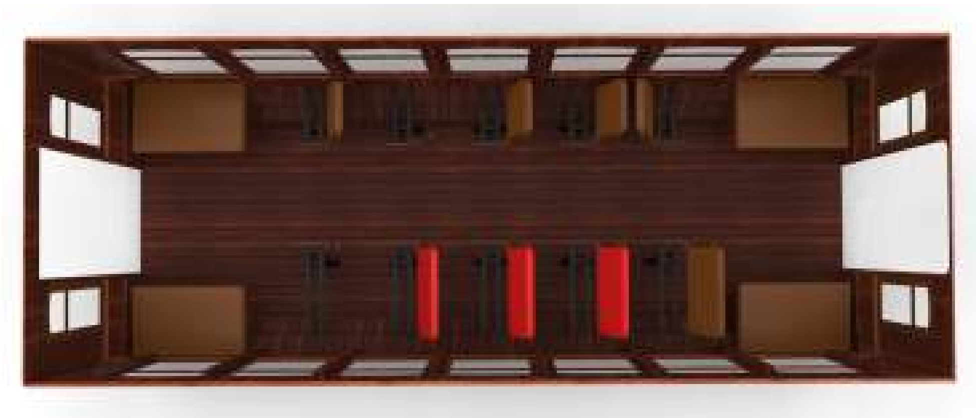
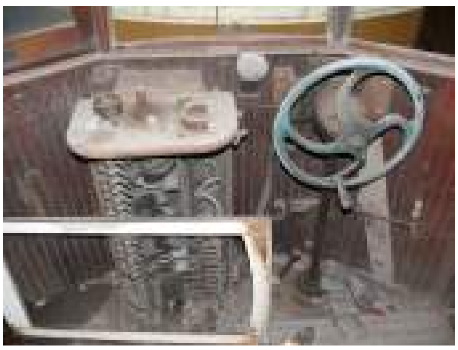


Fig. 9 - Final proposal for the passengers' cabin.

Volumetric reintegration of lost elements will be conducted in one of the controllers, specifically the one that still retains the hand brake wheel. It will be based on the reproduction of missing elements (such as levers, switches, etc) in polyester resin to ease the interpretation of the cabin area by visitors. The passengers' space will not be subjected to any reintegration, with only the preserved seats preserved kept in their original location.



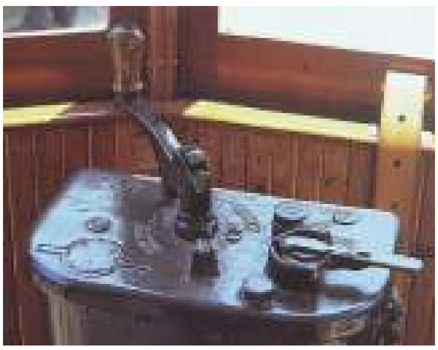


Fig. 10 - Current condition of the driver cabin (one of two). **Fig. 11 -** Proposal of volumetric reintegration for the same controller unit, with two handles, manometer and casing for an easier reading (in red). **Fig. 12 -** A controller in excellent, original condition.

On the outside, there are numerous scratches and chips on the paint coat and primer layers, on both metal and wood sections of the tramway's bodywork. Before chromatic reintegration is tackled, an acrylic resin will be injected into cracks (which appear along the gaps) to consolidate and preventing them from reopening. The following step will consist upon using synthetic stucco in the organic substrate case or polyester putty on the metal support. Finally, gaps will be painted over with acrylic paints matching original tonal values.

Fig. 13 - Gaps detail outside the bodywork.

PREVENTIVE CONSERVATION

Before considering control measures for environmental conditions in the exhibition area intended for the tram, a study about building issues such as thermal insulation or walls, doors and windows sealing, is mandatory. After pondering these aspects (passive control), active control needs will be examined by equipment or filters that permit the conditions to be stabilised at required levels.

POLLUTANTS

Control strategies will comprise coordinated measures to reduce one kind or more of airborne pollutants, reducing risks and/or the deterioration rate of objects exposed to such pollutants (Herraez; Rodriguez Lorite, 2009). This strategy calls for the reduction of environmental factors, such as light and compounds involved in the reaction, without necessarily being the main contaminants.

Since the Museum is located in an urban area plagued by heavy traffic, it would be advisable to resort to forced air extraction and filtration systems that can filter air particles in the room where the vehicle is (as well as the rest of the exhibits). Gas contaminants (SO2, NO2, O3 ...) are to be eliminated through the use of activated carbon filters fitted to the extraction systems in the exhibits' area. It would be interesting to consider the results of the tests performed with metal samples, as they form first-rate indicators on the presence of air pollutants (Tétreault 2003), reduced sulfur compounds (SH and COS) or volatile organic compounds (formic acid and acid in the environment).

RELATIVE HUMIDITY AND TEMPERATURE

The control of relative humidity levels must be made as accurately as possible and proprietarily regarding other factors, because moisture is the single most important microclimate factor for heritage conservation, especially in the case of metal surfaces. The power station and its equipment influence environmental conditions inside the space, acting more or less as a permeable membrane between exterior and interior.

A preferred range for the majority of displayed or stored materials can be established. These parameters should never exceed 55% RH and a temperature around 18°C, to a maximum of 3% daily oscillations. It is recommended to ventilate the room by air conditioning systems or by the use of permanent or portable partial control systems like dehumidifiers.

Aspects such as maintenance, ventilation or periodic cleanings are crucial to avoid moisture sources and dirt in the display area.

The control of environmental conditions requires the use of thermo hygrographs, thermo hygrometers or data loggers. These devices must always be located at the same metering place, protected against involuntary actions by the public and in the same height as the vehicle for obtaining correct data.

LIGHT

Light control can be achieved over radiation composition, lighting levels and exposure time. Since photochemical effects are cumulative, more lighting requires shorter exposure time and vice versa.

In the case of natural lighting, control can be obtained through special glasses or filters. While IR radiation can be controlled independently from the rest of band radiation, UV radiation is closely linked to the luminous flux so, even when effective filters are used, if light levels are too high, the resulting UV radiation will also be high. In what pertains artificial lighting, control can be achieved by the joint use of suitable emission spectrum lamps and coherent lighting planning, which would also help to enhance the enjoyment of the exhibit by the public.

To minimize this sort of damage, reference light levels (based on scientific studies (Sepulcre, 1999; Michalsky, 2016) over different nature substrates, including metals) for objects and collections' exhibitions have been adapted accordingly. Artificial lighting LED is the recommended cold light because it offers the same light quality as traditional sources without releasing radiation IR and/or UV with high yield and low power consumption. There are certain objects less sensitive to light such as stone or metal (as long as they are not polychrome-coated or with other decorations), which do not suffer photodegradation although thermal effects caused by IR radiation and through UV radiation can affect them. In this case, the most vulnerable elements are organic objects like wood or plant fibers.

CONCLUSIONS

Only few institutions (Canadian Museum of Rail Travel) and companies (Todd, 2011) view the preservation of original values in tramway collections as an essential goal in their intervention plans, as integral reconstructions are a recurrent approach. Unfortunately, more often than not, such interventions are carried out with no conservator-restorers within the work teams, who can devise an appropriate practical methodology to deal with the vehicles' particular restoration issues, thus endangering its integrity and specific features that distinguishes it as a unique object, plunging into the realm of historical fakery.

Accordingly, it aims to be an alternative to the usual methodology followed in the museum, as it respects the vehicle's original values, avoiding adding up new elements. It also aspires to readdress the significance of the exhibit as an essential element of Oporto's recent history and culture. Conversely, this approach would also avoid the current state of neglect stemming from the occasional reconstructions that had been carried out previously.
Furthermore, we want to encourage other professionals in the heritage field to act appropriately on industrial collections in general, through the application of sound and objective conservation criteria to respect the significance and integrity of the artifacts: exhaustive documentation, minimal intervention and reversibility.

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AUTHORS CV

Diego Lois

Post graduate in Conservation and Restoration of Cultural Goods by (School of Arts of the Portuguese Catholic University. Conservation and Restoration of Cultural Goods Degree by the School of Conservation and Restoration of

Galicia. Master in New Technologies for the Preservation of Immovable Cultural Heritage by Vigo University. Master in Archaeology and Heritage by the Autonomous University of Madrid. Trainee on Galician Museums and national and International Institutions. Free-lancer Conservator-restorer of archaeological materials.
Contact: diegoloisca@hotmail.com

Eduarda Vieira
PhD in Conservation and Restoration of Historic and Artistic Heritage by the Polytechnic University of Valencia, Spain. Assistant professor at the School of Arts of the Portuguese Catholic University (conservation of Inorganic Materials). Researcher of the Research Center of Science and Technology of the Arts (CITAR). Coordinator of the Study and Conservation of Cultural Heritage Group at CITAR. Editor of the Digital Journal Studies in Conservation and Restoration ECR.
Contact: evieira@porto.ucp.pt

Carmen Lorenzo
Fine Arts Degree by the University of Barcelona – restoration specialization. Teacher at the School of Conservation and Restoration of Cultural Goods of Galicia since 1993 and course director since 2011. Teacher of Master in New Technologies for the Preservation of Immovable Cultural Heritage by the University of Vigo.
Contact: lorenzorivera@edu.xunta.es