Incredible Industry

Preserving the evidence of industrial society

Conference
Proceedings

May 2009 Denmark

nkf dk
NORDISK
KONSERVATOR
FORBUND
DANMARK

Nordic Association of Conservators 18' Conference

Conference Proceedings

Incredible Industry

Preserving the evidence of industrial society

25-27. May 2009

Edited by
Morten Ryhl-Svendsen,
Karen Borchersen
and Winnie Odder

Nordic Association of Conservators 18’ Conference

nkf dk
NORDISK
KONSERVATOR
FORBUND
DANMARK

The digital version of this volume is available at:
www.nkf-dk.dk

The book is printed on
Gallerie Card 210g and CyclusPrint 100g
byHvidovre Bogtryk, Hvidovre

ISBN 987-87-990583-2-7

Foreword

The theme of the Nordic Association of Conservators' 18th conference is "Incredible Industry – Preserving the evidence of industrial society". We have chosen this subject because there is an urgent need to address the various problems that relate to the preservation of objects and materials of the industrial age.

We are in transition between the age of industrialism and the age of information. It could be said that globalization has now relegated industrialism to the history books and museums. The cultural heritage of industrialism is now being recorded and researched at museums everywhere and the objects from this period are being collected, preserved and exhibited accordingly.

In many ways industrialism has been a catalyst for the development of modern society throughout the 19th and 20th centuries. The multitude of objects produced in factories and sold to people represents a change from a culture based on unique wares to a culture of mass production. As conservators we must respond to that.

With this conference we have created a platform for the exchange of experience and knowledge, with focus on the conservation and restoration of the materials, products and production equipment of the industrial age. It is my hope that the conference has pinpointed a vast variety of the problems we need to address in the future and that this publication may serve as a helpful tool and an inspiration to conservators in the Nordic countries as well as to colleagues in the rest of our professional community.

Please enjoy!

Michael Højlund Rasmussen
Chair of Nordic Association of Conservators – Denmark

August 2009

Table of contents

Contributions

Keynotespeakers

Can the concept of industrialism be preserved?

Jacob Bjerring Hansen

I'm very pleased to get the opportunity to give a presentation at this conference. Not only because it is a pleasure to include a neighbouring field of work – i.e. preservation – into my cultural-historical perspective on museum work, but also because this invitation prompted me to reflect on my own field of interest from new angles.

I will now take you on a tour through the mind (or part of it at least) of a curator working within the field of industrialism. This might be a scary experience, especially since I will make an assassination attempt on the physical object as the sole true object worth dealing with in a museum. I promise you, however, that in the end I will try to get back on track!

I am a curator at a museum which in a Danish context has changed the way the public meets our most recent industrial history. The museum has used the interior principle in direct connection with thematic exhibits. Simply by putting the thematically organized showcases next to real living rooms the museum (as an expert) reaches out to the visitor and enlists the visitor himself as an expert.

We have done so by focusing on aspects of history which have been perversely neglected by historians and museum institutions - we have focused on the everyday industrial culture of ordinary men, women and children.

What is Industrialism?

Let me now move to the subject of this presentation. In the abstract given beforehand I talked about industrialism as an era giving birth to a new kind of materialism – a materialism best described as the principle of the non-unique object.

Over the last 150-200 years society has changed dramatically and most of the changes – at least when we focus on the physical representation – have been caused by the industrial revolution and constant changes of the industrial production in order to meet and exceed society's demands for goods.

Industrialism is characterized by a number of features; most importantly seen from my museum's point of view is the restructuring of the social hierarchy into a class society. But I will focus on two other key concepts: Mass production and big structures, and the concept or principle of standardization.

Mass Production and Big Structures

Production of a product in huge numbers has clear implications on the mode of production: Rational use of machines, division of labour, control of the workforce and constant boost of efficiency are essential parts of the industrial apparatus.

This form of production has grave implications for the materialism of the consumer. In the industrialized society, the consumer is actually invented by the industry in order to meet not the demand of a single buyer, but the demands of larger consumer groups. As opposed to the pre-industrialized industry where the consumer was the person, group or merchant that ordered the product.

Mass production changed the mode of production: Lots of people became workers in the ever growing industry, the workers worked with and at the machines and the product was no longer the result of a unique hands-on process.

Another clear physical evidence of mass production is the growth of the production apparatus. Machines, machine halls, transportation facilities – everything got bigger!

The big structures of industry are evidently causing problems in today's preservation strategy, a problem I will address later.

"The control and disciplination of the working process is a central characteristic in the industrialism"

Standardization

To be able to obtain efficient production, standardization of products – or at least standardization of components - was necessary. But standardization cannot be seen merely as standardization of product and production, it was in fact an all-intrusive change of mentality and of the concepts used for communication among people. Time and space needed definition and standardization.

The concept was used as a disciplinary tool by employers and as a collective protective mechanism that by agreement ensured the workers a standard for work which they could struggle to improve – like for instance over-time pay, and these facts changed the common understanding of their position from class awareness to active class consciousness. Concepts were invented and the meaning of existing concepts changed in accordance with the new society. Concepts connected to the cultural phenomenon of consumption, working, living and of time and space all got new meanings.

Representation and preservation seen from a curator's point of view

The characteristics mentioned above are not just a matter of categorization of an object, but of concepts that actually in themselves should lead to active collecting and the preservation of objects.

Now, working on a daily basis with objects, I often find myself - though I am very much aware of the fundamental characteristics of the industrialized materialism – retreating to the standard of museum collecting: I look for the unique. I feel safe in my decision to include an object in the collection, if I find that characteristic and odd story that makes this object special in comparison with all the other anonymous objects being offered us. It is my impression that this way of dealing with the objects lies very deep inside all of us who work with objects: We want the unique object. The question is whether we should abandon this well-known practice and chose a more sustainable and representative approach?

My suggestion is that – at least for a period to balance our collections – we should try to focus and unfold the unique story of the non-unique object!

The Concept of Mass Production

Just to clarify, before moving any further. I fully recognize that every object does have its own story. A bottle of milk opened in the kitchen of a Laestadian religious family in Kiruna could potentially tell us another story than the milk served at an "all-included breakfast" in a fancy bar in Reykjavik.
The main point is that in essence the object is the same. And that the strength of this standardized and mass-produced object lies in the multiple story: A mass-produced object with a mass-produced representativeness carrying not only the story of one family, but of hundreds of thousands of families.

Let us turn to another – in a Danish museological context - well known object type: Coming into a museum storage room, you can be quite sure to find several if not hundreds of engagement gifts from the period 1700-1850. One could argue that every object in the form of a personal gift is unique: Every gift has been manufactured on request, step by step, by a skilled woodworker or by the fiancé, the inscription is unique, the receiver and his or her use of the gift is unique. The answer to the question: "do we really need more than one" has traditionally been: "yes, we do want more to show that they differ, that they represent an individual story, which is normally hard to separate from the folk culture."

Now the obvious answer to the question "how many tetra-pack milk-containers do we need" could seem simple: "we need only one as they all look the same". But my point is just the opposite: we only need one or a few wedding gifts to show their uniqueness, the most common aspect about them is the way they were perceived by historians to be a representative of 18th century folk history. But we need hundreds of tetra-packs to show the basics of the industrialized and consumerized society.

If we do not get this balanced, then five hundreds years from now people will get a very strange perception of the period 1700-2000 with hundreds of wooden mangling-boards with inscriptions and none or very few milk cartons.

The Immateriality of the Consumerized Society

The museum collections should not only represent the told story, but also the untold or unexplainable story. Let me give you another example: "The concept of sustainability". This is a concept previously unknown to mankind. It involves several themes: one being the practice of re-use of raw materials, not because it seemed easy or to save time as was the case for our predecessors, but for the purpose of saving planet Earth.

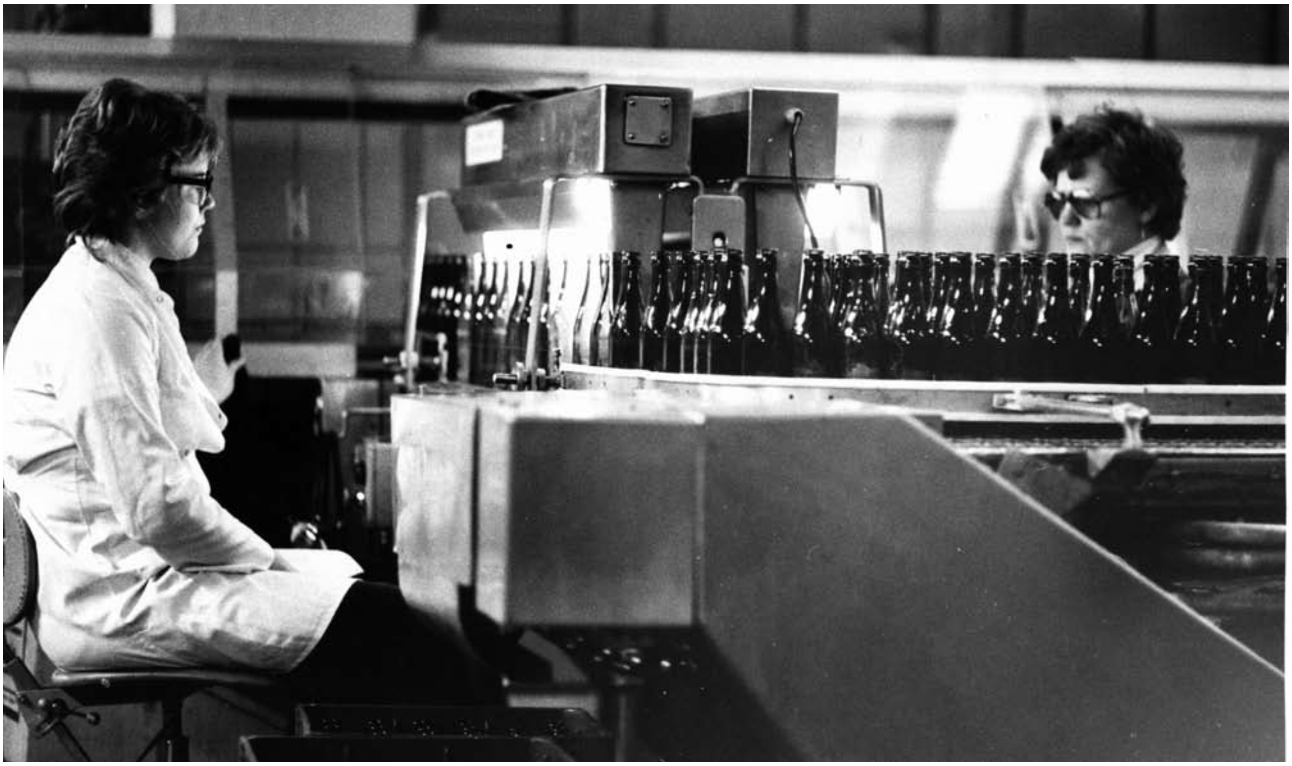
Now how is this theme best represented in museum collections? How can we possibly give an idea of the quantities of re-used materials, or the garbage-culture of year 2009?

My suggestion would be a listing of one of our rubbish dumps, the collection of one day's garbage in a specified area and finally the tracking of for example a reusable bottle from consumer to consumer.

The Big Structures

The big structures represent another problem and to preserve this unique characteristic of the industrialized production we need new approaches. The field of industrial archaeology and of industrial conservation has developed dramatically over recent years – especially in Great Britain and, I must add, Sweden.

What often strikes me especially in Denmark is the lack of courage to tackle the large objects and the



"Clearing ladies, approx. 1970. Detecting deformations in the glass was extremely demanding and the ladies staring at the bottles needed more brakes than their colleagues"

buildings of this age. To sum up: The aesthetics has always had higher priority than the functionality of the buildings. The focus has always been on the first "original" building structure or machinery, and not on the even more representative practices: the rebuilt and redesigned machine.

How to collect a 160 meter long assembly line from Ford Motor Company's factory in Copenhagen? – It was unfortunately never done. And what about the key objects from the 160 years of history of the Carlsberg Brewery that closed only 5 months ago? The huge vertical steel tanks could be one example; they represent a major shift in brewing technology and biochemistry.

Ways Out

Recognizing that it makes no sense to preserve if we do not preserve the right things, I have over the last three years been engaged in using the nomination of The Carlsberg Brewery as an industrial heritage site to point out new ways of applying curatorship to industrial heritage.
In this connection the Workers' Museum concluded that the best we could do for the time being was to leave the preservation to other museums, and focus on expanding the conceptual knowledge of the industrial age and accordingly document these structures.

To grasp the essentials we decided to do two things: First of all we needed a bird's-eye view of the field. The Workers Museum has therefore tried to come up with taxonomy – a grouping of thematically linked concepts – of industrial culture.
Secondly, the Workers' Museum has attempted new ways of dealing with the big structures.
This taxonomy of course has to be elaborated and sub-categorized into hundreds of keywords.

Using the Taxonomy on the Documentation and Communication of Industrial Culture to the Public

In this task it was important that the physically big structures as such were not interesting. The taxonomy can be used actively to open up the understanding of for example big structures.

The Taxonomy

The physical space	**The culture**
Buildings	Company culture
Geography	Work life
Architecture	The social life and "time off"
Infrastructure and logistics	Conflicts and settlements
	Traditions
	Gender
The production	**The surrounding "world"**
Organisation	The market
Process and production	Local relations
Trades and crafts	National relations
The product	International relations
	Ownership

Although we recognize that the industrial architecture is very prominent and that the machines are very BIG and represent the finest Danish-European ingenuity, we are not interested in architecture, the technological development, the big business – what we are interested in is the totality of the place, how these interesting fields of studies reflect on and interact with each other.
How do the workers look upon the architecture? How do the changes in machinery change the division of labour and relative numbers of men and women occupied in the production hall, and does culture change accordingly?

This is a holistic attempt to combine the different aspects of the taxonomy. In the combination lie many hidden truths of the industrial age.

Digital Documentation and Digital Representation of the Heritage

The other major problem mentioned above is the dealing with the big structures. In many cases they are bound to disappear with the closing of the factory. The Workers' Museum has compiled a web-site dealing with the industrial heritage site of the Carlsberg Brewery: The web-site www.humlenvedcarlsberg.dk organizes the information on the basis of the taxonomy, and besides that aims to deal with the difficult task of preserving the big structures. This is done in a three-dimensional model.

"An example of the virtual model on the homepage "humlenvedcarlsberg.dk", which the visitor can walk around in and meet former and current Carlsberg employees"

The virtual world can be a very good basic structure for the understanding of a physical environment; something that an architectural drawing, a photo or a film cannot do. In a few years' time the brewery environment will have a total different look - buildings are torn down, new ones erected, some are rebuilt. On the web-site the visitor walks around, interacts with the buildings, meets the workers and so on. And another great thing for the architects and the people working with administration of the listed buildings on the National Heritage Board is that the model may actually show changes to the listed environment before they are carried out.

But most important and an almost revolutionary aspect of the virtual technology is the ability to contain, organize and combine a lot of information that is normally not accessible on the web.

From the three-dimensional universe (id: a building) the visitor may link directly to a database, a more traditional web-site with thousands of photos, films, written and spoken memories, and new articles. The content is organized according to a new taxonomy of industrial cultural heritage.

Conclusion

The industrial heritage is in many ways different from that of earlier times. An object like the beer-cup from the 18th century could, along with a modern can of beer, represent one and the same story, since they are examples of how time off work was spent in two very different societies. But in every other way the two objects are completely different. A cup in the agrarian society is a unique object, both from point of view of manufacture and use, whereas we need tons of cans to fully understand the materialism of the industrial society.

Preserving the original building "body" of a 19^{th} century factory is a very limited story and in general not a very representative story, as most industrial buildings have constantly been changed in order to accommodate new machinery, new sources of energy and methods of transportation.

So we should try a holistic approach, and an approach with a direct connection between the conceptual – curatorial - work and the industrial heritage and the preservation of objects and listing of buildings. The approach could very well be traditional and serve the purpose, but new practices are necessary in terms of conceptualizing, documenting, preserving and presenting the industrial heritage.

Finally, having the chance to address you as conservators directly, I would like to add that the preservation in general should involve the public. Many of the mentioned structures – at least when we are dealing with buildings – are actually best preserved by people (re-)using them. If they understand the reasons for preservation – they can and will take action. This is a method used with much success by environmental activists dealing with the natural recourses – so I challenge them: let's keep the chimney, the ugly deserted factory, the rubbish dump and let's collect hundreds of beer cans - they tell a story about the industrialized world which is recognizable to the people actually living in it.

Author

Jacob Berring-Hansen
Curator
The Workers's Museum
Rømersgade 22
1362 Copenhagen K
Denmark
jbh@arbejdermuseet.dk

From mass-produced artefacts to mass treatments: the impact of industrial development on the museum field

Bertrand Lavédrine

Abstract

During the past two centuries, commercial industry – the purpose of which is the production of consumer goods - has become the source of our economic development. It would be very difficult today to find artefacts that have not been affected by industry in one form or another, via their constituents, production methods, the energy sources used for their processing and transportation, etc. Some of these consumer goods are destined to become a part of our cultural heritage because they are used by artists, or simply because they are evidence of human activities during certain periods of time. It is therefore natural and legitimate to find both treasures and scars left by industrial development in our museum collections.

Among these industrial legacies, it is possible to distinguish three categories that chronologically reflect the historical evolution of industrial development. First, from the 1850s, industrial **materials** were increasingly adopted by artists. These included completely novel materials such as artificial polymers, as well as improved versions of pre-existing materials and artefacts evolving from new innovations in the field of chemistry (e.g., paints, textiles, graphic arts, manuscripts, and photographs). Thereafter, new materials were introduced in greater quantities, until, by the end of the 19th century, mass-produced consumer **artefacts**, manufactured entirely by commercial industry, were being delivered to the market. These would eventually become a part of museum collections as industrial objects, design objects, and objects re-appropriated by artists. The final category, which emerged during the second half of the 20th century, concerns not only the materials or the artefacts, but artefacts intimately tied to **industrial technologies** themselves, and these open up new sets of questions and conservation problems.

However, the impact of industry on the museum field cannot be reduced only to the collections themselves; since the 1950s, industry has influenced the field of conservation in a very similar manner. First, conservation professionals adapted to new materials such as synthetic polymers. Then, from 1970 onwards, so-called "mass treatments" were introduced. Finally, and more recently, digital technologies have entered the field of conservation. Concerning the question of the industrial impact on the museum field in the 21st century, we can certainly assume that it will be connected to sustainable development; "green industry" will affect and benefit our field in terms of products, artefacts, and treatments. Ironically, even if the preservation of cultural heritage has never been a priority or a goal for mass-production industry, the preservation of our natural heritage and the environment will drive industrial development in the very near future.

Introduction

The rise of industrialization occurred in the late 18th century. At the beginning, it corresponded to the mechanization of traditional production methods, as manual labour was replaced by more efficient machines. These machines operated on water and steam power, and were the backbone of industrial expansion. They enabled an increase in production and lowered the costs, as expressed in 1851 (1): "The steam engine almost halved the number of workers in the spinning manufactory (...) the steam engine returned its value back to the clever man whose physical weakness prevented him from reaching the earnings. These are the benefits that it gave to humanity". Indeed, the textile sector was one of the first to be industrialized, and it benefitted from such development, with the spinning of cotton, wool, silk and linen, and the weaving factories for the manufacture of fabrics. Apart from the reduced labour cost, mechanized production allowed for better quality and greater uniformity of products. The same production methods were applied to the manufacture of paper; the first machine to manufacture a continuous sheet of paper was patented by Nicolas-Louis Robert in 1799 and was used from the 1820s. Wooden machines were gradually replaced by more robust machines made of metals such as iron, steel and copper. More foundries were established to provide the metals. The production of materials would grow alongside the development of inland waterways and railways, which increased and facilitated trades based on river and land transport.

However, during the 19th century, an important change - perhaps even a mutation - took place. Scientific methodology, applied to natural science since the end of the 18th century in order to enrich and organize the knowledge and carry out new investigation, began to find practical applications. It was clearly expressed within books such as "Treatise of applied chemistry to the arts" (2). It would be inaccurate to claim that science supported industry in its infancy: the two grew in parallel and the convergence would occur later; "it was the time for unlikely encounters between theories without applications and inventions without theory" (3). However, certain laboratory discoveries, made by chance or by laborious trial-and-error, found industrial applications due to the flair, initiative and creativity of their inventors. Industry no longer based its development only on engineering, but also benefitted from scientific discoveries and innovations in the field of chemistry. This led to the marketing of new materials, some having novel and remarkable properties, and produced in large quantities. These changes were celebrated in the literature of the time as a source of advancement and improvement. Louis Figuier's (1819-1894) publications reflected the faith in the progress of science and industry towards benefits for humanity as their titles suggest: "*The Wonders of Science" (1867-1869), "History of the Wonderful in Modern Time"* (1859-1862), *"Great Inventions, Ancient and Modern, in Science, Industry and the Arts"* (1861), "*New Conquests of Science"* (1883-1885), "*The Day after the Death or the Future Life According to Science"* (1889), etc. (4). These publications coincided with the organization of major international exhibitions devoted to industry. World exhibitions, so-called "Great Exhibitions of the Works of Industry of all Nations", were intended to be the windows to the industrial revolution and must testify to the most remarkable inputs (machinery, products, and materials) from the advent of industrialization. The first exhibition was held in London in 1851, followed by another in Paris four years later. France sought to catch up with England as an industrial nation, and the competition that arose between them often led to priority claims on inventions by one or the other country. Major discoveries and innovations that were celebrated at the time, and which would have important repercussions in museums collections, include paper made from wood (not from textile fibres), synthetic dyes, celluloid (artificial polymers derived from cellulose), and photography.

New materials

Paper from wood

During the 19th century in Europe, the demand for paper for printing newspapers and books was growing. The lack of old fabrics and cloths of hemp and linen would lead the paper industry to find a substitute to meet the increased need. Honoré de Balzac illustrated that turmoil in his book "*The Lost Illusions"*: "*you go get me the artichoke stems, stalks of asparagus, nettles to sting, reeds you cut off along your small river, and tomorrow I will walk out of your cellar with the beautiful paper." (5).* Finally, softwood cellulose would become the new raw material and, thanks to a chemical treatment, would provide the source of white paper sheets from the year 1844. To facilitate the printing of inks, cellulose fibres would be sized in an acidic mixture of rosin and alum (aluminum sulfate). This new sizing, replacing gelatine, would later result in a disaster for the graphic arts departments, libraries and archives; the acidification of paper. Indeed, this sizing induces acids that oxidize and hydrolyze the cellulose, and the paper becomes brittle within a few decades. This is currently a central issue for the conservation of books produced from the 1870s to the 1970s. Awareness of such a disaster for the printed heritage led industry to introduce a paper called "permanent" (ISO 9706) in the 1980s. This paper is designed to preserve its qualities over a longer period of time. Sizing is performed under neutral condition with ketenes alkyl or alkenyl succinic anhydrides, and an alkaline reserve such as alkaline calcium carbonate is also introduced into the paper pulp in order to neutralize further acidity. Such papers are identifiable by the presence of watermarks of the infinity symbol. If permanent paper is nowadays easily available, the care for acidic paper collections is still the topic of active discussion and scientific research.

Synthetic dyes

The exploitation of coal - a major energy source in the 19th century closely associated with industrial development - had interesting indirect repercussions. Indeed, the by-products of coal distillation contain aniline, an aromatic compound which would be used to synthesize dyes. In 1856, the young William Henry Perkin, seeking the anti-malarial quinine, discovered a purple-coloured compound soluble in alcohol and ether; mauvein. He realised the profit he could make by exploiting this new colourant, which dyed wool and silk. A patent was obtained, and the first synthetic dye factory was founded. Fashion and taste for the new hue was responsible for transforming Perkin's intuition into a commercial success. Other synthetic dyes would follow; in 1859, Emmanuel Verguin discovered a red-fuchsia dye of the triphenylmethan family, which he named fuchsin. Its exploitation by the *Renard Brothers* factory in Lyon (France) for the dyeing of silks promoted the development of these dyes and spread this new industry, which relied on advances in organic synthesis. Factories such as Bayer, Hoechst, and Badische Anilin- und Soda-Fabrik (BASF) would render Germany the world leader in the production of synthetic dyes. Carl Lieberman introduced the synthesis of alizarin and Bayer Company patented the synthesis of indigo. These discoveries had economic consequences in Europe. The dissemination of these new dyes would threaten the traditional cultivation and use of natural dyes like madder and indigo. Between 1860 and 1900, the majority of synthetic dye families were discovered, and they offered to the market an extraordinary range of dyes with a high dyeing power, opening up new horizons primarily for the textile industry and also for applications in the field of art.

Many dyed artefacts created during this period, now in collections, are likely to contain synthetic dyes which are considered to have a poor light-fastness by today's standards. This problem mainly concerned textiles, but was also relevant to graphic arts, as related to some inks and pigments prepared by precipitation of dyes on inorganic particles: for instance eosin found in some Van Gogh paintings. Light-fading was certainly not a new problem; craftsmen and artists knew that certain natural dyes are also light-sensitive. Nevertheless, they were carefully selected depending on the uses; for high-value pieces, the best-quality dyes were chosen. Such concern seemed overshadowed by the advantages offered by these new compounds. The light-fastness issue was eventually addressed by the industry and was the reason behind the introduction of an international method for classifying dyes according to their light stability: the "blue wool standard", widely used in museum conservation today.

Celluloid

The first synthetic polymer was introduced in 1832 when chemist Henry Braconnot discovered that starch reacted with concentrated nitric acid to give an insoluble substance he called xyloidine, which burned quickly. In 1838, Théophile-Jules Pelouze observed that the same reaction also occurred with paper, cotton, and linen. Christian Shönbein discovered a particular application for "xyloidine" as an explosive, which earned the name "Gun cotton" or "Fulmi-cotton". The production of this compound, later identified by chemists as cellulose nitrate or nitrocellulose, became strategic for the military. A civil application was credited to John Wesley Hyatt (6). A prize was offered to encourage the development of a substitute for ivory for the manufacture of billiard balls. Hyatt succeeded in 1870 by mixing cellulose nitrate with camphor to form celluloid. He founded a company known as the Celluloid Manufacturing Company in 1873. The use of celluloid was extended thereafter towards the production of various objects: domestic utensils and accessories (sunglasses, combs, wallets…), films, varnishes, etc. But over time, cellulose nitrate hydrolyses, camphor sublimes, and the objects deteriorate irreversibly. The poor life expectancy of nitrocellulose now poses many conservation problems for museums and archival collections. Later, industry would offer more durable, safer synthetic polymer alternatives.

Photography

In 1871, British physician Richard Leach Maddox introduced the gelatin-silver bromide photographic process (7). At the time, photographers were using collodion plates that had to be exposed and processed within a few minutes following their coating, before the collodion solvents could evaporate. Gelatin-silver photographic plates, by contrast, were used dry; they could be kept in their sensitized state for months before exposure and could be developed long afterwards. Thus, gelatin-silver materials could be manufactured industrially, distributed throughout the world, stored, and purchased for future use, all while still retaining photographic sensitivity. The advantage of the gelatin-silver bromide photographic plate was unquestionable; it was named “dry plate”. In 1873, the first dry plates were sold on the market by the English photographer John Burgess; this would be a radical break from the primitive period of photography; now the medium was marked by mass production. The following year, the *Liverpool Dry-plate Photographic Printing Company* was established, and other companies were to follow, such as Wratten & Wainwright (1878). The practice of photography became increasingly accessible to the general public, no longer exclusive to professional photographers and a few dedicated amateurs. New enthusiasts of photography were the main beneficiaries of the democratization of photographic activity. This resulted in the emergence of a flourishing industrial business that produced major photographic companies in Europe and in the United States. For instance, in France, the Lumière Brothers Company started the production of photographic plates in 1880s. The Company began with an annual production of 18,000 boxes. By 1886, production exceeded 100,000 boxes, and each subsequent year saw a growth in demand. In 1890, a hundred workers provided an annual production of 350,000 boxes, and 2,550,000 boxes in 1900.

At the time, heavy and fragile glass plates were increasingly replaced by a more flexible support base made of celluloid film. This new base would aid the invention of cinematography in 1895. Nevertheless, despite excellent physical and optical properties, celluloid poses serious problems in archival collections. One issue is that cellulose nitrate is very flammable, which caused its banning in the 1950s. This problem, already known for celluloid, also occurred with films; over time, cellulose nitrate hydrolyzed, releasing nitric acid. And if any cellulose nitrate base films are still in excellent condition after more than a hundred years, others have already degraded into powder or a mass of sticky residues, off-gassing acid fumes. Other cellulose derivatives were used instead, such as cellulose diacetate, cellulose triacetate, cellulose acetopropionate or cellulose acetobutyrate. However, their life expectancies were overestimated: an alleged promise of a few hundred years would be reduced to a few decades. Since the late 1980s, collections have been faced with “the vinegar syndrome” problem. This phenomenon, which occurred after about 40 years of storage, was reported as early as 1954 in film archives in India. The breakdown of cellulose acetate released acetic acid (hence the vinegar odour), accompanied by mechanical weakening of the film. The acid released into the atmosphere spread the phenomenon to the entire collection in the vicinity. This deterioration seemed inevitable, and sped up with increasing humidity and temperature. Since then, polyethylene terephthalate and polyethylene naphtalate have been introduced as a suitable substitute by the polymer industry, although cellulose triacetate is still widely used for 35 mm films.

These few examples show the consequences - often undesirable - of major innovations that were rapidly adopted and extensively employed in the production of consumer goods. The durability of materials was not a criterion because it was neither a need nor a demand from consumers. The low costs associated with innovative features were key to the success of an industrial product; this fundamental rule of consumerism emerged in the late 19th century. During the 20th century, the marketing of new materials based on advances in chemistry would increase, and industry would produce artefacts that found their place in museum collections, and sometimes even the machinery and production tools themselves became cultural goods.

Industrial objects

The industrial art artefacts

During the 19th century, industry gained recognition and pride; it was testimony to progress and a positive development of society. France witnessed the founding of the "Conservatoire des Arts et Métiers" - a museum devoted to the industry, the "École centrale des Arts et Manufactures" - a high school for engineers, and the "Salon des Arts et de l'Industrie"- a show room for industrial development. Industrial production was synonymous with a combination of quantity and quality as allowed by automation. However, this appreciative perception of mass-produced objects would decline during the 20th century as mass production often became synonymous with cheap, low-quality artefacts. In fact, the 20th century saw the marketing of all sorts of new objects, mass-produced to meet various applications: telephones, phonographs, radios, televisions, and other household appliances. And, if during the 19th century industry based its growth on innovations from the field of chemistry, it added, during the first half of the 20th century, contributions from the field of physics, particularly electricity and electromagnetism. All of these innovative mass-produced objects became an essential and significant part of daily life and of the consumer environment. These industrial artefacts were not only limited to a utilitarian function; they would incorporate an aesthetic function, clearly claimed for design objects, which would give them a place not only in museums of science and technology but also in decorative art museums. The growing status of industrial objects in society gradually conveyed new values that influenced artists themselves and have changed our view of art. Art was not merely the sum of what an artist created and his know-how, but also co-opted other objects which could be considered as art. Thus, Marcel Duchamp's works have brought to art collections "ready-made" industrial objects such as the "Bottle Holders" (1914) and the "Fountain" (1917). Artists not only re-appropriated such industrial artefacts, but also sought to emulate the industrial production of artworks by generating multiple copies, as exemplified by Andy Warhol's studio, aptly named "The Factory." Artefacts or installation art, where some parts may be updated or replaced by similar industrial artefacts according to the wishes of the artist, were included in museum collections.

Multiple versus single

The field of art was subjected to profound change influenced by industrial production. The essay by Walter Benjamin (8) entitled "The Work of Art in the Age of Mechanical Reproduction" reflected these new questions and concerns regarding an art that was no longer the result of a unique creative process. Multiplicity is an attribute of contemporary works of art, as Yannick Maignien explains: "the contemporaneity of works of art is one founded on their mass-production, their collective perception and ownership." (9) Benjamin's point was that with the introduction of the lens-based media of film and photography, the criteria of authenticity and uniqueness, which had been attached to artworks for centuries, started to fade. Yet the concept of multiplicity associated with art is not really new, as Gérard Genette (10) pointed out; it has existed for centuries in the production of bronzes, engravings, and prints. Such multiplicity did not change the recognition and status of those works of art; it would only influence the market value.

However, if a work of art can be embodied in several identical copies, copies are never fully identical. Any individual piece, even if mass-produced, is never completely the same as the others: it will always be possible to identify minute differences in the structure that characterize each artefact. Two objects thermoformed from the same mould probably will have very similar characteristics; however, slight variations in temperature, in the composition of the resin, or in the injection speed might result in different traces. Photographic prints from the same negatives will be different in their chemical or physical constitutions: residual salts, structure of the silver deposits, paper fibre organization, etc. The European research project entitled “Fingartprint” was specifically based on these micro-morphological differences (11). Furthermore, time adds its marks by creating or amplifying some differences, providing each artefact with a singular and unique history. This time dimension, which is indissociable from materiality, generates specificity. A look into collections of objects which were identical at the beginning would reveal very different states of deterioration that are often difficult to explain. And history can sometimes give symbolic values to common objects.

Still, multiplicity does not imply that different copies of the same work are interchangeable: “same same, but different”, as it is sometimes expressed in Southeast Asia. It would be more appropriate to define a “coefficient of similarity” to assess the degree of association between two works, knowing that such a value could never be equal to 100% and would only decrease with time. It is characteristic of matters to be unique in space and change over time. Also, the replacement of a damaged part of a work of art by a similar part in a better condition can never be justified as pseudo-similarity, it relies solely on the wishes or intentions of the artist. However, such uniqueness of museum artefacts, as defined by their materiality, would become less relevant in the case of new technologies emerging in the late 20th century. They introduce to museum collections artefacts of a very different nature.

Industrial Technology

Dependence on industrial technology

The last major change was inherited from the development of the electronics industry and information technology. This is reflected in the presence of technologically-based art works in museum collections: their accessibility is determined by playback devices. Audio, video, multimedia, and time-based artefacts all require suitable electronic interfaces (tape, CD, DVD players, VCRs, and computers). The role played by this new industry is growing significantly; it is no longer limited to the process of creating the artefact, but extends to its access, restitution, and recreation processes. In fact, museum professionals have become very dependent on industrial development if they want to ensure the sustainability of this non-human-readable heritage (12). The recurring appearance and accelerated development of new materials and recording formats, both analogue and digital, is a problem. Information stored in the early 1980s becomes difficult to read if the media have not been regularly taken care of, or if the information has not been made more readable with new software. This represents a significant requirement for investment, equipment, and labour. These phenomena, which are also experienced by a much wider audience than the museum world, have raised general awareness (13, 14). We are now at the very start of the emergence of the digital era. Standardization committees are working on this issue; however, the economic and technical advances do not always conform to such standards and measures. The digitally-derived artefact in collections poses not only technical problems but also philosophical issues as to what art embodies and what we should preserve. The objective cannot be limited to the maintenance of information carriers, as with traditional artworks. Digital preservation goes beyond the strict lifespan of materials (tapes, disks, etc.). The conservation of a “digital heritage” is a dynamic process that requires technological means for continuous data transfer to new, updated information systems.

The notion of authenticity

This technological evolution has introduced artefacts of a new genre to museums, requiring very different approaches not only in conservation practice but also in the terminology. Words like ‘original’, ‘reversibility’, ‘integrity’, ‘authenticity’, and ‘restitution’ must be clarified (15). In fact, the move from material objects to digital artefacts has changed the essence of works of art. Nelson Goodman (16) distinguishes autographic arts, such as paintings and sculptures, from allographic arts, such as music and literature. An art form is allographic if the most exact duplication is considered genuine. Conversely, it is not allographic, but autographic, when the most exact duplication cannot be considered genuine. For example, a copy of a Rembrandt painting cannot be considered an authentic Rembrandt, but a reprint of Shakespearean poem is an authentic poem by Shakespeare. This clearly shows that digital artefacts and material works of art belong to different categories, and there are practical consequences in the way we can preserve them. For a piece of autographic art, authenticity rests in the material object itself. This is the reason why we have to preserve the object. We assign a probative value to the materiality of an object that, as a last resort, may serve to justify its authenticity. For allographic art, where each copy is genuine, it logically ensues that this concept of authenticity is meaningless. To avoid this ambiguity, it is appropriate to consider a digital document as we would an immaterial datum or a sequence of numbers, that is embodied in any new recording, on condition that it be authentic, using the primary definition of authenticity, i.e., "Authenticity implies unabridged conformity with a verbatim original." As R. Lemaire (17) sums it up, a message is authentic if it its transmitted unaltered, down to its nuances, from a sender to a recipient.

All these changes that we have experienced in the museum collections, brought about by industrial development and ranging from tangible artefacts to time-based objects, also occurred in a similar manner to conservation and restoration practice.

The impact of industrial development on conservation practice

The conservation field did not resist the lure of modernity and industrial development. At first, this enthusiasm has led to the negligence of necessary precautions, assuming that chemistry and its industrial development would be capable of providing modern and efficient solutions to solve some conservation issues (18). Synthetic polymers are, without a doubt, among the materials which have enjoyed rapid acceptance in the conservation field, for example: cellulose acetate, soluble nylon, polyurethane foam, and PVC. From the 1950s, the use of new types of varnishes, adhesives, and consolidants spread among cultural heritage professionals. Pesticides and fungicides developed for agro-food were widely applied to collections. Over time, many of these treatments have proved disastrous for several reasons: lack of compatibility, lack of permanence, damage to artefacts, toxicity, and so on. It took a few decades to realise the extent of such damage, and to establish a more careful approach through the education of museum professionals. Alongside these new materials, the mechanization of certain treatments for restoration has been introduced. Equipment for lamination, leaf-casting, and paper splitting have been made available, sometimes opening up discussion in terms of the integrity of the work, even though the new apparatus only replicate what the restorer had been doing manually. The important inputs of industrial development are the mass treatments. They rely on advances in chemistry and physics to treat large volumes of artefacts without the need to treat them individually. Some of these techniques are derived from food industries. The most frequent mass treatments are freeze-drying for drying flooded and frozen paper documents, gamma radiation or ethylene oxide for disinfection or disinfestations, and mass deacidification.

Let us take the example of mass deacidification: it is crucial to take diverse parameters into account for this conservation treatment, which depends not only on technical performance but also on societal choices. Mass deacidification has been the subject of intense research since the 1970s. At this time, society was very confident in chemical treatments. To handle hundreds of books simultaneously with their bindings, it was necessary to develop appropriate techniques. Weit'o process was introduced in North America in the 1970's. The books were introduced into an autoclave and subjected to a mixture of alcohol, chlorofluorocarbon and methoxy methyl carbonate magnesium. The archives of Canada (1981) and the Bibliothèque Nationale de France (1987) were equipped with such deacidification units. In Houston, Texas, a deacidification plant based on the use of diethyl zinc or "DEZ" was constructed for the Library of Congress, but was later discontinued in 1994. Many other mass treatments

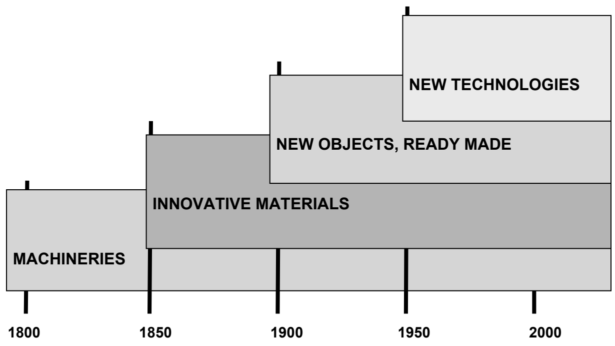


Fig.1: The impact of industry on the museum collections: with the achievement of industrial developments, museum collections have gradually inherited a different kind of artefacts.

were introduced, but all these R&D activities are currently under scrutiny and their future is uncertain. The use of new conservation techniques is not only questioned in terms of efficiency and compatibility with artefacts. The conservation decision process is also based on socio-economic, ethical, and humanistic considerations that also include aspects of costs, benefits, and hazards. The conservation community is now more circumspect about chemical treatments and, no doubt, more concerned about the implications they may have on the integrity of the work and about their impact on the environment. This is not limited to the conservation field but has reached all levels of industrial societies. The assessment of damages caused by excessive use of medications (such as antibiotics) or fertilizers have contributed to the public's resistance towards mass chemical treatment. Cultural and technological contexts have also changed tremendously. The explosion of digital technology tends to reduce the use of original documents that can be preserved under optimal conditions. This awareness has also contributed to the development of preventive conservation. In the field of audio-visual heritage, it has lead to the promotion of cold storage to slow down deterioration, and also to the development of tools to monitor the state of deterioration. The Danish Film Archives is a good example. Thus, if the application of freeze-drying is widely accepted, other mass treatments such as gamma-ray irradiation and ethylene-oxide disinfection will tend to disappear. It is true that the development of digital technology has played a significant role in the way our society is now considering these issues. Digital technologies have opened new possibilities in conservation-restoration: fast access, tools for documentation and imaging of works of art (from photograph to multi-spectral images), digital image processing for the recreation of damaged parts, etc. All this has proved useful for conservation work, from the decision-making process for restoration to the education of the general public (19).

Conclusion

For over 100 years, industrial development has been the backbone of our society and the source of our economic prosperity. It is therefore justified that we observe its repercussions in the field of cultural heritage. In fact, mass production was never intended to directly serve the field of cultural heritage, for it is a too-limited market for such a development. However, several mass-produced materials, objects, techniques, and technologies are nowadays in museum collections or have multiple applications and implications in the museum field, from the constituents of works of art to conservation activities. We could certainly list the most remarkable innovations as well as the more problematic ones for cultural heritage, but this would only consider the tangible aspect. The contribution to our field lies also in methods and approaches borrowed from the industry: the practises of standardization (e.g., accelerated aging tests, the blue wool standard, the Teas triangle) and quality control (e.g., the statistical survey of collections) were inherited from industrial practices. It is likely that the next industrial evolution will be connected to environmental issues. The "green industry" and the growing public interest in sustainable development will probably have a great impact on cultural heritage. This proves that industries are able to move ahead and take seriously into consideration new societal problems such as preservation of nature and environment. This is a good opportunity to remind ourselves that it would make sense to consider the preservation of cultural heritage as well.

Acknowledgements

Dr. Yot Boontongkong, Dr. Christine Capderou, and Mrs Hope Kingsley.

Author

Bertrand Lavédrine
Director
Centre de recherche sur la conservation des collections
MNHN-CNRS-MCC
36, rue Geoffroy-Saint-Hilaire
F-75005 Paris France
lavedrin@mnhn.fr

References and notes

1) *Exposition universelle de 1851. Travaux de la commission française sur l'industrie des nations,* tome IV, Paris, Imprimerie Impériale, 1854. p.6.
2) Dumas M., *Traité de chimie appliquée aux arts*, Paris, Bechet jeune, libraire éditeur, 1846.
3) Woronoff D., *Histoire de l'industrie en France du XVIe à nos jours*, Paris, éditions du seuil, 1994, p.238.
4) Exposition et histoire des principales découvertes scientifiques modernes (4 volumes, 1851-1857). Les Applications nouvelles de la science à l'industrie et aux arts en 1855 : machine à vapeur, bateaux à vapeur... (1856). Histoire du merveilleux dans les temps modernes (4 volumes, 1859-1862). Les Grandes Inventions anciennes et modernes, dans les sciences, l'industrie et les arts (1861). Le Savant du foyer ou Notions scientifiques sur les objets usuels de la vie (1862). Les Merveilles de la science (6 volumes, 1867-1869). Les Merveilles de l'industrie (4 volumes, 1873-1876). Les Nouvelles Conquêtes de la science (4 volumes, 1883-1885). Les Mystères de la science (1887). Le Lendemain de la mort ou La vie future selon selon la science (1889).
5) "*Vous irez me chercher des tiges d'artichaut, des tiges d'asperge, des orties à dard, des roseaux que vous couperez aux bords de votre petite rivière. Demain je sortirai de votre cellier avec du magnifique papier* ".
6) http://www.plastiquarian.com/hyatt.htm, March 2009.
7) Maddox R.L., "An experiment with gelatino-bromide", *British Journal of Photography*, 1871, vol. 18, n° 592, pp. 422-3.
8) Benjamin W., *L'œuvre d'art à l'époque de sa reproduction mécanisée*, rééd. In Écrits français, Paris, Gallimard, 1991, (Bibliothèque des idées).
9) "l'avènement de l'œuvre d'art contemporaine réside dans sa dimension de masse, de production, de perception et d'appropriation collectives" http://archivesic.ccsd.cnrs.fr/docs/00/06/21/25/PDF/sic_00000302.pdf, March 2009
10) Genette G., *L'œuvre de l'art. Immanence et transcendance*. Paris: édition du Seuil (Collection Poétique), 1994.
11) http://www.fingartprint.org/, March 2009.
12) Mallinson J.C., "Archiving Human and Machine Readable Records for the Millennia" in SPSE, *The Stability and Preservation of Photographic Images,* Second International Symposium, Ottawa, Ontario, Canada, August 25–28, 1985. Springfield, VA, USA: Society of Photographic Scientists and Engineers (SPSE), 1985, pp. 60–3.
13) Friend M., "Film.digital/film", *Journal of Film Preservation*, n°50, 1995, p.36-49.
14) Conway P., *Preservation in the digital world*, Washington, published by The Commission Preservation and Access, 1996.
15) Choay F., "Sept propositions sur le concept d'authenticité et son usage dans les pratiques du patrimoine artistique," Conference on Authenticity, Nara 1-6-XI-1994, Working papers compiled by ICOMOS.
Brock-Nannestad G., "The Rationale Behind Operational Conservation Theory", Preprint of the conference, Conservation Without Limits, IIC Nordic Group XV Congress 23-26 August 2000, Helsinki, Finland, pp.21-32.

16) Goodman N., *Langages de l'art,* Nîmes: éditions Jaqueline Chambon, 1990.
17) Lemaire R., "Authenticité et patrimoine monumental" Conference on Authenticity, Nara 1-6-XI-1994, Working papers complied by ICOMOS.
18) Torraca G. (1996), "The scientist's role in historic preservation with particular reference to stone conservation", in *Historical and philosophical issues in the conservation of cultural heritage : readings in conservation*, edited by N. Stanley Price, K. Talley Jr., A. Meluco Vaccaro, Los Angeles : The J. Paul Getty Trust, p. 439-444.
19) *Informatique et conservation-restauration*, Champs-sur-Marne: SFIIC, 1997.

Plastic - has the dream material of the 20th century become the nightmare of the 21st ?

Yvonne Shashoua

Plastic - the dream material

The world's annual consumption of plastic materials increased from around 5 million tonnes in the 1950s to nearly 100 million tonnes in the year 2000. In 1982, plastics production surpassed that of steel worldwide and that year was heralded as the start of the Plastic Age [1]. Increase in the number of processing and fabrication techniques has allowed modern plastics to be manipulated in thin film, bulk and foam forms, and to be combined and reinforced with fibres, metals, wood and other materials. Different plastics types can also be laminated together using heat. Today there are approximately 50 different basic types of plastics included in 60,000 formulations. Packaging is the biggest market sector for plastics [2]. Polyethylene and poly (vinyl chloride) are the most highly consumed of all plastics worldwide.

Synthetic plastics have had a significant influence on industrial, domestic and cultural aspects of everyday life in the 20th and 21st centuries. Their significance is reflected in the prophecy by artists Marcel Biefer and Beat Zgraggen in 1991 which states that 'plastic artefacts will be the most important witnesses to our time'[3].

Plastics represent advances in technology, illustrated by the dramatic growth in number and type of information storage media available since the 1970s, credit and payment cards and food containers which can be taken directly from freezer to microwave oven to dinner table without damage. Before the 1940s, it was not possible to drink hot coffee from a plastic cup without it softening and becoming too hot to hold - an activity which is commonplace today.

Plastics have largely replaced natural materials. Restrictions on imported rubber latex, wool, silk and other natural materials to Europe during World War 2 stimulated the development of synthetic alternatives. Between 1935 and 1945, many new polymers were introduced including polyethylene, polyamides, poly (methyl methacrylate), polyurethanes, poly (vinyl chloride), silicones, epoxies, polytetrafluoroethylene and polystyrene. Polyethylene was incorporated into radar systems while poly (vinyl chloride) replaced the limited stocks of natural rubber as cable insulation.

Plastics have become commercially valuable. Prices of contemporary art, designs in plastic, jewellery and plastic models associated with movie films have increased dramatically since the mid 1980s. At auction in February 2007, Naum Gabo´s `Linear Construction in Space No.3´ was sold for a record £1,252,000 [4]. Previous sales of Gabo´s work had realised a maximum £350,500. In September 2006, a Barbie doll manufactured in 1955, ´Barbie in midnight red´, was auctioned for £9,000 and is the most expensive doll sold at auction.

Today, almost all international museums and galleries possess collections which contain plastics either as objects in their own right or as components of composite objects (Table 1). The majority of private collections are devoted exclusively to particular plastics such as Bakelite, or contain a significant proportion of plastics (e.g. button, toy and radio collections) whereas in museum collections, plastics are more widely distributed and include components in addition to whole objects of plastic[5].

Degradation - the bubble bursts

Until the late 1970s, plastics were widely believed to be dream materials and to last forever, a belief fuelled by the plastics industry. The first publication concerning degradation of a commercial polymer appeared in 1861 in the Journal of the Chemical Society [6]. It concerned the failure of gutta percha cable insulation used to construct the East Indian telegraphs which deteriorated immediately after

Table 1. Collections containing plastics

Type of collection	Examples of objects
information carriers	plastic sheets, maps, tapes, floppy disks, CDs, DVDs, photographic film, plastic newspapers
technology	electronic circuit boards, cable insulation, housings for electrical equipment
transport	upholstery, bumpers and dash boards in cars and lorries, agricultural machinery, bicycles, windows in side cars, fibreglass boats, protective clothing, spacesuits
military	uniforms, protective equipment, rucksacks, tents, parachutes, transport
building	gutters, pipes, flooring, wall coverings, furniture
modern history	clothes, shoes and other fashion accessories such as bags and jewellery, makeup containers, furniture, toys
medical equipment	blood bags, prosthetic limbs and joints, false teeth, spectacles, tubing, syringes
sports equipment	surfboards, racquets, clothing
modern (from 1880s to 1970s) and contemporary art (from 1970s to present)	paintings, collage, sculptures, video film art, photographic art
coins and medals	tokens, badges
packaging	bubble wrap, photograph pockets, laminating sheets, book coverings, plastic bags

installation, resulting in substantial financial loss. Gutta percha is an inelastic natural polymer produced by the tree *Palaquium gutta*. However, the plastics industry did not research degradation of synthetic polymers in a structured way until the 1960s and the subject is still at an early stage of development.

Degradation of a plastic is any change which has adverse effects on its properties or function. Quackenbos, an industrial chemist, defined the lifetime of polyvinyl chloride (PVC) as the time taken to lose 10% of original weight because after such loss, its performance was no longer acceptable [7]. Degradation of plastics in museums is not defined by physical and chemical changes alone but by the resulting loss in function, form or significance of the object. In addition to establishing the degradation pathways for plastics in museum objects, it is also necessary to decide how much degradation is acceptable. While yellowing is valued as a sign of maturity in materials such as oil paint, the same changes in plastics are deemed unacceptable [8].

Industrial plastics are designed to function for a predetermined period (Table 2). Degradation takes place during two phases in plastics' life cycles. During manufacture, plastics are subjected to high temperatures under moulding and extruding which provide an opportunity for thermal and oxidative degradation. During use, plastic is exposed continually to air, moisture, light and heat initiating and accelerating changes in the chemistry of the polymer chains and additives. Most objects have been used or displayed prior to collection by museums. Their history contributes to their rate of degradation. Prolonged exposure to light, heat, moisture, chemicals and gaseous pollutants during that period will reduce longevity.

Four plastics have been identified as being more vulnerable to degradation than others in museums, namely cellulose nitrate, cellulose acetate, plasticised polyvinyl chloride (PVC) and polyurethane foams. Instability of the earliest plastics, cellulose nitrate and acetate is expected due to their poorly stabilized, experimental formulations and because they are the oldest man-made plastics dating from late 19th and early 20th centuries. However, PVC and polyurethanes were first commercially available after the Second World War and are still used, so their short lifetimes are more difficult to accept.

Table 2. Average designed lifetime for industrial plastics

Application	Average lifetime (years)
electrical cable insulation	21
upholstery covering	17
housings for domestic electrical appliances	11
blood bags	2-10
carrier bags	1

Figure 1: The frames of these cellulose nitrate spectacles made in the 1960s, began to show degradation by crazing and by the plastic´s ability to corrode copper ear wires and screws in the frame in the 1980s (left of image). By 1995, degradation had progressed so dramatically that the spectacles could no longer function and were hardly recognizable as a cohesive object (right of image). They were therefore deaccesioned by the National Museum of Denmark

Cellulose nitrate

Cellulose nitrate undergoes thermal, photochemical and hydrolytic degradation reactions, the latter being the most important [9]. In addition, breakdown of the polymer is autocatalytic. This means that, if not removed from the undegraded material, the breakdown products catalyse a faster and more extensive reaction than the primary processes. This may happen if a pair of spectacles with cellulose nitrate frames is stored in their closed case, for example. The major product of thermal degradation is the highly reactive, oxidising agent nitrogen dioxide NO_2, identified by its yellow vapour and distinctive odour.

Nitrogen dioxide reacts with moisture in air to form nitric acid. Water diffuses into cracks at surfaces, reacts with nitrogen dioxides evolved in the bulk of the CN object and produces nitric acid there. The acid attacks the cellulose polymer chains resulting in chain scission along the backbone between the cellulose rings. A reduction in molecular weight follows which is manifested typically by a network of cracks which start inside the object before spreading to surfaces causing brittleness and weakening. As degradation continues, internal cracks or crazes develop and cellulose nitrate yellows (Figure 1). In the final stage, crazing known as crizzling is so extensive that cellulose nitrate disintegrates.

Some metals, particularly copper, accelerate the rate of degradation of cellulose nitrate. Nitric acid produced by cellulose nitrate corrodes metals. If the metal is a structural component of the object, such as the shaft of a knife, corrosion can lead to destruction of the handle. Because of the corrosion layer formed, the volume occupied by the metal increases until the CN cracks and bursts. Nitric acid may also corrode metals in the vicinity of the CN object.

Cellulose acetate

Like cellulose nitrate, cellulose acetate (CA) is deteriorated by both physical and chemical factors and the physical cause of degradation is plasticiser loss. Three-dimensional objects moulded from cellulose acetate comprise 20-40 per cent by weight plasticiser. Typical plasticisers include triphenyl phosphate (TPP), a solid with melting point 48.5ºC which also acts as a flame retardant. Migration and subsequent evaporation of plasticiser from between the cellulose acetate chains give rise to shrinkage, tackiness and increased brittleness (Figure 2).

The major chemical degradation reaction of cellulose acetate is also similar to that of cellulose nitrate,

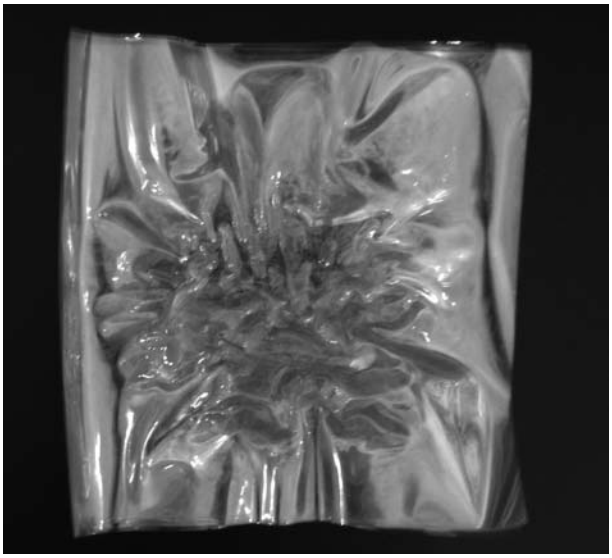


Figure 2: A pile of transparent cellulose acetate tracing sheets from the 1980s illustrate typical physical deterioration. Sheets have shrunk and droplets of lost plasticiser can be seen at surfaces

the primary reaction being hydrolysis also known as deacetylation, during which hydroxyl groups replace acetate groups (CH_3COO) on the cellulose ring, producing acetic acid (CH_3COOH). Cellulose acetate undergoes autocatalytic breakdown if acetic acid is allowed to remain in contact with the degrading polymer. This happens easily because the solubility of acetic acid in cellulose acetate is high, similar to the solubility of acetic acid in water in atmospheric moisture [10].

Deacetylation is accelerated by water (usually in the form of moisture in air), acid or base. Because the loss of acetyl groups from cellulose acetate results in the formation of acetic acid which gives a distinct vinegar-like odour to degrading materials, the process is also known as the 'vinegar syndrome'. Because the acidic vapours are mobile, acetic acid produced by deteriorating cellulose acetate contributes to degradation of other organic materials in the vicinity. Metals are corroded by the acetic acid produced by deacetylation. With time and loss of acetate groups, the production of acetic acid lessens and the cellulose acetate is reduced to its starting raw material, namely cellulose.

Plasticised polyvinyl chloride

In many museum collections, degradation of plasticised PVC materials such as clothing and footwear, furniture, electrical insulation, medical equipment, housewares, toys and packaging materials, is detected only 5-10 years after acquisition. Degradation is usually manifested first as tackiness at surfaces accompanied by a glossy appearance, then by discolouration and sometimes with white crystals at surfaces. The degradation pathways exhibited by plasticised PVC are the result of degradation of the two major components of its formulation, namely polymer and plasticiser. Although the two components deteriorate independently of each other, the resulting products destabilise the whole.

Plasticisers are the major modifier for PVC formulations in terms of percentage weight (between 15 per cent for vinyl flooring and 50 per cent for waterproof boots) and physical properties. Plasticiser molecules are evenly dispersed throughout the PVC, and are weakly attached to the surfaces of polymer chains. The largest single product used as

Figure 3: Plasticised PVC photograph pocket from 1980s showing liquid plasticiser which has migrated from the PVC polymer and will contaminate any enclosed materials

a general purpose plasticiser worldwide since the 1950s is di (2-ethylhexyl) phthalate (DEHP) and this has been identified in many museum plastics [11]. The tackiness and development of high gloss in deteriorating PVC indicate that liquid plasticiser has migrated to surfaces (Figure 3). From there, plasticiser evaporates at a rate dependant on its vapour pressure. DEHP has a boiling point of 386ºC and evaporates slowly under ambient conditions.

The PVC polymer is susceptible to degradation when exposed to heat, light and oxygen. The pathway by which degradation of the PVC polymer takes place is complex but comprises one major reaction involving the evolution of hydrogen chloride (dehyrochlorination). Dehydrochlorination occurs at imperfections in the PVC structure and starts with the breaking of a C-Cl bond. This leads to the progressive 'unzipping' of neighbouring chorine and hydrogen atoms to form a conjugated polyene system (alternate single and double carbon bonds), accompanied by the formation of hydrogen chloride. After between 7 and 11 repeat polyene units have formed, absorption of light shifts to longer wavelengths until the deteriorated PVC is absorbing in the violet, blue and green parts of the spectrum. The rate of degradation can therefore be followed using colour changes from white to yellow to orange to red, brown and, ultimately black. Dehydrochlorination is an autocatalytic reaction so if the hydrogen chloride produced is not removed from the environment surrounding PVC, degradation continues at an accelerated rate.

The rate and extent of degradation of the PVC polymer and the migration and loss of plasticiser, particularly phthalates, are related. Because DEHP inhibits the degradation of the PVC polymer, when it either migrates to surfaces or is absorbed by other materials, PVC discolours, becomes tacky and brittle. Addition of phthalate plasticisers to PVC has been shown to reduce the rate of dehydrochlorination by the polymer, by inhibiting the growth of the polyene sequence [12].

Like all esters, phthalate plasticisers are susceptible to hydrolysis (addition of water) when exposed to strongly acidic or alkaline environments. Acidic conditions develop when PVC polymers undergo dehydrochlorination and results in acid hydrolysis of plasticisers to form phthalic acid, a white crystalline solid acidic hydrogen chloride. Although phthalic anhydride disfigures objects, it does not accelerate degradation (Figure 4).

Figure 4: Star Wars figures are made from plasticised PVC and are highly collectible. Darth Vader has remained in his original packaging with the result that the migrating plasticiser has hydrolysed in the acid environment. White crystals of phthalic anhydride are visible on his once-black head

Polyurethane foams

The many pores or cells in polyurethane foams make the polymer highly accessible to oxygen, light and water in air. In addition, the processing of foams may involve blowing air through polyurethanes in liquid form, providing perfect conditions for oxidation. The extent of sensitivity of polyurethane foams to chemical degradation factors is dependant on the polyol base used. Polyester-based polyurethanes are more readily hydrolysed than polyether-based materials. The degradation products catalyse further hydrolysis.

Polyurethane ether (PUR-ether) foams are thought to degrade primarily by oxidation, particularly in the presence of light, resulting in discolouration and a loss of mechanical properties. Polyurethanes synthesised from a polyether polyol and an aromatic diisocyanate such as diphenylmethane diisocyanate (MDI) are highly vulnerable to photooxidation whereas polyester-based polyurethanes are more resistant to ultraviolet radiation [13].

Photooxidation results in chain scission, in which energy breaks polymer chain bonds to create a polymer with two or more shorter chains and is manifested by collapse and crumbling of foams. Scission of the urethane link (-NHCOO-) results in the formation of amino and carbonyl groups with the evolution of carbon monoxide and dioxide. Crumbling often starts at surface skins of foams and, when the surfaces crumble and fall away from the object, fresh, undegraded foam is exposed to light, perpetuating degradation to the point of complete failure (Figure 5).

Conservation - the nightmare challenge

Once initiated, degradation of plastics cannot be prevented, reversed or stopped, but only inhibited or slowed. Slowing the rate of degradation is achieved by storing objects in conditions which exclude the main factors causing degradation, particularly oxygen and moisture. Interventive conservation involves adhering broken sections, cleaning and strengthening. It is poorly developed compared to inhibitive conservation due to the high sensitivity of plastics to cleaning agents, adhesives and consolidants. There is a high risk of causing irreversible damage to plastics, a nightmare scenario for conservators. However, pressure from professionals who study plastics, the commercial art market, private collectors and exhibition organisers is accelerating progress in this field [14].

Figure 5: Photo-oxidation of polyurethane ether foam frequently results in loss of structure and crumbling

Inhibiting degradation using adsorbents

Adsorbents, also known as molecular traps or scavengers, can be used to inhibit the rate of degradation of plastics by minimising those factors which either initiate or accelerate deterioration. Adsorbents may either be installed in an active filter system, simply placed in a dish or polyethylene bag inside the storage area or incorporated into packaging materials.

Activated carbon is widely used for industrial, domestic and medical applications and is effective at adsorbing large non-polar molecules. It has a huge surface area of 300-2000m^2 per gram and contains millions of microscopic pores each 1-5 molecular diameters across. Molecules at surfaces of activated carbon are retained by physisorption, primarily via weak dispersion forces. Activated carbon is used to reduce the rate of degradation of cellulose nitrate CN. When used as a filter in an active system, carbon has been shown to remove as much as 90% nitrous oxides, CN's primary degradation products, from air in a single pass [15].

Because of activated carbon's poor specificity, water molecules and other pollutants in air compete with nitrous oxides for sites (Figure 6). Activated charcoal is not self-indicating so the first sign that the adsorbent is exhausted may be renewed deterioration of an object.

Zeolites are hydrated silicates of metallic ions, most frequently calcium and aluminium, which contain micropores of pre-determined diameters. The dimensions of micropores determine which gases, vapours or liquids particular zeolites are able to trap. Whereas activated carbon retains molecules weakly by physisorption, molecules are held onto zeolite's walls by chemisorption or covalent bonds which contain about 10 times greater energy.

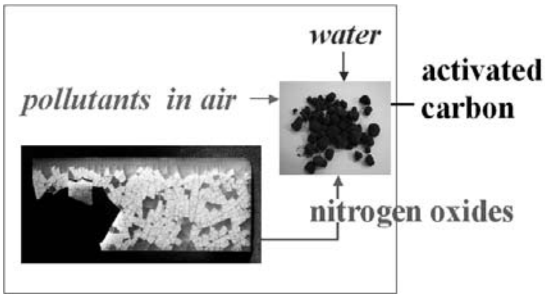


Figure 6: Acivated carbon adsorbs many different gases and is used to remove nitrogen oxides from degrading cellulose nitrate. Because activated carbon also adsorbs water and pollutants in air, it is readily exhausted

Zeolites were first shown in 1994 to inhibit the rate of deterioration of photographic negative film based on cellulose acetate [16]. The technique has since been adapted to inhibit the deterioration of three-dimensional materials containing cellulose acetate including handbags, jewellery and modern art [17]. They are thought to inhibit the degradation of cellulose acetate by both trapping water vapour from the polymer, thereby minimising the rate of hydrolysis and by trapping acetic acid vapour which reduces the opportunity for more dominant, rapid autocatalysis to occur. When both water and acetic acid are present, they compete for sites in the zeolite lattice, reducing the effectiveness of adsorption of acetic acid by approximately one third.

Because most synthetic materials react with oxygen, removing oxygen limits degradation. Since the 1990s, commercial products such as Ageless® and Atco® oxygen absorbers designed to inhibit the oxidation of packaged foods, have been applied to plastics [18]. They comprise gas-permeable sachets containing finely-divided iron which forms iron oxides in the presence of water, binding oxygen from the surrounding air. Ageless® oxygen absorber can reduce the oxygen concentration of an air-tight container to 0.01% (100ppm) or less. Objects are placed in an oxygen-impermeable envelope, such as those prepared from Cryovac® BDF-200 film (a transparent laminate of nylon and polyolefins) or Escal®, a ceramic-coated film together with oxygen absorbents.

Interventive conservation

Interventive treatments for plastics include cleaning, joining broken and failed components, consolidation, impregnation and filling. There is little in the conservation literature detailing interventive treatments for plastics, probably due to the high sensitivity of many plastics, especially when deteriorated, to organic liquids, aqueous solutions and water. Interventive conservation of plastics has attained a reputation of high risk and irreversibility.

Cleaning plastics

Although condition surveys of museum collections containing plastics suggest that approximately 75% require cleaning, the practice is still poorly developed and is one of the major research areas of the EU 7th Framework project, POPART (Strategy for Preservation Of Plastic ARTefacts in Museums) which started in 2008 (http://popart.mnhn.fr). Cleaning techniques may be divided into mechanical and chemical. Mechanical cleaning involves removal of dust and residues from surfaces, either by blowing air from a can or cylinder or via suction, using brushes or cloths. Plastics with a glass transition temperature approaching ambient, particularly plasticised PVC and polyethylene, are readily abraded. Scratches are areas of low energy and vulnerable to chain scission manifested as a reduction in tensile strength and eventual failure. Scratches decrease the light reflective properties of surfaces, resulting in a reduction in gloss.

The purpose of chemical cleaning is to dissolve dirt, residues or other unwanted material at surfaces and to displace it. The type and polarity of the plastic, its condition and the presence of conservation materials influences the effectiveness of cleaning agents. For example, since hydrolytic breakdown is a major pathway for semi-synthetic polymers, the use of aqueous cleaning agents is not advisable for them.
The risk of organic liquids swelling, dissolving and extracting additives from plastics is higher than that posed by aqueous washing agents [19]. Another phenomenon to be considered when cleaning rigid plastics such as polystyrene, polycarbonate and

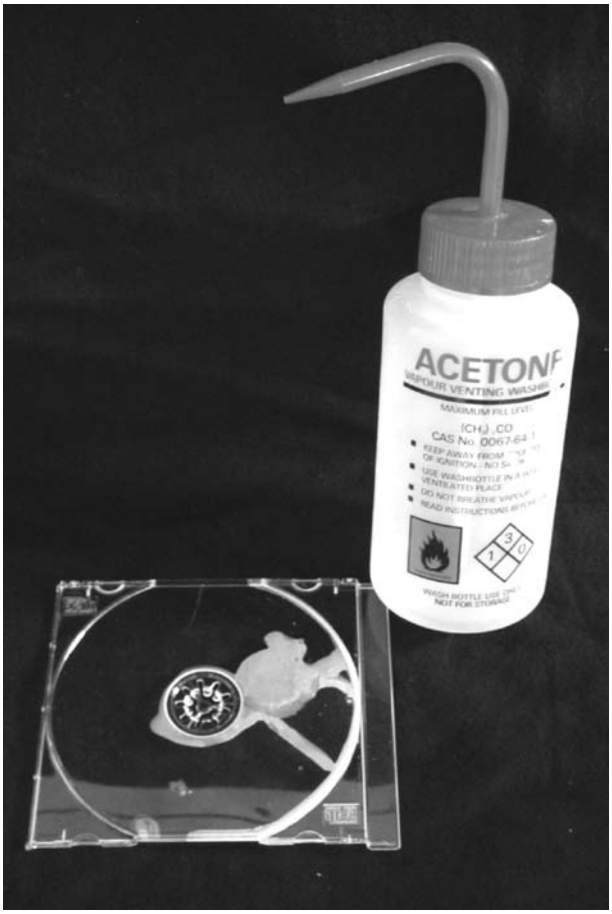


Figure 7: Environmental Stress Cracking (ESC) can be induced by cleaning a rigid plastic such as with a low boiling point solvent. The polystyrene jewel case shown here has been treated with acetone

polymethyl methacrylate is stress cracking, correctly known as Environmental Stress Cracking (ESC), which results in white crystalline structures or interconnecting cracks [20]. Stress cracking is irreversible and may occur either immediately after application of a solvent or develop gradually. Chemicals that do not attack a polymer in an unstressed state can attack the area weakened by localised stress causing a crack or craze and partial breaking of polymer chains. Chain separation allows air into polymers. Due to differences between the refractive indices of air and polymers, the fractures are observed as whitening (Figure 7). One possible cause of ESC is that absorption of high concentrations of solvent vapours induces compression and the release of strains from manufacture. Another option is that evaporation of the solvent results in heat loss by the plastic causing localised cooling. Plastics have low thermal conductivity, so while the cold areas contract, adjacent areas remain warm causing changes in dimension.

A systematic approach to selecting liquids with which to clean plastics is to compare the polarity of the liquid with that of the plastic to avoid those liquids most likely to dissolve or soften. Solubility parameters are experimentally determinable measures of the forces of attraction which hold molecules together. Solution occurs when solubility parameters of polymer and solvent are within around 2 $MPa^{1/2}$. Based on solubility alone, water is unlikely to damage the surfaces of plastics if used as a cleaning agent and acetone-based materials are likely to soften or dissolve cellulose nitrate, polymerthyl methacrylate, PVC and polyethylene terephthalate so should be avoided [2].

Commercial polishes which claim to remove scratches from plastics are either based on abrasive particles suspended in a solvent-based medium or contain silicone polymers. The former physically smoothes the edges of scratches in acrylic, polycarbonate and other rigid plastics when applied at right angles to the scratch eg Star Brite® Plastic Scratch Remover. The second type of polish fills the scratch with a silicone polymer which wets the surfaces of flexible plastics and imparts high gloss e.g. Vinyl Makeup®. Because silicone polymers have very low surface tensions, it is very difficult to retreat or remove polishes, so their use must be considered irreversible.

Joining plastics

It is almost impossible to successfully repair plastics without partial dissolution, melting or other type of disruption to surfaces [21]. Joining plastics may be achieved by mechanical fastening, adhesion, thermal- or solvent welding. In the near absence of established conservation techniques, an overview of the industrial approach to joining plastics is presented here.

Mechanical fastening of plastic components is reserved for non-rigid plastics which can withstand the strain associated with inserting screws, push-on clips and nuts. Thin sheets or films of flexible plastics can be joined by stitching, using synthetic thread

Table 3. Critical Surface Tensions of common plastics and metals

Material	Critical surface tension mN/m at 20ºC
acrylonitrile-butadiene-styrene	35
acrylics	32
aluminium	c. 500
cellulose (paper)	45
copper	c.1000
cyanoacrylates (superglues)	37
epoxy	47
polyamide	46
polycarbonate	46
polyethylene	31
polyethylene terephthalate	43
polymethylmethacrylate	39
polystyrene	33
polytetrafluoroethylene	18
polyvinyl chloride	39
silicone	24
water	73

such as polyester to accommodate dimensional changes which occur with variations in relative humidity and temperature.

An adhesive should have a surface tension lower than its intended adherend. It is difficult to find adhesives with lower critical surface tensions than those of plastics (Table 3). A dilute, water-based adhesive is unlikely to wet plastic because the surface tension of water is 73 mN/m compared with only 30-45 mN/m for most plastics. A surface contaminated with silicone (18 mN/m) from, say, waterproofing polish, will also be difficult to wet and subsequently to adhere. Plastics must be free of contaminants if adhesion is to succeed.

Selection of an appropriate adhesive for joining industrial plastics is initially dependant on whether a structural or a non-structural material is required. If a structural adhesive is required, thermosetting adhesives such as epoxies, polyurethanes and acrylics are those most frequently chosen because they exhibit toughness and flexibility. Non-structural materials include pressure-sensitive, contact and hot-melt adhesives.

Conclusion

It is now indisputable that both early and modern plastics have a finite lifetime and will deteriorate. Because their degradation pathways are complex and often poorly understood, the preservation of plastics gives conservators and collectors nightmares. Once initiated, degradation of plastics cannot be prevented, reversed or stopped, but only inhibited or slowed. Slowing the rate of deterioration of most plastic types is achieved by storing objects in an appropriate microclimate which removes the main factors causing degradation including oxygen, acidic gases and moisture. Broad-spectrum, adsorbents such as activated carbon and zeolites are currently used to achieve appropriate microclimates. They are inefficient and require frequent renewal. Pilot studies on the effect of cold storage on physical properties of selected plastics indicate that storage of plastics in a domestic freezer should be considered as an alternative.

In addition to prolonging the lifetime of plastics materials, preservation of their appearance and significance is a requirement in museums, galleries and private collections. This area of conservation has been neglected due to the high sensitivity of plastics to cleaning agents, solvents, adhesives and consolidants. However, the risks of causing irreversible damage to plastics by interventive treatments can be minimised by adapting established adhesive and cleaning techniques from the plastics industry to meet conservation ethics. Applying tools such as solubility parameters and critical surface tension values would facilitate intelligent choices of conservation materials.
Investment in time and resources to collaborate with the plastics industry who have experience of production of plastics is required now to develop more effective and less damaging techniques for conserving plastics in the future.

Author

Yvonne Shashoua
Senior Researcher
Department of Conservation
National Museum of Denmark
I.C. Modewegsvej - Brede
DK - 2800 Kongens Lyngby
Denmark
email: yvonne.shashoua@natmus.dk

References

1. Ward, P. (1997). Fantastic Plastic the kitsch collector's guide. New Burlington Books, London
2. Brydson, J.A. (1999). Plastics Materials. 6th edition. Butterworth-Heinemann, Oxford
3. Biefer, M. and Zgraggen, B.(1991). Prophecies no.27. Elwick Grover Aicken, Brighton
4. The Associated Press.(2007). 95 million pound sale of art gets European record for Sotheby´s [online]. Available from: http://www.iht.com/articles/ap/2007/02/06/arts/EU-A-E-ART-Britain-Art-Sale.php [Accessed 16 July 2007]
5. Morgan, J. (1994). A survey of plastics in historical collections . Plastics Historical Society and The Conservation Unit of Museums and Galleries Commission [online]. Available from: http://www.plastiquarian.com/survey/survey.htm [Accessed 7 March 2007]
6. Grassie, N. (1966). Fundamental Chemistry of Polymer Degradation. In Weathering and Degradation of Plastics (S.H. Pinner, ed) London Columbine Press, pp1-13.
7. Quackenbos, H.M. (1954). Plasticizers in vinyl chloride resins', Industrial and Engineering Chemistry, 46 (6), 1335-1341.
8. Van Oosten, T.(1999). Here Today, Gone Tomorrow? Problems with plastics in contemporary art In Postprints of Modern Art: Who Cares? (U.Hummelen and D.Sillé, eds), The Foundation for the Conservation of Modern Art and the Netherlands Institute for Cultural Heritage, Amsterdam, pp. 158-163.
9. Hamrang, A.1994.Degradation and stabilisation of cellulose based plastics and artefacts, Ph.D. thesis, Manchester Metropolitan University.
10. Ligterink, L.J. (2002). Notes on the use of acid absorbents in storage of cellulose acetate-based materials. In Contributions to Conservation, Research in Conservation at the Netherlands Institute for Cultural Heritage (J.A. Mosk and N.H.Tennent eds.) pp.64-73, James and James.
11. Shashoua, Y.R. 2001. Inhibiting the degradation of plasticised poly(vinyl chloride) –a museum perspective. Ph.D. thesis, Danish Polymer Centre, Technical University of Denmark.
12. Beltran, M. and Marcilla, A. (1997). PVC plastisols decomposition by FTIR spectroscopy, European Polymer Journal.33 (8), 1271-1280.
13. Kerr, N. and Batcheller, J. (1993). Degradation of polyurethanes in 20th-century museum textiles. In Postprints of Saving the Twentieth Century: The Conservation of Modern Materials Ottawa, 15-20 September 1991 (D. Grattan, ed) pp. 189-206. Canadian Conservation Institute.
14. Shashoua, Y.R. (2008). Conservation of Plastics-materials science, degradation and preservation. Elsevier, London, ISBN: 978-0-7506-6495-0
15. Hatchfield, P.B. (2002). Pollutants in the Museum Environment, Archetype Publications.
16. Ram A.T et al. (1994). The Effects and Prevention of the Vinegar Syndrome. Journal of Imaging Science and Technology, 1, p.7.
17. Derrick, M., Stulik, D. and Ornendez, E. (1993). Deterioration of cellulose nitrate sculptures made by Gabo and Pevsner. In Postprints of Saving the Twentieth Century: The Conservation of Modern Materials Ottawa, 15-20 September 1991 (D. Grattan, ed), pp. 169-182. Canadian Conservation Institute.
18. Grattan,D.W. and Gilberg, M. (1991). Ageless® oxygen absorber: chemical and physical properties. Studies in Conservation, 37, 267-274.

19. Sale, D.(1995). Standing out like a sore thumb:a damaged sculpture made of three synthetic polymers. In preprints of From marble to Chocolate, the conservation of Modern Sculpture London 18-20 September 1995 (J. Heumann, ed), pp. 89-103. Archetype Publications.
20. Fenn, J. (1993). Labelling plastic artefacts. In Postprints of Saving the Twentieth Century: The Conservation of Modern Materials Ottawa, 15-20 September 1991 (D. Grattan, ed), pp.341-350. Canadian Conservation Institute.
21. Coxon, H.C. (1993). Practical pitfalls in the identification of plastics. In Postprints of Saving the Twentieth Century: The Conservation of Modern Materials Ottawa, 15-20 September 1991 (D. Grattan, ed), pp. 395-409. Canadian Conservation Institute.

CONTRIBUTIONS

The industrialisation of canvas production in Denmark and its implications for the preservation of Danish nineteenth century paintings

Cecil Krarup Andersen, Troels Filtenborg,
Annemette B. Scharff and Mikkel Scharff

Introduction

Certain canvas paintings are prone to respond dramatically to moisture introduced accidentally or as part of a conservation treatment. The response, a general or more or less localised marked shrinking, typically produces flaking of the ground and paint-layers in tent-like formations parallel to the directions of the treads in the canvas. (fig 1)

Aspects of this well-known phenomenon have been discussed in a number of papers over the years, and it has generated research into the various elements of primed painting canvases, their interaction and their response to changes in humidity, as well as into the fundamental mechanical properties of woven fabrics. A number of factors in the fabric, size and priming have been identified or suggested as significant to the response of a painting at moisture absorption or desorption.

General response patterns of canvas, primed canvas and paintings at changes in relative humidity (RH) have been examined by several authors [1]. The mechanism by which swelling of the cellulosic fibres and yarns at high moisture content (RH >80-85%) leads to contraction of the woven fabric was discussed by Hedley and Bilson [2] emphasizing the swelling of the yarn diameter, not a longitudinal shortening of the yarns, as the dominant factor in the shrinkage. The model explains how tightly spun yarns and closely woven canvases will shrink more as there is less intrinsic free space to take up for the swelling fibres in a compact yarn, moisture absorption produces greater swelling of the overall yarn diameter thereby accentuating the crimp of the transverse yarns in the weave and thus inducing the shrinkage in that direction. A closely woven canvas with little separation between the yarns will by the same mechanism shrink more easily than a loosely woven canvas. The significance of the morphology or geometry of the fabric to the shrinking process is further demonstrated by the fact that, as a rule, most contraction will occur in the direction parallel to the yarns with the greater crimp – often the warp yarns. However, an additional – less predictable - type of response, called relaxation shrinkage, is triggered by the release of internal stress in the fabric, incorporated during its manufacture.

The modifying effect of (warm) size application on the mechanical properties of a canvas, tending towards more isotropy in the response of the fabric, has been shown [3]. And the role and properties of the size and ground layers have been discussed in a number of publications [4]. The cohesion within the ground itself has been investigated [5] showing the significance of the hygroscopic capacity of a ground as a factor affecting its adhesion to the canvas.

The occurrence of marked shrinkage and the accompanying tenting of the ground and paint layers are high in especially 19th century paintings, and the technological background for this has been inferred from early on. As it happens, the big shift in linen manufacture took place c. 1820-50 in Britain when power-spinning and power-weaving of flax were established. It has been generally accepted that the yarns and fabrics produced by the mechanisation were often more tightly spun and woven than their equivalents made by hand.

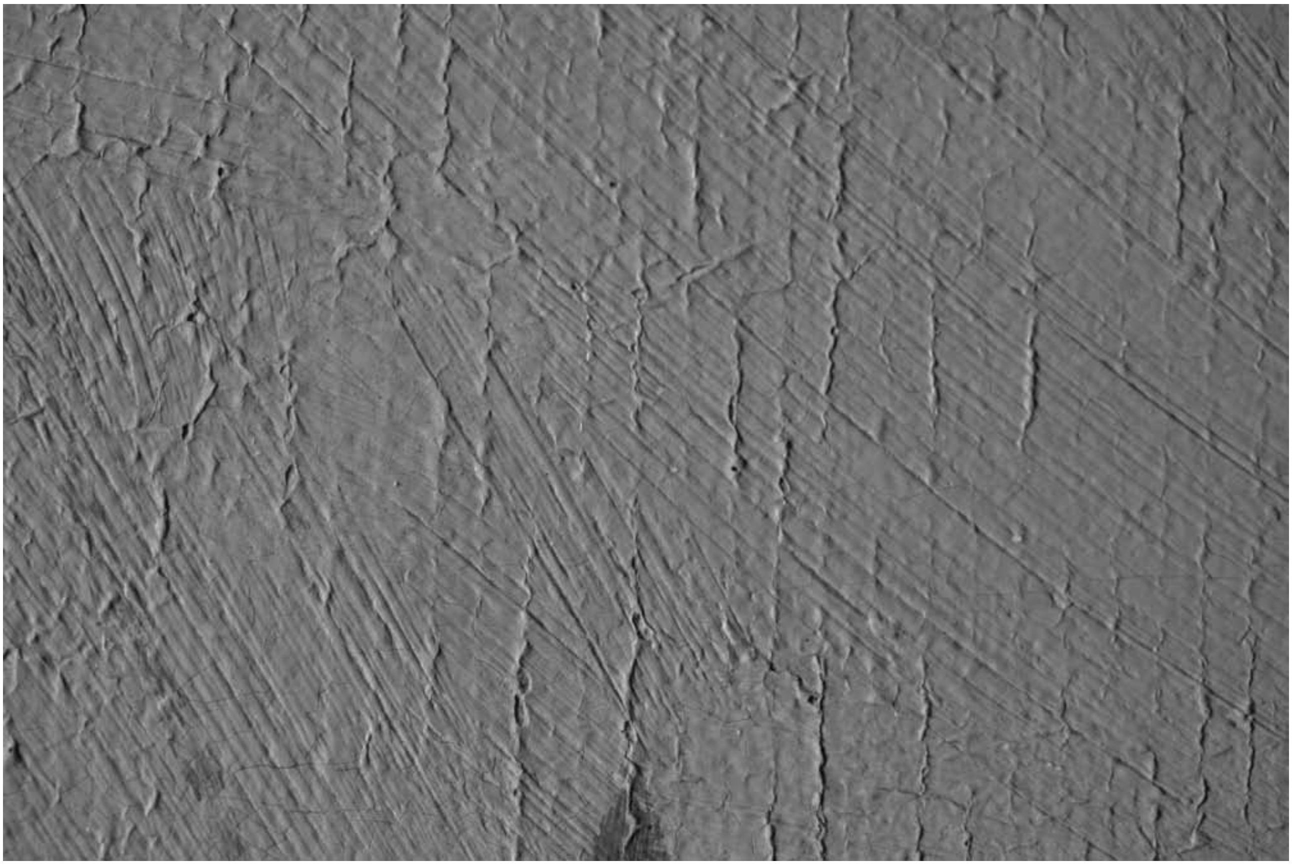


Figure 1. H.A. Brendekilde, Odense Kanal, 1895-1900. Private collection. Detail in raking light, showing tenting of the paint at an angle perpendicular to the shrinkage of the canvas.

By the late 18th century commercially prepared painting canvases with single or multi-layered grounds and saturated as well as underbound, more absorbent grounds were widely available [6]. In addition to the structure of the canvas itself, commercial priming methods, by which cold size in gel-form was applied on top of the canvas without permeating it, have been widely seen as predisposing the structure for shrinkage, as the size layer when exposed to high levels of moisture will revert to the gel form, thereby acting as a release layer between canvas and ground layers instead of restraining the shrinking forces of the fabric.

The result of the new techniques in canvas production, in combination with the commercial priming of the painting canvases, has thus by wide consensus been seen as the key to the shrinkage problem. And many European paintings produced during the 19th century have indeed proved to be the so-called *shrinkers* dreaded by conservators. In view of the unnerving scenario of a dramatically shrinking painting, a tradition has then evolved within the profession, based on which a choice of method can be made when dealing with a candidate for humidity treatment. A set of characters has been defined as the typical signs of a potential *shrinker*: a closely woven canvas, tightly spun yarns and a priming with a more or less well-defined size coating on top of the canvas and covered by a commercial ground (e.g. an oil ground) are generally accepted as being the main warning signs. However, not all *shrinkers* have exhibited these well-defined characteristics to the same degree, pointing towards a more complex combination of factors influencing their behaviour.

The aim of this study is to investigate the history and effects of the industrialized production of canvas with a specific view to Danish 19th century paintings. Evidence of Danish painters' access to, purchase of, and use of commercially produced and primed canvases is examined as well as their probable suppliers and manufacturers. In this context it is obviously important to identify the period in which one could expect to find a higher incidence of canvases with a strong potential for shrinkage. The initial British export ban of the relevant technology and Danish protectionist customs regulations affected the import of foreign linen as well as yarns for part of the 19th century. This means that the occurrence of industrially produced canvases in Denmark would hypothetically show a delay in date, compared for instance to British equivalents. An investigation of paintings in the collections of Aarhus Kunstmuseum and Statens Museum for Kunst, produced throughout the 19th century, does indeed seem to corroborate this hypothesis (see below) showing an occurrence of tenting in Danish paintings delimited to the last two thirds of the century. An awareness of this is of course important when assessing a given 19th century painting canvas in terms of its potential response to treatment.

The industrialisation of canvas production in Denmark

In the second half of the 18th century and during the 19th century the spinning of yarn and weaving of textiles slowly changed from hand to machine production. England was one of the first countries to take up the change, while Denmark more reluctantly followed.

Cotton and short wool fibres were the easiest fibres to spin mechanically. This is due to their elasticity and relatively short length compared to flax and hemp strands. The mechanisation started 1764 with the invention by James Hargreaves of the hand driven Spinning Jenny, which made it possible for one person to spin 16 spindles at a time. In 1769 this was followed by the water-driven Spinning Frame invented by Richard Arkwright, a machine that consisted of rollers turning at different speed, which made it possible to spin stronger cotton yarns that could be used as warp yarns.
The change from hand to machine spinning of flax was a much longer process due to problems with the long stiff fibre strands and their natural gum content. This was no problem for the hand spinner, who often used saliva in the process. This softened the gum and made it easy for the strands to slide between each other, thus it was possible to spin flax yarns in all possible qualities. In the beginning it was only possible to machine spin coarse yarns that could be used for sail cloths and coarse canvas. The first attempts dates back to around 1790, where a method for dry spinning flax was patented in England. Later wet spinning was introduced, something that made it possible to spin flax in thin and shinny qualities that were usable for fine linen. It was a French engineer Philippe de Girard, who in 1810 took out a patent for the invention that introduced a soaking of the flax fibres in hot alkaline solution prior to spinning. In 1814 the inventions were patented in England, but probably not used very much. James Kay (1825) is normally the person credited for inventing the wet spinning of flax. According to his method the flax strand were soaked in cold water for 6 hours prior to spinning. Later, hot water came into use for wet spinning of flax.

In Denmark the policy was to protect and nurse the household production as late as into the 1820s. It was not until 1843 that the first spinning mill in Denmark was established at Svanholm, sponsored by the government who had realized that power spinning was the way forward. But the factory was greeted with great suspicion, as the quality of its products was claimed to be too poor and the yarns too coarse. By general agreement only hand spun flax could make fine yarns due to the saliva used in the spinning process [7]. The fact remains that the factory closed again in 1851.

According to the contemporary writer O.J. Rawert (1844) the change from hand to machine spinning of flax fibres had a significant effect on the resulting yarn and canvas: not only were the dry spun yarns more frayed and contaminated with remains of tow. They also had less actual substance in the threads, and canvas woven of these yarns would absorb 30% more water than canvas woven of yarns spun by hand [8].
Nonetheless, the machine-spun flax did become more popular in Denmark during the 1840s and 50s and an increasing amount of spun flax and linen fabrics was imported. In the period 1837-1855 the import of linen goods quadrupled while the import of spun flax rose by 20 times. The import of unhackled flax fell accordingly, showing how the domestic preparation and spinning of flax was being superseded [9]. In the

weaving, the imported machine spun yarns were often used for the warp while the hand spun yarns were preferred for the weft.

The use of power looms for weaving flax was also more complicated than the weaving of cotton and wool, as it was difficult to keep en even tension of the warp threads. The invention of a vibrating roller and the introduction of a dressing of the warp threads solved some of the problems, but it was not until the second half of the 19th century that power weaving of flax escalated in England, and in Denmark power looms were probably not introduced until the late 19th century.

The power looms for weaving linen were initially used to produce sail cloth and coarse canvases, and during the second half of the 19th century canvases woven on power looms were becoming increasingly common in England whereas it took longer before the machines came into use on the continent (in Germany and France around 1875) and finally in Denmark in the late 19th century. In 1893 Grenaa Dampvæveri started using the "new technology" power looms. After a few years it became the biggest manufacturer in the country of cotton and linen as well as woollen textiles [10]. However, some mills kept up hand weaving like the Køng Mill where power looms were never employed [11].

In 1883, inspector of customs J. Hjorth notes in his dictionary of commercial products that the foreign mass production, as a result of the power loom, meant that the domestic handicraft was about to be phased out [12]. As mentioned, the power loom was by all accounts still not common in Denmark by then [13]. The general picture in the textile trade during the 19th century was in fact that the popularity of linen fell during the century as its place was taken over by cotton products. Yet linen remained the chosen support for canvas paintings due to its durability and stiffness.

Customs regulations

A particular issue affecting the 19th century linen trade in Denmark was the customs regulations. Early in the century the laws were defined by protectionism. High customs barriers meant that for instance flax and linen cloth was among the most expensive goods to import, as the Danish government was trying to protect the local linen market from the competition. In 1838 a slightly more liberal customs law was passed, setting the duty for importing flax, wool and cotton yarns relatively low at 3 -8% of the value, as these commodities were used in the local industries [14]. The woven canvas, on the other hand, was still taxed with 25-30% of its value, though cheaply made, inferior qualities of linen from Germany as well as international trading politics meant that some foreign canvas was still competitive on the Danish market [15]. At the same time the high customs duties led to smuggling, and ships from Pomerania for instance, supposedly carrying timber, were caught having canvas as contraband [16].

But ideas of liberalism were gaining support, and in 1863 yet another customs law was passed by which flax, hemp and cotton could now be imported free of duty. However, canvases were continually taxed heavily and the law was not the radical reform that some had hoped for. This came much later, when the linen industry in Denmark was no longer of any significance.
Canvas remained a highly taxed import commodity during the entire 19th century, whereas foreign yarns could enter into the Danish manufacture at a realistic cost, especially after 1863. An example of this was the Køng Mill where imported machine spun flax was weaved by hand [17].

Danish 19th century artists' access to commercially produced, primed canvas

Various written sources indicate that Danish painters had access to commercially produced and primed painting canvases as well as other materials from an early date in the 19th century. Among the firms selling artists' tools and materials one of the earliest was the Copenhagen firm of H.J. Bing & son, established 1819, which was supplier to several of the Danish Golden Age painters [18]. Later in the century other firms emerged, like Valdemar Kleis (est. 1831), A. Stelling (est. 1860), August With (est. 1875), Ernst Henriques (from 1891) and M. Arnbak (est. 1890s). Some of these also had imported products in their assortments, for instance from Lefranc and Windsor & Newton [19].

The painter C.W. Eckersberg (1783-1853), who had a lasting influence on the following generation of artists, kept a diary during his entire adult life which is a source of information about his painting practice. It contains several references to his suppliers and the purchase of materials, including canvas. The majority of this was most likely primed, as he often records making the underdrawing as the phase directly following the stretching of the canvas [20]. Only on two occasions does he specifically mention having a canvas primed after the purchase. One of these was for a large altarpiece while the other case was one of a series of very large paintings for the Christiansborg Palace [21]. On a separate occasion he applied for special permission to import canvas free of duty from Dresden, Germany, which was granted, probably on the grounds that it was intended for paintings for the same Royal commission [22]. In this case the imported canvas was apparently also primed already, since no further mention of priming is made.

Judging from Eckersberg's diary entries he used a variety of suppliers, the number of which suggests an active trade even in a moderately sized town like Copenhagen in the early and mid 19th century [23]. Among the names appearing is the Bing shop as well as the Køng linen mill and the Meier factory [24]. The latter being in fact a manufacturer of oilcloth makes you wonder if Eckersberg actually tried this (or intended to) as a support for paintings though he is otherwise not known for experimenting technically.

The Køng linen mill, established in 1774, had a competitive advantage in the sense that it could produce canvas of exceptional width for that time in Denmark. Founded by the merchant and industrialist Niels Ryberg, it most likely delivered the large canvas for his family portrait painted by Jens Juel in 1796 (Det Rybergske Familiebillede, 253 x 336½ cm, Statens Museum for Kunst) [25]. According to correspondence, the mill also delivered large numbers of painting canvases in the late1820s for the decoration of the rebuilt Christiansborg Palace [26]. In 1829 it was announced that the mill's store was now stocked with painting canvas [27].

In its correspondence with the commission for the rebuilding of the palace the mill claimed that it could produce canvas of a higher quality than those normally imported from abroad [28]. Other evidence that imported canvas too was available, for instance from Germany, indicates that there was after all a market for the foreign products in spite of their price which in all probability was higher due to the restrictive customs regulations. After his experience with the canvas imported for the Christiansborg paintings, Eckersberg bought the Dresden canvas on at least two more occasions [29].

Other occasional references in 19th century written sources seem to confirm the pattern known from Eckersberg's practice, for instance the sales catalogue after the death of the painter Martinus Rørbye (1803-1848) which among other painter's tools and materials lists primed canvas and stretchers with canvas [30]. Another source is letters from painters sporadically mentioning supplies being bought or ordered [31]. For the later part of the century surviving correspondence by for instance Valdemar Kleis, August With and M. Arnbak, as well as product catalogues from their firms, point to an active interchange between the suppliers and their customers about artists' materials, among these also stretchers and canvas [32]. All three Copenhagen firms evidently had a comprehensive selection of well-known contemporary painters as their clients. References to supports are actually scarce, but again, when canvas is mentioned in the correspondence it is generally understood to be primed [33]. This is confirmed by the fact that it is highly unusual for the period to find paintings on canvas primed on the stretcher (i.e. primed by the artist and not already commercially primed by the time of purchase).

A possible exception, the painter J.F. Willumsen (1863-1958) who carried out extensive experiments with his materials at all levels and with many types of canvases and homemade grounds, only started this practice a couple of years beyond the turn of the century [34].

Figure 2. T. Kloss. Den danske eskadre under sejl på Københavns rhed. 1837. Statens Museum for Kunst. Detail in raking light, showing tenting of the paint. This was caused by shrinkage of the canvas in connection with a glue-paste lining carried out in 1882.

Tenting identified in 19th century Danish paintings

A survey of Danish 19th century paintings in two major collections intended to add a factual element to the general perception of the shrinkage problem being related to 19th century paintings (fig. 2). In other words, to investigate the actual dates of paintings showing the typical effects of a shrinking canvas. The collections of Statens Museum for Kunst, The Danish National Gallery and ARoS, the art gallery of Aarhus provided the material for the investigation in which paintings produced in Denmark between 1800 and1900 were examined. The examination of the paint layer, in raking light, included paintings on view in the galleries as well as paintings in storage. Tenting of the paint, i.e. the specific tent-like flaking in the directions of the warp or weft or both, was used as the indicator of the particular canvas reaction in question. Only paintings showing actual localized or general tenting, or paintings which had a conservation record with well documented tenting, were recorded. Cupping of paint or cracks were not counted as tenting, and neither were other kinds of flaking, delamination or other signs of failing adhesion in ground and paint layers. No examination of the canvas in the paintings concerned was carried out in this investigation.

In a material of 756 paintings in all, the investigation identified 30 paintings showing the relevant features, with the earliest examples dating from 1835. Seen as a whole the distribution of paintings covers the subsequent decades of the century with no clear fall or rise in the incidence. The seemingly large fluctuations in the range of occurrence are related to the limited number of data

Discussion and conclusion

In the survey a few artists, such as F.T. Kloss (1802-1876), Jørgen Sonne (1801-1890), P.C. Skovgaard (1817-1875) and P.S. Krøyer (1851-1909), each had more than one painting represented on the list, suggesting that certain elements of their particular technique or materials – apart from the choice of canvas – may have predisposed their paintings to shrink even more readily than the norm. The elements in question could be one, or more, of the earlier mentioned like commercially primings and cold size.

The fact that the paintings with tenting found in the survey were all dated later than 1835 may be related to the circumstance, described by Rawert, of the earliest imported power spun yarns being of poor quality and the initial reluctance of Danish weavers to apply them. Otherwise the incidence of *shrinkers* in the investigated material also complies with the time scale for the import of these yarns rather well. The machine spun yarns may have triggered the shrinkage reaction, being liable to absorb much more water than the yarns spun by hand. Subsequent swelling of the yarn then caused shrinkage of the canvas. The fact that the machine spun yarns were as a rule used for the warp also fits the most common pattern of shrinkage, which is particularly pronounced parallel with the warp threads.

The majority of the machine spun yarns causing the shrinkage in the present material were most likely dry spun. Even though yarns produced by wet

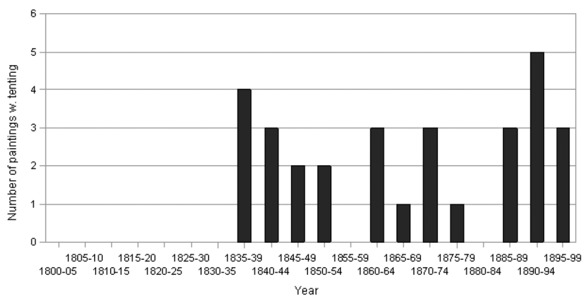


Figure 3. Danish paintings on canvas 1800-1900 with tenting of the paint layer, in the Statens Museum for Kunst and ARoS collections

spinning did appear on the international market in the 19th century they would normally have been too fine to be used for the quality of linen needed for painting canvases.

As opposed to the yarns, the power weaving could hardly be considered the culprit in terms of shrinkage, as it did not come into use in Denmark until the end of the century, although by then it may have added to the problem.

The amount of data is yet too moderate to allow certainty on the above mentioned points, and it is worth keeping in mind here that a number of paintings within the examined material with similar characteristics and response pattern will remain undiagnosed, as these have not been affected in the past by a moisture level high enough to induce shrinkage (and thereby tenting).

Nevertheless the indication of a period in which *shrinkers* can be found and an awareness of the potential problems with the frayed machine spun yarns can help the conservator to get a clearer picture of the danger of moisture treatments on certain canvas paintings from the 19th century.

There are still factors whose effect on the properties of the yarns is little known, such as the preparation of the flax prior to the spinning. An example is the new ways of rotting established during the century, which made the process more efficient but at the same time led to products considered to be inferior in quality. Their particular influence on the shrinkage liability of the canvases is one of the parameters which remain unexamined and a topic for future research.

Authors

Cecil Krarup Andersen*, MSc.
Floras Allé 7,1.sal,
DK-2720 Vanløse.
E-mail: cecil.andersen@gmail.com

Troels Filtenborg, MSc.
Statens Museum for Kunst,
Sølvgade 48 – 50,
DK-1307 Copenhagen K,
E-mail: troels.filtenborg@smk.dk
** Presenter*

Annemette B. Scharff, MSc.
The Royal Danish Academy of Fine Arts,
School of Conservation,
Esplanaden 34,
DK-1263 Copenhagen K
Email: abs@kons.dk

Mikkel Scharff, MSc.
The Royal Danish Academy of Fine Arts,
School of Conservation,
Esplanaden 34,
DK-1263 Copenhagen K
Email: ms@kons.dk

References

1. Mecklenburg, M.F. and Tumosa C.S., 'Mechanical Behaviour of Paintings subjected to Changes in Temperature and Relative Humidity', in *Art in Transit*: *Studies in the Transport of Paintings,* ed. M. F. Mecklenburg, National Gallery of Art, Washington (1991) 173-216.
   Hedley, G., 'Relative humidity and the stress / strain response of canvas paintings: uniaxial measurements of naturally aged samples', *Studies in Conservation* 33 (1988) 133-148.
   Hedley, G., 'The practicalities of the interaction of moisture with oil paintings on canvas' (1989)Ed. By A. Phenix for *Measured Opinions*, ed. C. Villers, United Institute for Conservation (1993) 112-122.
   Berger, G.A. and Russel, H.,'The new stress tests on canvas paintings and some of their implications on the preservation of paintings' in *Preprints of the 7th Triennial Meeting of ICOM-CC*, Copenhagen, 10-14 September 1984 ed. D. de Froment, The International Council of Museums, Paris, in association with the J. Paul Getty Trust, (1984) 84.2.7-84.2.9
   Berger, G.A., 'An evaluation of the preparation of canvas paintings using stress measurements', *Studies in Conservation* 33 (1988) 187-204.
   Young, C.R.T., 'Biaxial Properties of Sized Cotton-Duck' in *Preprints of the 11th Triennial Meeting of ICOM-CC,* Edinburgh 1-6 September1996, ed. J. Bridgland, James & James Ltd, London (1996) 322-331.
2. Hedley (1988) 133-148
   Hedley (1989) 112-122
   Bilson, T., 'Canvas shrinkage: A Preliminary Investigation into the Response of a Woven Structure' in *Preprints of the 11th Triennial Meeting of ICOM-CC,* Edinburgh 1-6 September1996, ed. J. Bridgland, James & James Ltd, London (1996) 245-252.
3. Hedley (1989) 112-122
   Young, (1996) 322-331.
4. Hedley (1989) 112-122
   Young, (1996) 322-331.
   Bilson, (1996) 245-252.
   Rouba, B.J., 'Die Leinwandstrukturanalyse und ihre Anwendung für die Gemäldekonservierung' in *Restauratorenblätter* **13**, Vienna (1973) 79-90.
   Boissonnas, P., ‚Ein typischer Schadensfall der Malerei des 19. Jahrhunderts' in *Das 19. Jahrhundert und die Restaurierung*, ed. Althöfer H. and S. Euler-Künsemüller, Callwey, München (1987) 268-271.
   Rehbein, S. and Huisgen, M., 'Modellversuche zu Grundierungstechniken der Leinwandgemälde im 19. Jahrhundert' in *Das 19. Jahrhundert und die Restaurierung*, ed. Althöfer, H. and S. Euler-Künsemüller, Callwey, München (1987) 255-260.
   Schaible, V., 'Neue Überlegungen zur Feuchtigkeit am Leinwandbild', in *Zeitschrift für Kunsttechnologie und Konservierung* **1** (1987) 75-94.
   Karpowitcz, A., 'A study on development of Cracks on paintings' in *Journal of the American Institute for Conservation* **2** (29) (1990),169-180.
   Ackroyd, P. and Young, C., 'The preparation of artists' canvases: Factors that affect adhesion between ground and canvas' in *Preprints of the 12th Triennial Meeting of ICOM-CC, Lyon*, 29 August – 3 September 1999, ed. J. Bridgland, James and James, London (1999) 265-270.
5. Ackroyd and Young (1999), 265-270

6. Haaf, B., 'Industrielt vorgrundierte Malleinen. Beitrage zur Entwicklungs-, Handels- und Materialgeschichte', *Zeitschrift für Kunsttechnologie und Konservierung* **2** (1) (1987), 7-71.
   Carlyle, L., *The Artist's Assistant. Oil Painting Instruction Manuals and Handbooks in Britain 1800-1900 With Reference to Selected Eighteenth-century Sources,* Archetype Publications, London (2001), 165-186
7. Nielsen, A., *Industriens Historie III andet halvbind*, Gad, København 1944, Genudgivet af Selskabet for Udgivelse af Kilder til Danmarks Historie (1975), 104-128
8. Rawert, O.J., *Beretning om Linnedvæveriets, fornemmligen Linnedhusflidfens nuværende Tilstand i de danske Provindser*. Gyldendal, København 1844, p. 100
9. Nielsen (1944), p. 127
10. http://www.kulturarv.dk/kulturarv/industrisamfundet/kort/midtjylland/grenaa_damp/index. jsp (21.01.2009)
11. Information kindly offered by curator Berit Christensen from the Køng Museum.
12. Hjorth, J. *Almindeligt varelexikon indeholdende i alfabetisk form : en nøiagtig beskrivelse af de i handelen forekommende varer og producter, en fremstilling af deres bestanddele, sammensætning og anvendelse, oplysninger angaaende deres productionssteder, hovedmarkeder, forfalskninger, forsendelsesmaader osv osv.*
    København 1883. p.332.
13. Ibid. p.335
14. Nielsen, A., *Industriens Historie III første halvbind*, Gad, København 1944, Genudgivet af Selskabet for Udgivelse af Kilder til Danmarks Historie (1975), p. 282.
15. Rawert (1844), 107-08
16. Nielsen, A., *Industriens Historie III andet halvbind*, (1944) p. 128
17. Information kindly offered by curator Berit Christensen from the Køng Museum.
18. Cf. for instance ref. [23] below and Bing family letters from the 1820s, Det Kongelige Bibliotek, Copenhagen.
19. Cf. Lehman, Pauline: 'Skagensmalernes leverandører af kunstnerartikler' in *Undersøgelse af industrielt fremstillede malerlærreder omkring århundredeskiftet. Konservering og restaurering af 4 malerier med skader, der relaterer til grunderingen.* Unpublished dissertation, the School of Conservation, Copenhagen, 1988, p. 43-51.
    Cf. also Vald. Kleis, Aug. With, and M. Arnbak correspondences, Det Kongelige Bibliotek, Copenhagen.
20. Cf. for instance Eckersberg diaries, entry 26.8.1816:
    For 4 Alen sparglet lærred – 8 ..(?).
    2.10.1816:
    Kjøbt 5 .. (?).. med Blindrammer – fra fru Mørk – og noget sparglet Lærred.
    24.1.1817:
    Et Stykke sparglet Lærred 11 Rdl.
    19.8.1832:
    Kjøbt, spændt Lærred på Ramme, og begyndt at optegne et nyt Maleri.
    4 Alen Lærred af Fieldsøe.
21. Eckersberg diaries, entry 26.3.1828:
    Faaet den store Dug sparglet i dag (depicting the duke Adolf, for the Christiansborg Palace. Eckersberg purchased c. 31 feet of canvas for this painting, the fourth in a series).
    Entry 3.3.1832:
    Til Fieldsøe for Sparglingen af 2 Duge til Altertavlen samt 4 Alen Lærred, i alt 5 Rdl.
    The altarpiece was commisioned for the church of Skævinge.

22. Eckersberg diaries, 29.7.1834:
Der blev syslet med Adskilligt samt skrevet et Brev til Generaltoldkammeret, om at sende Lærredet ufortoldet.
1.8.1834:
Betalt Fragt for Lærredet fra Kiel til Kjøbenhavn 3Rdl 2Sk.
I dag imodtoges Lærredet fra Dresden, til de store Malerier, som Toldfrit tillodes mig tilbragt, hvorimod de mindre Stykker maatte betales Told af 2 Rdl 38½ .(?). pr. s.
(the large canvas was intendend for the big paintings in Christiansborg while the smaller pieces were for Eckersberg himself).
2.8.1834
Været på Holtens Comptoir for at betale Lærredet fra Dresden.
23. Cf. ref. [20] and Eckersberg diaries, 12.12.1827:
Kjøbt en Alen Lærred hos Bing.
16.5.1828:
Kjøbt 2 Alen Lærred af Jens J(?)..tag. … 2 Rdl
5.11.1828:
4 Alen Lærred af Fjeldsøe.
17.2.1829:
4 Alen Lærred af Jens Fieldsøe.
21.1.1830:
Betalt Fieldsøe for 4 Alen Lærred 3 Rdl
6.7.1830:
Opspændt nogle Duge.
8 Alen Lærred. 6 Rdl
19.1.1830:
Kjøbt Lærred hos Bing.
21.1.1830:
4 Alen Lærred af J.(?). 3 Rdl.
16.7.1832:
Kjøbt en Alen Lærred hos Bing.
30.10.1832:
Til Fieldsøe for Lærred 3 Rdl.
28.12.1833:
Til Kolmes(?) for 5 Alen Lærred a 8 .(?). – 6 Rdl 4 Sk..
30.12.1833:
For et Stykke rent Lærred 7 Alen betalt Rdl
23.6.35:
2 Alen Lærred af Fieldsøe 9 .(?).
24. Eckersberg diaries, 24.3.1832:
Revet Farver, kjøbt bredt Lærred af Kiøngs fabrik og spændt det paa Ramme.
16.6.1837:
Seet Meiers Voxdugsfabrik og kjøbt Lærred – 3 Alen .. 7.(?). Rdl.
25. Cf. Paludan, Charlotte: 'Køng Fabrik 1774-1804' in *Kulturhistoriske Studier*, Sydsjællands Museum, 2003, p.56-57.
26. The archives of the Køng mill in the National Archives, Rigsarkivet, Correspondence records 1820-41: 30.10.1827, 9.11.1827, 15.1.1828, 4.3.1828, and copy letters nos. 111, 120 of March1828 and copy letters nos. 144, 195 of April 1828.
The above information was kindly supplied by Charlotte Paludan.
27. Ibid. Copy letter no. 177, 1829.
28. Ibid. Copy letter 3.10.1827, Copy letter book 1827.
29. Eckersberg diaries, 25.1.1832:
Kjøbt et Stykke Dresden Lærred
1.6.1836:
Kjøbt 2 Alen Dresden Lærred. Opspændt Duge.
30. From the auction catalogue of effects after the death of the painter Martinus Rørbye, 1849, Group XIII: ... *noget sparglet Lærred og en rulle carton Papir, 3 Lærreder med Blindramme…*
(cited in Hartmann, Jørgen B.: *Fra maleren Marinus Rørbyes vandreaar. Meddelt på grundlag af rejsedagbøger og breve*. Bianco Lunos Bogtrykkeri, Kbh. 1950, p.64).
31. Letter from the painter Frederik Vermehren to his brother Christian, 14.9.1854:
Det var kjedeligt, at Du ikke selv kunde gaae hen til Bing. Penslerne vare af første og bedste Qualitet, men mere skikkede til Vandfarve end til Olieditto … Farverne kom tidsnok, da jeg endnu havde lidt lak. Det var egentlig den, jeg trængte haardest til.
(cited in Voss, Knud: *Vermehren, Frederik: Breve og erindringer / J.F.N. Vermehren med indledning af Knud Voss*. Reitzels Forlag, Kbh 1984, p. 46-47).
32. Cf. ref. [19].

33. Letter from the painter Louis Jensen to Aug. With, 26.9.1887:
Vær saa god, snarest mulig, at sende mig en Blændramme, Uden Lærred, af Størrelse 19½ knapt x 1 Alen 6 (Det Kongelige Bibliotek).
Letter from the painter Wenzel Tornøe to Aug. With, 31.10.1887:
... Jeg skal forsøge at ... male Dem en god Gjentagelse af "Osteriscenen" og i et nogenlunde stort Format, nemlig 29¾"x21¾" hvis De vil sende et Lærred i dette Format. (Det Kongelige Bibliotek).
34. Cf. Filtenborg, Troels: *J.F. Willumsens Maleteknik*. J.F. Willumsens Museum, Frederikssund, 1993.

The St Just Coast Project 1995 - 2005

JON BROOKES

The National Trust (the Trust) was founded in 1895 by three Victorian philanthropists - Miss Octavia Hill, Sir Robert Hunter and Canon Hardwicke Rawnsley. Concerned about the impact of uncontrolled development and industrialisation, they set up the Trust to act as a guardian for the nation in the acquisition and protection of threatened coastline, countryside and buildings. More than a century later, we now care for over 248,000 hectares of beautiful countryside in England, Wales and Northern Ireland, plus more than 700 miles of coastline and more than 200 buildings and gardens of outstanding interest and importance. Most of these properties are held in perpetuity and so their future protection is secure. We are a registered charity and completely independent of Government, therefore relying heavily on the generosity of our subscribing members (now numbering over 3.5 million) and other supporters.

If someone had predicted to the founders of the National Trust in 1895 that the great steam engines and grand granite buildings that housed them would become part of their heritage some 100 years later, they would have been astonished. However, in 1995 The National Trust commemorated their centenary with each Region nominating an aspect of the Trust's work and the Cornwall Region's focus was to celebrate the Industrial Heritage of St Just through The St Just Coast Project. The main aims were to acquire and conserve as much of this unique industrialised landscape as possible, thereby securing in perpetuity its archaeological value, and to make the area safe and accessible for locals and visitors alike.

A significant foundation for the initiative was The St Just Survey vols. 1&2 Sharpe, published in 1992 by The Cornwall Archaeological Unit. The report

evaluated the District's industrial heritage in terms of both its historic importance and its frequently fragile and dangerous character and this comprehensive study, sponsored by the Trust and local partners, identified the wealth of industrialisation in the area and through an area inventory was instrumental in identifying many of the sites and issues which were ultimately addressed by the Project.

The parish of St Just-in-Penwith, located as it is within the Land's End peninsula, is remarkable for its 13 kilometres of spectacular coastal landscape and the extensive number of industrial archaeological sites it contains. The richness and density of the region's industrial heritage is internationally renowned, with sites dating from prehistoric times to the present day. The entire coast is designated as a Site of Special Scientific Interest, for its Biological and Geological significance, whilst its mineral interests are recognised by extensive designations of Regionally Important Geological Sites. In addition, the area is also designated as an Area of Outstanding Natural Beauty. This ancient and unique landscape together with sandy beaches, relatively safe seas and a mild, oceanic climate attracts many visitors thus bringing a much needed boost to the economy.

In the 1980's, the Trust acquired 2 coastal properties, Boscregan and Cape Cornwall and began work on restoring the Levant Beam Engine to steam power. During the period to 1995 additional acquisitions followed to give 8 kilometres of continuous ownership of coast and a wide cross-section of the area's assets and challenges.

The additional acquisition of industrialised land at Kenidjack, Cot Valley and Levant in 1995 fully established the Coast Project, and led to the employment of local National Trust staff to manage both the complex and challenging nature of the properties and to secure local support through engagement opportunities. To these ends, the Trust acquired the strategically located Botallack Mine Count House (1995) as the Area Warden's property office and work base. The site, with its adjoining former restaurant, outbuildings and land, also offered a flexible space with a range of potential uses, making it an important and prominent resource for both the local community and visitors alike. A striking mid-19century building (listed grade 2), the Count House fulfilled a variety of roles during its working life which reflected the ever-changing fortunes of the mine, and subsequently entered into domestic use some 70 years ago. A visitor information centre and community space were established in the workshops adjoining the Count House, to promote the Trust's work and provide interpretation for the area's heritage and wildlife, and for hosting events and educational activities.

The cost of the St Just Coast Project has been of the order of £11 million (this figure includes acquisition costs). This has been met in the main by funding bodies such as the Heritage Lottery Fund (HLF), Regional Development Agency (RDA) and contributions from local Councils, businesses and individuals.

Throughout its lifetime, the Coast Project has operated in accordance with several key principles which undoubtedly contributed towards its success. Partnerships with statutory organisations, local Town and District councils and Cornwall County Council were instrumental in gaining grant aid. Additional benefits accrued from employing contractors and sourcing materials locally, not least being the Trust's desire to support local businesses and individuals directly, which in turn encouraged the continuity of traditional practices and the use of traditional materials, a rationale which benefits an area by maintaining the distinctiveness of its character through the type of work that takes place within it ensuring authenticity, and thorough consultation with members of the local community.

Two community groups were formed: - the St Just liaison group made up from leading members of the local community who met regularly to discuss progress, plans, giving the ability to confront problems before they arose and the Working liaison group, made up from representatives of local mining and interest groups and individuals with specialist knowledge who met monthly on site to view progress, identify specific footprints of structures and thereby guiding authenticity.

During their construction and lifetime, the walls of many of Cornwall's mining structures were pointed with traditional Cornish lime-based mortars.

Prior to the St Just Coast Project's inception in 1995, however, the utilisation of this material for conserving the County's industrial buildings was not widespread, as most contractors and engineers felt that it was a weak substitute for cement mortars, which hardened quickly and were judged to be the strongest solution for consolidating engine houses. This seems surprising, as the flexibility and strength of lime mixes had ensured the long-term survival of many historic structures, in spite of years of neglect and unprotected exposure to the elements. Despite the near abandonment of lime mortars elsewhere, the Trust developed the use of lime throughout the decade-long Project. The earliest attempts were largely determined by the desire to replicate the colour and texture of the original mixes as they appeared after years of weathering, rather than their actual make-up. As a result, dark sands from nearby Gwithian Beach, rab (orange granitic subsoil) and mine-waste were added to the lime, as was a degree of Portland cement. Over time, however, it became apparent that this method was imperfect, due to the inflexibility of the cement, and the high clay content of the rab and sand, which greatly negated the lime's chemical effectiveness. This resulted in the development and constant refinement of lime mortar mixes and their application, and led ultimately to the employment of a lime-pointing specialist for the Project's final phase.

Working in conjunction with the structural contractors, this specialist consultant developed a much more authentic and efficient mix, which utilised a significantly higher lime content, and abandoned the use of clay-rich inclusions and cement. This mixture, which was partly based on the analysis of original pointing from structures at Botallack and Kenidjack, was much stronger physically than previous attempts. It was, however, also much lighter in colour, and was generally applied to a greater (i.e. less recessed) depth, which had a significant visual impact on the newly consolidated structures, especially when contrasted with the 'invisible' pointing which had defined earlier works. Despite this, the later mixture and the methods for its application are now widely regarded by many masons, archaeologists and industrial experts as the best and most historically accurate for consolidating the County's industrial buildings illustrating its significant conservation value.

Over 100 dangerous mine-shafts and workings located close to publicly accessed areas have been addressed by the Coast Project since 1995. The vast majority were treated by the construction of an encompassing Cornish Hedge, and internal fence with attached signs. The Trust in West Penwith has always resisted the use of concrete plugs, and have instead favoured keeping shafts open to retain their archaeological and interpretive value and to maintain their role as a habitat for bats. The construction of a prototype hedge at Ballowall in 1995 convinced the funding bodies that the methodology was appropriate in both conservation and safety terms. As a result this method has been widely used ever since, both in West Penwith and elsewhere, and is now frequently regarded as the most desired and sensitive model for dealing with Cornwall's many open mine-workings.

The design was based on the practice employed during a mine's lifetime, when it was required to make the old shafts safe for the public and local grazing stock. These original hedges were generally dry-stone constructions, often with an internal rab core, and were built out of local stone and mine-waste. The hedges constructed by the Trust have adhered to this style, having been constructed with locally sourced materials of the same type as those originally used. Indeed, in many cases the required stone was found on-site, particularly when a hedge formerly existed, shafts generally tend to be more isolated than structures, and have therefore often not suffered from the same degree of stone-robbing.

During the 10 year life-span, which was divided into four phases, the project has conserved 106 mine shafts, conserved 71 structures, supported

and worked with local craftsmen, businesses and the community, secured 8 km of industrial coast for ever for everyone and underpinned Cornwall's bid for World Heritage Site status.

St Just Coast Project Phase 1: 1995

The first physical works to be undertaken as part of the St Just Coast Project's launch was the consolidation of two engine houses at Kenidjack, Wheal Edward and West Wheal Owles. Wheal Edward was unlikely to survive another winter, so decrepit and dangerous was its remaining stonework, yet it remained an important contribution to the St Just landscape. Considering the importance of both sites and the imminent loss, the work was undertaken and 100% funded by the National Trust.

St Just Coast Project Phase 2: 1996 - 1998

Following the removal of a long-term traveller's site at Kenidjack, a partnership between the National Trust, Cornwall County Council and the Cornwall Archaeological Unit was formed. The first part of the work was to secure a small clearance grant to remove a substantial amount of landfill material which had been dumped on the cliffs at Wheal Edward, to re-profile and cloak the remainder of the site, and to erect a safety hedge around Wheal Edward incline shaft. Considering the considerable number of collapsing engine houses and open mine shafts on the Kenidjack property (most of which had long been used for rubbish disposal), the partnership proposed as a second stage a substantial bid (£148,750) for land reclamation funding to English Partnerships, to undertake safety and amenity works on the Wheal Owles site and neighbouring area. The National Trust supported this bid with an application to the Heritage Lottery for match funding toward the Count House and restaurant restoration and undergrounding of 1.5 km of overhead electricity and telephone lines.

In 1996 10 open mine shafts and 1 gunnis were protected adjacent to public access on Ballowall and Carn Gloose properties.

The same year saw the commencement of the restoration of Botallack Mine Count House, restoring bay windows, chimneys, replacing the scantle slate roof and shaft protection at a cost of £100,000. This work was followed by the restoration to the Counthouse restaurant, development of information centre and addition of Geo Thermal underfloor heating.

1997 to 1998 saw a variety of works completed including the collaring of 15 shafts and 1 gunnis at Ballowal and Letcha; consolidation and safety works to 15 shafts at Kenidjack and Cape Cornwall; stabilisation and pointing of Bellan Mill, Cot Valley

St Just Coast Project Phase 3: 1999 - 2002

In 1999 the National Trust acquired land surrounding Levant Engine House and a further application was submitted to funding bodies. The scope of the project included the treatment of 13 shafts on Watchcroft, Morvah and consolidation to the Levant pumping engine house, compressor house, Man engine house chimney, electric winder house, temporary winder house, Higher Bal engine house, Man engine shaft, Boscregan shaft, guide shaft (Higher Bal), Levant powder house and the Levant Counthouse.
As this part of the project neared completion, the consolidation of Wheal Drea Engine House, Wheal Drea miner's dry and farm buildings at the Kenidjack Hamlet was begun as well as the consolidation of the Cargodna Winding Engine House and Wheal Owles Engine House.

St Just Coast Project Phase 4: 2003 - 2006

This phase of the project was known as the St Just Regeneration Project, being a three year package of works funded primarily by Objective One, with further contributions from the South West Regional Development Agency, Cornwall County Council, English Heritage, The National Trust, Cornwall Wildlife Trust and others. The project was aimed at regenerating the St Just District through settlement enhancements (in St Just and Pendeen), and the rehabilitation of significant parts of the surrounding mining landscape (the 'Heritage Works'). The planned consolidation of many of its famous industrial heritage sites formed the key to ensuring the District's sustainable economic future.
Over seventy industrial and other sites were included in the project, all but one being owned by the National Trust. Among these were the Arsenic Works at

Botallack and Carn Praunter (Kenidjack Valley), and Levant Man-Engine Tunnel, which was the site of Cornwall's second largest mining disaster (in terms of men lost). As always, a crucial element in the successful completion of these works was local consultation and liaison.

Funding was facilitated by the Rural Development Agency and its general application was project managed by Cornwall County Council in partnership with the National Trust. The overall figure provided for the Heritage Works was just over £2,million, of which the National Trust provided around £210,000 - £150,000 in actual funds and around £60,000 as 'works-in-kind'.

The first stage involved the thorough decontamination of Arsenic Works (Calciner, Labyrinths, Flues & Chimney), named among the top ten Scheduled Monuments at risk, followed by the structural consolidation (including partial reconstruction) of the 1860s Dressing Floors, Stamping Engine, Crown's Pumping Boiler House Retaining Wall, Pearce's Whim Chimney & Lintelled-Flue, Powder House, Counthouse Service Buildings, Wheal Cock Dry and shaft safety works on four shafts including Wheal Cock Engine Shaft. In 2004-5 safety works to a shaft that had unexpectedly opened up at Botallack Vean (National Trust Volunteer Accommodation) were undertaken and a new workshop built.

As a departure from the usual consolidation of mining structures an ongoing programme of Japanese Knotweed Control was begun in the Kenidjack Valley. This invasive, water-loving plant was quickly spreading throughout the valleys - clogging the waterways, diminishing native plants and detracting from the visitor experience. As ever, the project's success was dependent on working with all land owners (which included organisations such as South West Water) and ensuring good local community liaison.

Towards the end of this phase further decontamination and consolidation works were undertaken e.g. Arsenic Works, Carn Praunter, Beach Retaining Wall, Wheal Hermon and safety works to a further fifteen shafts throughout the area.

In 2005 the slipway at Cape Cornwall cove was found to be seriously deteriorating. This slipway, an essential requisite for the livelihood of the local hand line fishing community was built in early 1900 and its successful consolidation was undertaken by the National Trust staff with a voluntary community team.

The final works were at Levant Mine. The Man-Engine Tunnel (the passageway used originally by the miners in late the 1800s to access the workings 1 mile down under the sea) was reconstructed; the Man-Engine Shaft was made safe; the original Drawing Office was reconstructed and the Tramway Tunnel and other stabilization works were undertaken. Part of the funding was used to stage an Opening Ceremony of the Man Engine Tunnel (now open to the public) where relatives of the original Levant miners, local dignitaries, representatives of the funding and other involved organisations, together with an open invitation to the local community (including the press) enjoyed a pleasant day which ensured that Levant and by association the St Just Coast Project success was firmly established.

Conclusion

There are two main strengths which will secure the future of the project work: the Trust's ability through the National Trust act of 1907 to declare land inalienable and the commitment of employing staff on the ground to maintain and care for the area. There is now an established engagement programme, utilising the Counthouse facilities and surrounding landscape where events as diverse as cliff top drama, steam fairs, guided trails, illustrated talks and film shows take place.

New acquisitions have included Cornish Mines and Engines at Pool (a small visitor property), Godolphin and the Great Lode and Trewarvas engine houses, perched on the cliffs on the South coast. This latest acquisition recognised the Trust's ownership of the three most iconic engine houses in Cornwall, the other two being the Crowns at Botallack and Wheal Coates at St Agnes.

In July 2006, the most important designation was achieved with the success of Cornwall's bid to gain World Heritage Status, conferred in recognition of the remarkable advances in hard rock mining and engineering technologies made during the 18th and 19th centuries, which transformed the landscape, economy and society of the region, placing it at the forefront of the Industrial Revolution. These technologies quickly spread to every corner of the globe as the international migration of Cornwall and West Devon's highly skilled workforce forged extensive cultural links between mining communities worldwide. As well as recognising the unique role of Cornish Mining in shaping modern industrial society, World Heritage Site status will bring tangible socio-economic benefits to the region. It will draw down conservation funding, be a major asset to international tourism marketing and assist in the regeneration of former mining communities. Arising from the status is an association of mining attractions which has bought together people from all over the County to promote and ensure Cornwall's Industrial Heritage maintains a secure future.

Author

Jon Brookes
Treveal Farm
Zennor
St Ives
Cornwall
TR26 3BW
jon.brookes@nationaltrust.org.uk

Degradation of modern synthetic polymers in museums and environmental assessment with EWO dosimetry

Terje Grøntoft and Susana Lopez-Aparicio

Introduction

The initial production of modified and synthetic polymers was a part of the major scientific progress in the 19th and first part of 20th century. Modification of cellulose to produce cellulose nitrate was discovered around 1850 and cellulose acetate about 15 years later. The first truly synthetic polymer, Bakelite, was discovered in 1907. The advances in material science in the second part of the 20th century resulted in a great increase in the use of synthetic polymers for all kinds of industrial products, but also in the work of artists and conservators. Museums and galleries today possess objects made from the thousands of different plastics that have been produced and also use a large range of plastics for objects conservation purposes. It has been observed that some plastics deteriorate faster than many other items in museums collections and have useful lifetimes of 5 – 25 years[1]. The degradation mechanisms of synthetic polymers differ, but generally it involves photochemical reactions with UV excitation of molecules in the polymer and following quenching and chemical conversions when the conditions are "favourable".[2] The mechanisms of the chemical conversions often include acidic or oxidative agents, such as e.g. O_3 for the initial oxidation of elastomers or "rubbers", and reaction rates usually depend on humidity, which can participate in the degradation process in complex chemical and physical ways, and on temperature. Guidelines for the conservation of different polymeric materials have been formulated based on knowledge about their degradation mechanisms, e.g. the removal of autocatalytic NO_2 by absorbers in the packing of cellulose nitrate materials or the removal of oxygen, and other oxidants, from storage bags with objects made from rubbers and polyurethane foam[1]. In exhibition or storage rooms preventive environmental control can be more difficult and / or costly. Whichever level of control is possible it is important to be able to assess the expected environmental degradation effects on exposed objects. The easiest way to do this is by using a sacrificial material, or dosimeter, which reacts much faster than the museum object and for which the amount of degradation after exposure at the location of interest can be measured. To be able to assess the effects of the environment on the objects of interest the effect on the dosimeter must be calibrated towards the effect on the real objects. When the dosimeter consists of a similar kind of material as the objects, calibration may be performed by comparing the reaction rates of dosimeter and objects. For all dosimeters calibration can be performed by comparing the specific effects of the environmental parameters on the dosimeter and on objects in the collection.

The PPO/EWO – Early Warning Organic dosimeter

One such existing dosimeter that can be used to evaluate the environmental effect on modern synthetic polymers is the EWO (Early Warning Organic) dosimeter (Figure 1) developed by the Norwegian Institute for Air research in the previous EU project MASTER.

This dosimeter measures the actual effect of the environment on a synthetic polymer and can be exposed in any small (e.g. a sachet for a small object) or large (e.g. an exhibition room) location. The dosimeter is simply placed at the location to be evaluated for three months and returned to NILU who will provide a results diagram and report that shows the measured condition compared to tolerable levels for the location as generally evaluated by conservation scientists. The active substance in the

Figure 1: The EWO dosimeter holder with the PPO polymer covered glass sensor chip (inset).

EWO is a PPO (Polyphenyloxide) polymer that is suggested to be degraded by photo oxidation in several steps[2] common in polymer degradation, such as UV absorption and excitation of a conjugated species, oxidation and peroxide formation, and radical formation followed by chain scission or cross linking depending on conditions. The result of the degradation in the presence of oxygen or other oxidizers is a decrease in molecular weight and increase in opacity of the film that can be measured with a spectrophotometer. Although PPO is degraded by the similar environmental influences as many other modern synthetic polymers the exact steps and rates of degradation reactions are different. For most polymers many different degradation mechanisms are proposed. E.g. for polycarbonate, which is a much used modern synthetic polymer, initial UV absorption and excitation of either carboxyl groups followed by CO or CO_2 abstraction and molecular rearrangement or chain scission, or of methylene groups followed by cross linking or further oxidation, or direct hydrolysis without radiolysis, are proposed[2].

The environmental effect on the EWO was measured and it was calibrated against the effective environment (UV, O_3, NO_2, T / RH) in a field test in 10 European museums during the EU project MASTER[3]. Tolerable levels of environmental parameters and related effect levels for the dosimeter, representing organic cultural heritage objects in indoors locations with five levels of environmental control, from archives to open structures with no control, were determined by conservation scientists. As the dosimeter is itself made from a modern synthetic polymer it should be well suited to assess the potential for environmental degradation of modern synthetic materials in collections.

To use PPO/EWO as an effect dosimeter for modern synthetic polymers ideally one would like to know the dose-response functions not only for the PPO/EWO, but for the different specific synthetic materials in museum objects and collections. However detailed environmental dose-response functions do not exist for most modern synthetic polymer materials. In addition, many collections include a range of different modern synthetic materials, and it may be more useful to determine levels of tolerability for such collections as a whole, with additional guidelines for particular materials, such as e.g. cellulose nitrate, where mechanisms and reaction rates are more known. The EWO could be calibrated and threshold levels determined for collections including modern synthetics by comparing its rate of degradation with that of a range of modern polymers in museums. Alternatively, or in addition, the degradation rate of the EWO can be compared to known effects of environmental parameters on other specific modern polymers.

Effects calibration and results reporting for the EWO

The calibration of the environmental effect observed on the EWO was performed by statistical correlation of the values for the environmental parameters and EWO effects measured in the MASTER project. A non linear dose-response formulation found to represent degradation processes in a range of economically important polymers; polyurethane (PUR), polyvinylchloride (PVC), fibre reinforced polyester (PES) and resin based lacquer[4] was used. The following dose-response functions were determined for the EWO, for a situation in showcases (Eq. 1) where UV light was absent, and in museum rooms (Eq.2)

$$\text{EWO-G effect (x1000)} = 4.5+\sqrt{T}(0.3NO_2+0.1O_3) \quad (1)$$

$$\text{EWO-G effect (x1000)} = 8.7+\sqrt{UV}+\sqrt{T}(0.2NO_2+0.3O_3) \quad (2)$$

With units: T (°C), UV (mW/m^2) and NO_2 and O_3 (ppb).

Table 1: Environmental parameter values used as input in the calibration equations (1) and (2) to determine EWO dosimeter response at the tolerability - location levels 1 - 5. Due to the additive nature of the calibration equation and the generally similar oxidative effects of NO_2 and O_3, the values for NO_2 and O_3 in Table 3 are half of those determined from the literature for each gas (Table 3 and 4).

Threshold / Tolerability - location levels	Trigger values					
	NO_2 (ppb)	O_3 (ppb)	UV (m W/m^2)	T (ºC)		
				RH = 45 %	RH = 55 %	RH= 65 %
1 – Archive store	1	1.15	1	20.8	19.3	18.2
2 – Purpose built museum	2.5	3	3.75	22.9	21.4	20.2
3 – House museum	5	6.5	15	24.5	23	21.8
4 – Open structure	10	12.5	37.5	26.8	25.3	24.1
5 – External store with no control	15	25	37.5	29.0	27.6	26.2

Table 2: EWO dosimeter trigger response values determined from the values in Table 1 and the dose-response equations 1 and 2. The tolerable response for a location is for values below the trigger value. In the EU project MASTER it was evaluated that showcases should be one level lower than its location.

Thresholds / Tolerability - location levels	Trigger value (ads-units)		
	RH = 45 %	RH = 55 %	RH = 65 %
1 – Archive store	0.0064	0.0064	0.0063
2 – Purpose built museum gallery	0.0174	0.0171	0.0170
3 – Historic house museum	0.0273	0.0268	0.0264
4 – Open display in open structure	0.0448	0.0440	0.0433
5 – Outside store with no control	0.0717	0.0703	0.0689

The EWO-dosimeter was measured to be sensitive to SO2 as a single pollutant only at high concentrations (> 60 ppb) and high humidity (> 60 %). It is not sensitive to organic acids, and does not measure effect of particles or dust.

Table 1 gives threshold levels for environmental variables for different relevant locations, determined as realistic low levels giving similar LOAEDs (Lowest Observable Adverse Effects Doses)[5] for vulnerable organic materials such as coloured silk and paper, for durations decreasing inversely to the concentration values for less protected locations at higher levels.

The values in Table 1 were used as input to Eq. (1), for location 1, Archive store, and to Eq. (2) for the other four locations to obtain the threshold levels or "location-tolerability" levels for the measured EWO effect, given in Table 2. The EWO does not respond to RH, so the slight RH dependence in Table 2 was determined from the T / RH isoperm values valid for paper[6].

Figure 2 shows an example of the results diagram presently accompanying the end reporting to an EWO user.

This building (Figure 2) was not designed for storage of museum artifacts, and was in the process of being refurbished. Most of the locations measured had an oxidizing environment only tolerable for an open display in an open museum, which is probably not satisfactory for the planned storage rooms. The museum may be interested to do similar measurements after the refurbishing process is finished to get a measure for the expected improvement and conditions for the objects to be placed in storage.

EWO assessment of degradation risk for modern synthetic materials – based on environmental threshold levels

Ideally valuable museum objects should have no contact with air contaminants that degrade them. It is technically possible, but expensive, to store and / or display objects in vacuum or under inert gases such as e.g. argon. Most museum objects are and

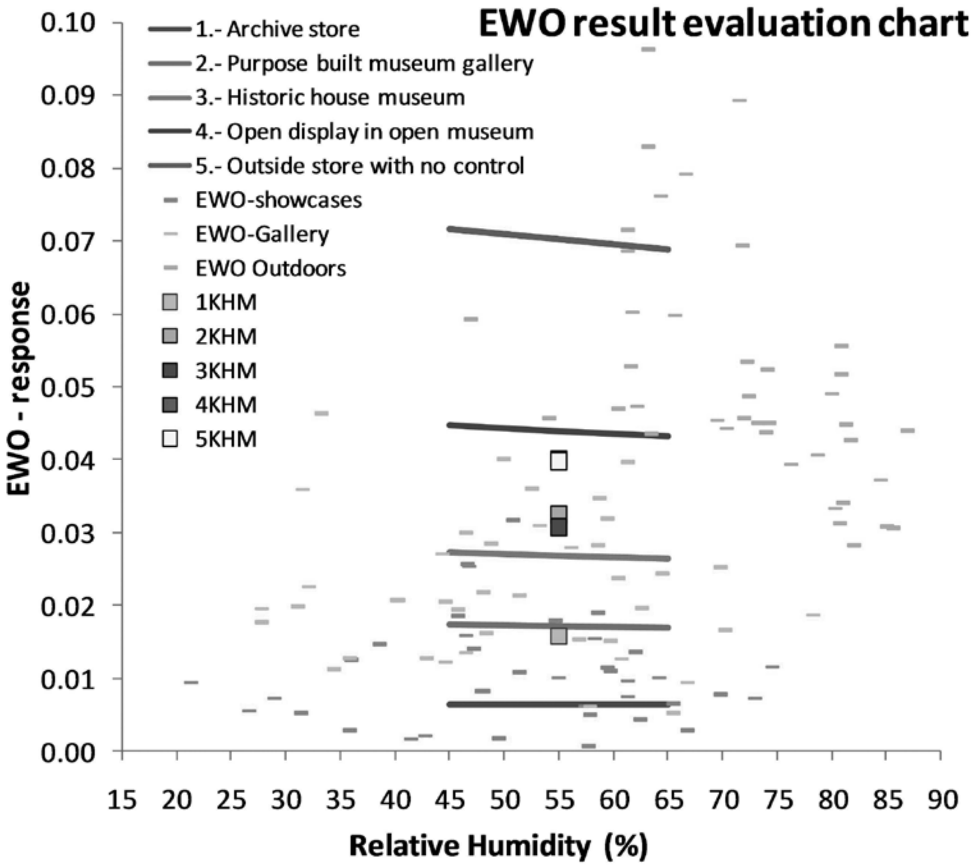


Figure 2: EWO results reporting diagram. The diagram is for five measured locations in a building planned to be used as storage rooms for the Historical Museum in Oslo (KHM). The results for locations 4 and 5 are near the same value. The short horizontal markers represent all the EWO measurements performed in the EU project MASTER, in showcases, gallery locations and outdoors, from which the dose-response equations (Eq. 1. and 2) were derived.

will for the foreseeable future be kept in "normal atmospheres" where the level of pollutants will mostly be determined by the location, construction, materials, and ventilation properties of buildings and "containers" (showcases, microclimate-frames, storage boxes etc.) where the objects are kept. For any location a lowered pollution level and exposure is always preferable. However, for the conservator, it is useful to know if a particular pollutant level is down to a "tolerable level". A "tolerable level" could be when further reduction of the pollutants for that location becomes much more expensive or is not technically or aesthetically feasible. The threshold levels in Table 1 were evaluated to be obtainable good conditions for the respective five major representative classes of museum locations. Tables 3 and 4[7] show a selection of degradation effects observed on materials for doses (concentration * duration of exposure) of NO_2 and O_3 at these levels. [3,5]

Table 3 shows that plant dyes on cotton are more sensitive to NO2 than paper strength which is more sensitive than natural organic colorants on paper. Table 4 shows that most sensitive organic colorants are more sensitive to O3 than photographic film dyes and images which are more sensitive than paper and organic colorants on water colour paper and silk. The observational data in Table 3 and 4 were used as input for Table 2 and give, although not exactly, equal weight to the concentration levels and years of exposures in the dose calculation, - so that e.g. 2 ppb * 10 years = 10 ppb * 2 years. This is represented by linear dose-response correlations of the form:

Table 3: Sensitivities expressed as LOAED levels of vulnerable materials to NO_2, used to determine EWO response thresholds. Values in brackets are years of exposure.

Thresholds / Tolerability - location levels	NO_2 (ppb)	Paper loses strength, ppb*year (year)	Changes in typical plant dyes on cotton ppb* year (year)	Change in natural organic colorants on paper ppb* year (year)
1 – Archive store	2	20 (10)	10 (5)	40 (20)
2 – Purpose built museum	5		5 (1)	25 (5)
3 – House museum	10	20 (2)	5 (0.5)	
4 – Open structure	20	20 (1)		40 (2)
5 – External store with no control	30	15 (0.5)		30 (1)

Table 4: Sensitivities expressed as LOAED levels of vulnerable materials to O_3, used to determine EWO response thresholds. Values in brackets are years of exposure.

Thresholds / Tolerability - location levels	O_3 (ppb)	Paper and organic colorants on water colour paper and silk ppb*year (year)	Photographic film dyes and images ppb* year (year)	Most sensitive organic colorants ppb* year (year)
1 – Archive store	2.3	46 (20)		1.15 (0.5)
2 – Purpose built museum	6	60 (10)	30 (5)	
3 – House museum	13	52 (4)	26 (2)	
4 – Open structure	25	50 (2)	25 (1)	
5 – External store with no control	50	50 (1)	25 (0.5)	

$$R = C * t^x \qquad (3)$$

Where: R = response

C = pollutant concentration

t = time

x = time dependence = 1 for the linear case

Thus, for any material with LOAED levels that can be derived from similar linear equations the threshold levels in Tables 1 and 2 and the derived EWO evaluation of environments are valid if the important degrading environmental variables are included and the concentration levels for the respective locations are accepted. However, as is discussed below, such an effect evaluation is not necessarily complete.

Reichert et al. (2004) report the following dependences of degradation effects on two modern synthetic polymers:

Penetration depth of a dye in polyurethan PUR = 0.5777 + 0.49*(G*t)^0.5

+ 0.0253*(10-9*T*108/3.142)^0.5 * RH*t

+ 0.0184*(10-9*T*108/3.142)^0.5 * NO_2*t

+ 0.0122*(10-9*T*108/3.142)^0.5 * O_3*t (4)

Colour change of Fibre Reinforced Polyester (PES) = 0.4383 + 0.5979*(G*t^0.4)^0.5

+ 0.0354*(10-9*T*108/3.142)^0.5 * RH*t^0.65

+ 0.0064*(10-9*T*108/3.142)^0.5 * SO_2*t^0.65

+ 0.0195*(10-9*T*108/3.142)^0.5 * O_3*t^0.65 (5)

Where: G = global radiation (radiance, annual average in W/m^2)

T = exposition time in years

T = averaged air temperature at exposition (annual average in °C)

RH = averaged relative humidity at exposition (annual average in %)

O_3 = averaged concentration for ozone in $\mu g / m^3$

NO_2 = averaged concentration for nitrogen dioxide in $\mu g/ m^3$

SO_2 = averaged concentration for sulphur dioxide in $\mu g/m^3$

Eq. 4 has linear time dependence on the pollutant concentrations, but this is not the case for Eq. 5. A time dependence < 1, as in Eq. 5 is typical for many materials[8] as the very first degraded surface layer reduce the reaction rate. For LOAEDs corresponding to the first surface effects of a slow reaction it may, even in this case, be possible to fit a linear equation, with little error. However, for such cases (x < 1 in Eq. 3) it would generally be necessary to recalculate the EWO trigger values and responses in Table 1 and 2. Using the same concentration values for lowest level, the consequence would be higher tolerable concentration levels and EWO responses at the higher location levels (1-4) in the tables. It could be argued that this is a good thing, as the levels now determined

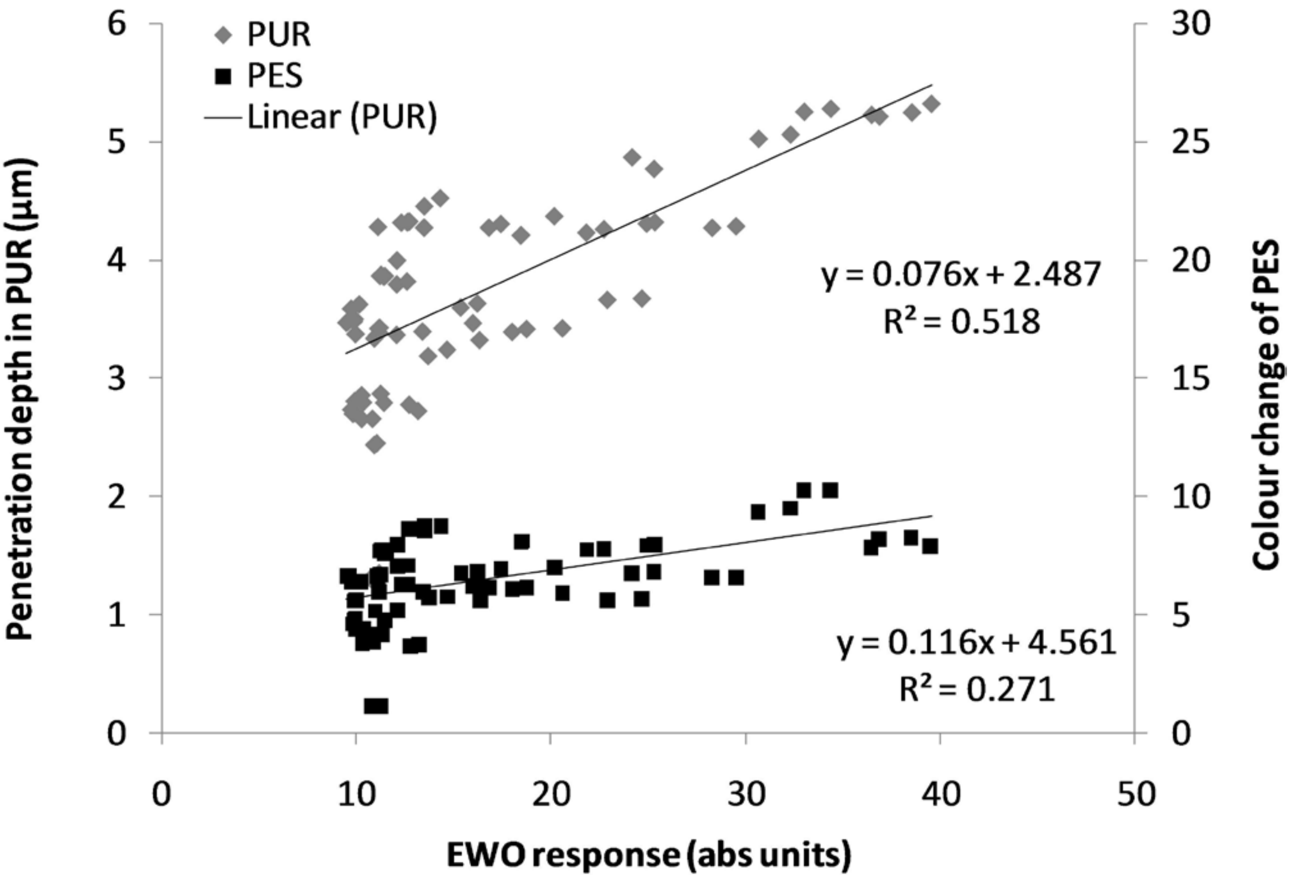


Figure 3: Correlation of EWO response (Eq. 2) and PUR (Eq. 4) and PES (Eq. 5) response using input from measurements in 20 room locations for 4 periods of three months in 10 European museums from the EU project MASTER. The figure shows the measurement results from the MASTER locations in relation to tolerable levels determined for the EWO for different types of locations at RH = 55% (Table 2). The determination of the first level, "Archive store" was based on the dose response equation for showcases (Eq. 1), for which the measurement results are not shown in the diagram.

in Table 2 are more stringent than the demand may be for other materials, and an "error" of keeping to these levels will only give additional protection, although possibly at a price. As the levels in Table 1 and 2 are determined to be practically achievable, a general simplification of the approach to meet such "best standards" seems reasonable.

It is important to note that the RH dependence of the tolerable levels in Table 1 and 2 are a simplification based on RH / T isoperms valid for paper material. This may not be appropriate for modern synthetic materials. The RH dependence may be different. The RH / T interdependence, from RH = 45% to RH = 65 %, in Eq. 4 and 5 was calculated to be a change of 1.2 °C for PUR and 1.4 °C for PES, using average values for the environmental parameters measured indoor in museums in the MASTER project and the PUR and PES responses calculated from those values. The comparable temperature change in Table 1 varies from 2.6 to 2.8 °C. Thus, the humidity response of these synthetic polymers is about half that of paper. This can be accommodated in Table 1 by reducing the T / RH variation to this value.

EWO assessment of degradation risk of modern synthetic materials – based on direct comparison.

Another possible approach is to directly compare effects on the EWO with those on the modern synthetic polymers. To know if the effects can really be compared it is then necessary to know how the environment reacts with the modern synthetic polymers, preferably by detailed dose-response equations such as Eq. 4 and 5. A comparison of Eq. 1 and 2 for the EWO with Eq.

4 and 5 shows general similarity in the responses. However there are some differences. Eq. 4 and 5 show dependence on RH, but not Eq. 1 and 2. This may be due to larger variation in environmental parameters, including RH, during the 8 years natural weathering experiment from which Eq. 4 and 5 were derived[4], as compared to the indoors experimental exposures of the PPO/EWO. Eq. 5 also shows dependence on SO_2 which was not found for the PPO/EWO, except at high doses and humidity in the laboratory. Figure 3 shows correlation of calculated effects on EWO with that on PUR (Eq. 4) and PES (Eq. 5) using input from the 80 measurements of the environmental parameters in 10 European Museums in the EU project MASTER[3]. Measured values for UV were not used in the equation due to the difficulty of recalculating the UV values measured in units of mW/m^2 into the global irradiance units used in Eq. 4 and 5. As the UV values measured in the indoors locations were 0 or very low this should not give a large error.

Even if the correlations between EWO/PUR and EWO/PES seen in Figure 3 are not very good they do suggest degradation mechanisms that depend on the same environmental parameters, as is also seen from the Eq. 1, 2, 4 and 5. The numerical change in the damage parameter for the PES compared with the EWO is somewhat higher than that for PUR. However, to compare EWO levels with damage of these materials it would be necessary to establish levels of "real" perceived damage dependant on environmental levels as in Table 3 and 4. For modern synthetic materials that in some cases may be more vulnerable to degradation than most other organic materials, lower tolerable levels and more stringent environmental control may be needed.

The humidity dependence in Eq. 4 and 5 explain 94 % (PUR) and 74 % (PES) of the effect on PUR and PES not explained by EWO (the constant in the correlations) in Figure 3. The SO_2 dependence in Eq. 5 only explains 0.6 % of the effect on PES not explained by EWO in Figure 3. Thus, the EWO can represent PUR and PES degradation effects except the unfortunate lack of sensitivity of the EWO to humidity. EWO values representing determined threshold levels for the degradation of PUR and PES (Eq. 4 and 5) can be calculated from the correlation equations for PUR and PES in Figure 3. The constants in the correlation equations would then mainly represent average humidity effects expected on PUR and PES indoors in museums. When directly comparing degradation of dosimeter and object material, the EWO response cannot be indirectly adjusted for RH effects using the RH-T interdependence as was the case above when using environmental threshold values. From Eq. 4 and 5 it can be seen that the RH effect is linear at constant temperature and duration of exposure and relatively large compared to that of the pollutants. Thus, to reduce the rates of these degradation effects it is important to keep the RH as low as possible. It would be recommended to perform independent RH measurements. This should be reflected in guidelines accompanying use of the EWO.

Conclusion

Dosimetry is a useful method to assess the quality of museum environments to assure good preventive conservation of museum objects. The main advantage of dosimetry, compared to measurements of single environmental parameters, is that dosimeters measure generic effects comparable to those on objects, of several environmental parameters usually including both pollutants and climate. A main challenge in using dosimeters is to relate the measured effects on dosimeters to the real effects observed on objects. This can be accomplished by relating the measured effects to tolerable levels of the single environmental parameters or by direct comparison with the objects to protect. In both cases the dosimeters need to be sensitive to the major degrading influences on the real object. If this is not the case combined use of several dosimeter types, e.g. one sensitive to oxidising another to acidic pollutant gases, is an option. EWO-dosimetry can most easily be used to assure good environments for collections including modern synthetic materials by applying general threshold levels set for organic museum objects, or possibly levels modified to fit effects on modern synthetics. To measure degradation risk for particular modern synthetics one needs to compare known dose-response data for those materials with the EWO dose-response equation, to evaluate applicability and determine threshold levels.

The EWO is available on direct order from the Norwegian Institute for Air Research (NILU) to be applied for the simple assessment of the environmental quality for organic museum objects kept in indoor environments. This paper shows that evaluation with the EWO of the air quality and consequent conservation conditions for synthetic polymers used in cultural heritage objects, based on the presently applied tolerability levels of environments for different indoor archive and museum locations, is feasible. Such an evaluation will give similar or increased protection as that offered to other vulnerable organic objects, by the environmental conditions specified for each level. One needs however to be aware of the possibility of increased need for protection of particularly sensitive materials, for which the generally determined tolerability levels may not be valid.

Authors

Terje Grøntoft and Susana Lopez-Aparicio
Norwegian Institute for Air Research (NILU)
P.O.box 100, NO-2027 Kjeller, Norway.
teg@nilu.no
http://www.nilu.no/

Notes

1 Shashoua, Y. (2006) *Inhibiting the Inevitable; Curent Approaches to Slowing Deterioration of Plastics.* Macromol. Symp. 238, 67-77.
2 Wypych, G. (1995) Handbook on Material Weathering. ChemTec Publishing, Toronto-Scarborough.
3 Grøntoft, T., Dahlin, E., Henriksen, J.F., Rentmeiseter, S., Hanko, M., Heinze, J., Taylor, J., Blades, N. And Cassar, M. (2006) *An early warning system for organic materials in museums, historic buildings and archives.* In Drdácký, M. and Chapuis, M. (ed.) Proceedings of the 7th European Conference "SAUVEUR" Safeguarded Cultural Heritage. Understanding & Viability for the Enlarged Europe. Volume 1 – Papers. 31st May – 3rd June, Prague, Czech Republic.
4 Reichert, T., Poshner, U., Ziegahn, K-F., Fitz, S., Anshelm, F., Gauger, T., Schuster, H., Droste-Franke, B., Friedrich, R., and Tidblad, J. (2004) *Effects of Modern Environments on Materials – Polymers, Paintings and Coatings.* In: Kucera, V., Tidblad, J., and Hamiltion, R. (ed.) Bulletin 110E. Cultural Heritage in the City of Tomorrow. Developing Policies to Manage the Continuing Risks from Air Pollution. Proceedings from the MULTI-ASSESS Workshop, London, United Kingdom, June 10-1, 2004. Swedish Corrosion Institute AB.
5 Tétrault, J. (2003) *Airborne Pollutants in Museums, Galleries, and Archives: Risk Assessment, Control Strategies and Preservation Management*, Ottawa: Canadian Conservation Institute,.
6 Sebera, D. (1994) *Isoperms: an environmental tool*, Washington: Committee on Preservation and Access.
7 J. Taylor, N. Blades, M. Cassar, T. Grøntoft, E. Dahlin, S. Rentmeister, M. Hanko and J. Heinze. (2006) *Preventive Conservation Strategy.* In Dahlin, E. (Ed.) EU project MASTER. Preventive Conservation Strategies for Protection of Organic Objects in Museums, Historic Buildings and Archives. Final Report. Del no. 8.2. Part 2. Chap 2.7.
8 Graedel, T.E., Leygraf, C. (2000) *Atmospheric Corrosion.* Electrochemical Society Series. John Wiley & Ins Inc. New York.

Action plan for industrial monuments - a proposal for research into improving the management of large sites

KORNELIUS GOETZ, STEFAN BRUEGGERHOFF AND NORBERT TEMPEL

Incredible Industry: that's typical

Industrial sites are increasingly being turned into monuments, both as a result of deindustrialization and because they give identity to a region and symbolize the industrialized era; sometimes, however, the conversion is simply a matter of saving the cost of an environmental clean-up.
The usual problems associated with the maintenance of a monument are amplified in both character and complexity with industrial sites, because they often involve a huge physical expanse and a complex structure with a complicated range of diverse materials. Moreover, such sites are often laden with toxic substances and they were never designed to last for centuries.

Shortly before their shutting down, a great deal of wear and tear occurs at industrial sites for economic reasons. Between shutting down and recognition of the site as a monument, several years of vandalism may occur. Both of these problems might be avoided if only the heritage status of the site was identified in a more timely fashion.

After becoming a cultural heritage site, limited financial resources may be insufficient to cover the costs of proper maintenance. At the same time, access is a high priority for authorities. Maintenance and public access are thus forced into an unholy alliance. The owners of industrial monuments feel pressured to solve all of these problems at the same time. Estimating the scope of a project takes time; frequently scopes are only applicable to a limited part of the entire complex. In some cases it is deemed necessary to sacrifice the greater parts of the site in order to "save the rest".

Despite 30 years of experience with the preservation of historical industrial monuments in Germany, the current situation there is rather unsatisfying. Thus we have initiated a research project sponsored by the German Environmental Foundation, whose timescale is 2009-2010. Upon completion of the project, we

Figure 1a-b. Industrial monuments are symbols and give identity to a region, such as the headgear of world heritage site of Zeche Zollverein at Essen, Germany (left). The court of honour nowadays is a picturesque scenic attraction for wedding couples (right).

Figure 2. Nature is back at coking plant of Zollverein.

will present a handbook (White Paper) about the principles for dealing with industrial monuments including guidelines for concrete measures. Our recommendations should be applicable in principle to all industrial monuments. We describe our proposal in more detail below.

In for a penny, in for a pound?!

According to this maxim, it might be expected that all German legal statutes dealing with historical monuments contain a criterion recognizing the historical value of major industrial sites. This is by no means the case. The Law for the Protection of Historical Monuments (Denkmalschutzgesetz), enacted by North Rhine Westphalia in 1980, has remained the exception. Only here do we find a statement recognizing the historical value of industrial facilities: it is established if a structure had a noticeable impact upon "the development of the conditions for labor or production". Considered in this light, it is not surprising that the justification of the value of industrial monuments still entails greater effort than for established structures such as castles, public buildings, or basilicas.

Second, it is a tenet of the preservation of historical monuments that monuments can only be maintained indefinitely if they can be put to good use. The belief in the maintainability of major industrial monuments is thus continually and severely challenged. How does one preserve a monument that has been seen through structural change as a portent of failure and as a poisonous legacy and that lacks the "proper age"? The "International Construction Fair IBA Emscher Park" did away with this prejudice and showed a way towards an ecological and cultural representation of structural change, all the while preserving the industrial legacy.

Nonetheless, the "generational covenant" promulgated by the IBA failed because of the resistance by the objects themselves, i.e. due to the planned obsolescence of the structures and materials. In the same vein, this provides an end to the concept of "controlled breakdown" - acceptance of continuing decay - as a rhetorical device for justification. It is expensive as a preservation measure in the medium-term, according to the principle of "as little as possible, as much as necessary". The ability to preserve cannot be obtained at costs below the going rate (c.f. Section "Assessment of Expenses and Timeframes").

Action Plan

Therefore, instead of a comprehensive and complete restoration in one go, we must follow a strategy of continuous inspection and maintenance. To this end, action plans oriented towards a gradual restoration of monuments are needed. Also, for various reasons, it may become necessary to consider not only the preservation of the whole but also the loss of certain parts of the site, and to plan accordingly. Such a plan is also imperative for structuring possible rebuilding projects.

With this in mind, a maintenance strategy, in line with practical experience, should be developed for the preservation of heritage-protected industrial sites. The plan of action should follow four basic principles: The main focus should be the unity of the site; second, the defined goals of the project should be achieved before treatment is introduced; third, treatment should be based on priorities; and fourth, an action plan should make possible an assessment of related expenses and time-frames.

Unity of the Site

The main principle is our respect for the whole range of different levels of information: from creation of the site, through time of use and finally, the aftermath. And we see industrial monuments

Table 1. Definition of goals

		Conservation	Restoration		
		Preventive	Remedial	Reconstruction	Repair/Rehabilitation
	creation	+			+
	time of use	+			-
	aftermath	+	<----- blurry transition ---->		--
	unity	+			-
grade of historical tradition		++++			---
	integrity*	-			+
	not defect**	-	<----- blurry transition ---->		+
appearance		--			++
		ruine	realistic		former glory

**material wholeness, completeness, and unimpaired or uncorrupted condition*

***perfection of an object or item due to the production process*

as unity of buildings and equipment. The levels of information and the unity of the site form a holistic cosmos. Together they form historical tradition.

Definition of Goals

A definition of goals is not automatically provided by the industrial monument itself. First of all we have to decide carefully, which period of the site should guide the specification of concept. As a goal we may choose what we find on site: an industrial monument years after shutdown, possibly vandalized and heavily damaged. This goal could be named 'ruin'. Or we try to bring the site back to a very early period, a goal called 'former glory', which is, of course, never really possible. A good compromise is to choose the period shortly before final shutdown: we conserve evidence from time of use and call it 'realistic'. After the definition of goals, fixing of treatment is possible. In principle treatment ranges between conservation and repair / rehabilitation: conservation is a typical treatment for the goal 'ruin', repair / rehabilitation for 'former glory'.

Conservation: All measures and actions aimed at safeguarding cultural heritage while ensuring its accessibility to present and future generations.

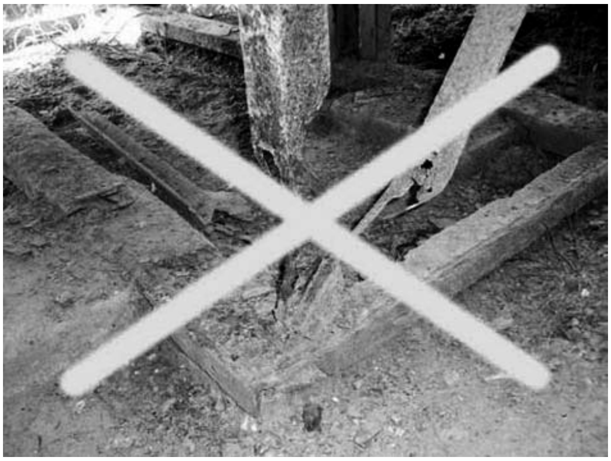
Repair: limited intervention on an object or item to recover its functionality;

Rehabilitation: Intervention on a building, garden or landscape in order to recover its original use or adapt it to a different use.

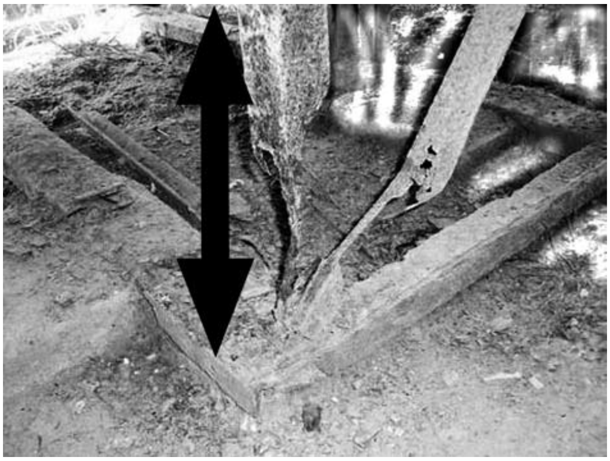
For sources of terms and definitions, see [2].
There is a blurry transition between these extremes; intermediate treatments are possible too. This results in a broad range of possible treatments. Whatever decision is made will affect the grade of historical tradition and the appearance. For a simple scheme see table 1.
As a result, we never achieve an optimal degree of historical accuracy together with "best" appearance. Preferring historical accuracy will affect "best" appearance and vice versa.
Finally definition of goals for an industrial monument may result in sub-goals for certain objects within one site: While trying to achieve a realistic appearance for most objects on site, some single items are repaired to former glory and one area may be conserved as a ruin if this specific part was shut down long before final closing of the rest.

3a

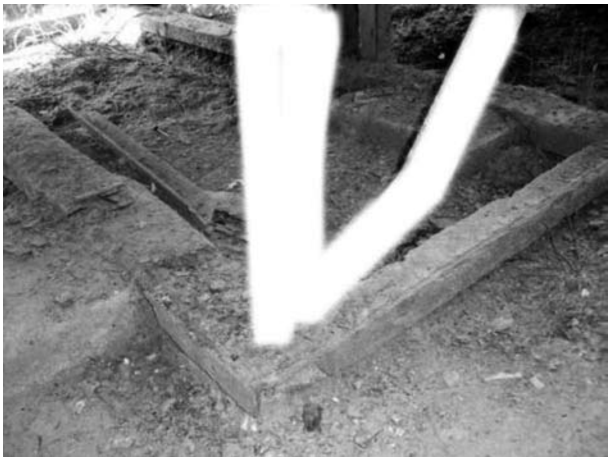
3b



3c



3d



3e

Figure 3a-e

Being different may result in doing it later (3a),
doing it partly (3b),
not allowing access (3c),
backing the structure (3d),
removing it (3e).

Principles for Measures

The following principles are to be recognized in the implementation of restoration measures on monuments:

- The task differs completely from other (re)building projects and often represents a departure from established technical procedures.
- The static-constructive treatment of industrial monuments requires experience and good judgment.
- Durability of construction is substituted for regular inspections.
- The aging process must be accepted as an unavoidable, continuous change of material properties.
- Maintenance means preventive conservation, viz. precautions and indirect measures aimed at the prevention and reduction of further degeneration or loss.
- Conservation (as defined above)
- Repair (as defined above)
- Renewal or Renovation (as defined above)
- Reconstruction consists of the rebuilding of an object with old or new materials in its presumed original form based on documentary or material evidence.

For sources of terms and definitions, see [2]

Treatment Priorities

Simple first! More extensive treatment follows, if simple fails. As a consequence we establish a hierarchy starting with conservation, restoration, reconstruction followed by repair / rehabilitation. This will result in significant cost savings effects with a significant amount depending on the size of the site.

Preservation: dos and don‘ts

The preservation of industrial monuments should be guided by four principles:

1. Look for a strategy to estimate levels for proper action and safety
2. Be different, which may mean
   - do it later
   - do it partly
   - don‘t allow access
   - back the structure
   - remove it (and save examples)
   - Decision-making means setting priorities
3. Define standards for action
4. Guide volunteers and ‚non-experts‘ from make-work programs

Assessment of Expenses and Timeframes

The definition of goals has consequences. It results in treatment and allows an assessment of expenses and timeframes. Both are effects of goals – never vice versa! Our action plan will point out this fact very clearly.

A special problem is the question of extent and means of financing of measures to restore industrial monuments: large industrial sites do not fit into the classical system of support for monuments. So far there are no “pots of money” for industrial monuments in Germany.

In this context, a comparison with established objects of monument preservation may be helpful. Consider, for instance, the Frauenkirche in Munich: Over the next 20 years, half a million Euros will be provided “preliminarily” each year for the renovation of the facade of this-admittedly very prominent-edifice. This amounts to an expected total of 10 million Euros, a sum in which cost overruns due to the ambitious choice of restoration measures are already anticipated. In comparison, the four sites of our case studies (see Figure 4) require only a fraction of this amount, even though each individual construction volume is comparable to that of the Frauenkirche!

Consequently, the handbook for our action plan will make the case that major industrial monuments rank on the same level of importance as other monuments. This also means that they should be treated similarly financially.

Case Studies

As examples we will discuss several industrial sites in the Rhine-Ruhr area: The blast furnaces of the Henrichshuette at Hattingen and Meiderich /

Table 2. Case studies

location	Hattingen	Meiderich	Essen	Dortmund
former use	blast furnice	blast furnice	coking plant	coking plant
name	Henrichshuette, now: LWL-Industriemuseum Henrichshuette Hattingen (LWL = regional authority)	Landschaftspark Duisburg-Nord	Kokerei Zollverein: white side	Kokerei Hansa, Dortmund*
shutting-down	1987	1985	1993	1992
dimension of quantity (hectares)	circa 13	230	circa 50	circa 11,5
number of objects	circa 30	90	36	54
theme	industrial museum	landscaped park	industrial site and center for creative industries	industry and nature
status	listed monument	listed monument	World Heritage Site	listed monument
annual budget	not specified	not specified	not specified	not specified
investive	not specified	none	not specified	not specified
structural maintenance	circa 300.000 Euro	not specified	not specified	420.000 Euro
financial support	first investment: 90% Staedtebaufoerderung, 10% LWL	50% government, 17% city of Duisburg, 33% from rent and lease	cost against the risk of damage	between 50% - 90% by government, rest by foundation
space of time for development	circa 10 years	completed	discharge from mining law (2013)	2023
form of organisation	LWL-Industriemuseum	Duisburg Marketing GmbH (operating company)	Ruhrkohle AG (until 2013)	Foundation for the Preservation of Industrial Sites and History Culture
conserved basic fabric (%)	circa 80 %	75%	circa 75%	circa 65%
rate of reuse	circa 75 %	100%	8%	circa 25%
status quo of development	partly finished, partly under construction	finished	not started	partly finished, partly under construction
perspective for development within next 10 years	selective development of single objetcs if funding is available	selective development of single objetcs if funding is available	not specified	selective development of single objetcs if funding is available

** Source of data Foundation for the Preservation of Industrial Sites and History Culture*

Duisburg as well as the coking plants at Zollverein (white side) / Essen and Hansa / Dortmund. These sites show a wide range of different maintenance-related issues. Right now, most of them have not been sufficiently resolved. Details for each site are given in the table above.

Interdisciplinary Approach

Our action plan will be based on an interdisciplinary approach. Members of our working group have expertise in documentation and inventory, structural analysis, corrosion protection and material science, clean-up of former waste deposits, conservation and restoration, practical application to monuments and, last but not least, client needs.

Summary

There is no maintenance strategy for industrial monuments yet, but we see a strong need for action planning. Our approach includes several subtasks such as example selection, definition of general methods, development of tendering documents and checklists, training of inspectors and people for monitoring.

Table 3. Interdisciplinary approach

specialisation	task under the auspices of heritage
documentation and inventory	recording information and identification of heritage status
analysis of damage	recording of present situation
statics	calculation of stability under load and assessmanet of statics provisions
corrosion protection	assessment of materials in the context of corrosive environment
toxic substances	assessment of relics / and waste disposal
coating technology	development of coatings
conservation / restoration	evaluation and proposals for conservation and restauration
industrial maintenance	transfer of knowledge from industrial maintenance technologoy
security	acess for visitors
action planing	planing of maintenance and esdtimate of costs
preservation of monuments	balancing all proposals under the auspices of heritage
state of art, transferability	looking for other case studies from the Rhine-Rhur-Area
owner	input of specifications based on experienced data

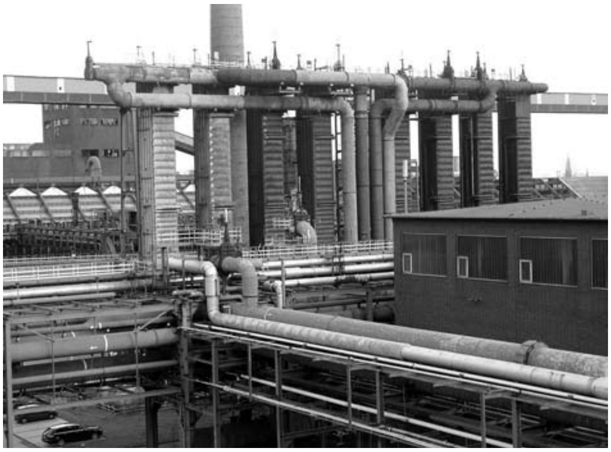


Figure 4. Details from Kokerei Zollverein (white side) showing pipeline bridges, buildings and tube cooler units in the background.

Potential Benefits

In creating an action plan for "Incredible Industry" benefits may arise for owners in guiding and shaping the long-range development of their site. They may adapt our work to their own large site as a template. Future generations may benefit, because they may enjoy evidence of industrialization in a unified site. The public will save resources, because an action plan saves money and improves safety for staff and visitors and creates public acceptance.

Authors

Kornelius Goetz,
Bureau for Restoration Advice, Oettingen
(corresponding author)
Dr. Stefan Brueggerhoff;
German Mining Museum Bochum
Norbert Tempel,
Westphalian Museum of Industrie, Dortmund
goetz@restaurierungsberatung.de

References

[1] Generational Covenant: the amount expended for the preservation of industrial monuments is sufficient to guarantee their survival into the next generation.

[2] The terminology used here is based on the unpublished document WI00346002 Conservation of cultural property - Main general terms and definitions concerning conservation of cultural property - Result of CEN/TC346/WG1 meeting, Munich, 16/17 October, 2008 (document will be made available as European Standard EN 15898 by the end of 2009).

Flameproofed textiles in museums and conservation

Cajsa Hallgren

Introduction

This paper deals with the issues of preservation of textiles with flame retardant finishing and aims to spread knowledge of flame retardants in textile objects. It is important for conservators to recognise the problems caused by flame retardants, since their actions might decide the future state and existence of objects.

In general textiles are quite easily ignited and are often the starting point of fire in buildings. Many people die each year as a result of building fires. Objects therefore need to meet the requirements of fire safety in public buildings. Flame retardants are used in the purpose of creating a safer indoor environment for humans. But flame retardants only have the capability of delaying ignition and can not prevent it completely. A flameproofed fabric once ignited will burn at the same pace, or maybe even faster, than an untreated fabric.

The usage of flame retardants is controlled by laws and regulations which mean that objects must meet certain safety standards. Different countries have different standards but there are no lists or recommendations in Sweden of specific flame retardants that would fulfil the requirements of the standards. Great Britain, Ireland and USA have the strictest laws and regulations. [1] In Sweden the regulations can vary in different parts of the country. Places in Sweden that are required to be safe from a fire perspective are public buildings such as hospitals, hotels, theatres, restaurants and public transportation. Textile objects in these places that are usually subjected to fire-retardant finishes are theatre curtains, upholstered furniture and textile art and drapes. There are also certain criteria to be met in places where there is a risk of arson such as psychiatric facilities and prisons. [2] Museums are not viewed as a public building in this sense and there are therefore no requirements that museum objects should be flameproof.

A short history

Flame retardants have been used on cellulose materials since at least 400 BC in Egypt. First vinegar and later alum was used on wood. Flame retardants were also used by the Romans in 200 BC who mixed alum and vinegar for use on wood. During the 17th-19th century flame retardants were developed and also patented. Among the most frequently flameproofed objects were theatre curtains, starting with substances such as gypsum, clay or alum at an early stage and later developing into more effective solutions of ammonium salts and boron. [3]

The interest of treating textiles with flame retardants grew in the 1940s and in 1953 the Flammable Fabrics Act (FFA) came into force. The FFA now lies behind many of the laws and regulations in EU and internationally. Fabrics on textile furnishing became commonly treated from the 1970s onwards. [4]

The use of flame retardant chemicals today

Flameproofing is achieved by treating textiles with flame retardant chemicals. Flameproofing of textiles as an aftertreatment can be carried out by anyone who wishes to buy the products. (It is also done industrially in mills during or after the making of yarns and fabrics.) The treatment can be done at home by private consumers or by the retailers or possibly by a conservator. The usual application method for the small scale treatment is by spraying or by immersing the object in a solution of flame retardant and water. It is important to document the treatment because it might help in the future conservation treatment of textiles.

The types of flame retardants used can be divided into four groups: inorganic- , organophosphorus-, halogenated- and nitrogen-based flame retardants. The inorganic flame retardants such as metal salts and phosphorus compounds as well as the organophosphorus flame retardants have been commonly used on textiles. [5]

Most flame retardants used by private consumers are water soluble. These are called additive flame retardants, as oppose to the reactive water resistant ones. A good thing (apart from their flameproofing qualities) is that they are non-durable and can be washed out. Examples of water soluble flame retardants are acids like boric acid, salts of boric acids and inorganic salts. [6] Dangerous flame retardants like polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) are also additives. [7] Nitrogen and phosphorous based substances are more water resistant because they form polymers within the cellulose fibre structure. [6]

It is mostly cellulose textiles that receive flameproof finishes because the fibres ignite easily and burn rapidly. Even though the flame has been put out they continue to glow, causing a possibility of re-ignition. [8]

Ammonium phosphate and ammonium sulphate are examples of the most commonly used substances for stage textiles and textile art because they are cheap and effective. This is even though they have been known to degrade textiles and cause damage. The only substances that will suffice for woollen fabrics are injurious to health. [9] But since wool has great ability to withstand fire a flameproofing treatment is usually quite unnecessary.

Upholstered furniture often has fabrics with an industrially applied flame retardant finish in the form of a back side coating. Poly-urethane, sometimes used in upholstered furniture, might contain a brominated flame retardant. Museums taking in upholstered furniture and textile art or tapestries from public buildings, should be aware of the possibility that they are taking on chemically flameproofed objects.

It is a goal for the future that all flame retardants will be environmentally approved and cause no bio-accumulation. No brominated flame retardants are used in textiles in Sweden at present. Some flame retardants have been banned in textiles that come into direct contact with the skin, such as bed sheets, sleepwear and underwear, due to their possibly dangerous health effects. These are Tris(2,3-dibromopropyl)fosfat, tris(1-aziridinyl)fosfinoxid, and polybrominated biphenyls (PBB). [10]
The topic of flame retardants was also brought up in an article by Halvorson as a way to recommend and guide those with plans to or in the process of flameproofing public textiles. [11]

Textile degradation caused by flame retardants

Flame retardants are very durable, a quality desired by the producers and users of them. Retailers often promise that no harm will be done to the textile but that is often not the case. Flame retardants are not developed for eternal use and the chemical compounds can change over time. The products presently used as flame retardant finishing have not been studied from a conservation/preservation point of view. It should be a standard procedure to test and evaluate all flame retardants in use, especially the new environmentally friendly ones that are becoming frequently used. Another test that needs to be carried out is whether a flameproofed lining affects the object.

Metals are very sensitive to flame retardants and should therefore not be kept close to flameproofed textiles as the metal might get stained. More importantly, textiles with metal elements should not be treated. [12]

A brief overview of documented negative effects

The negative effects of flame retardants on textiles was noticed and documented by Karen Finch in 1969 and concerned a 15 year old tapestry hanging which according to American laws had been flameproofed with an ammonium sulphate based substance. The tapestry hanging had damage caused by strong acidity created as an effect of sunlight (UV radiation). [13]

Eva Lundwall at The Swedish National Heritage Board documented one example where woollen curtains were destroyed because of flameproofing chemicals. Because of uneven application the fibres were partially very brittle. Water cleaning of the curtains resulted in colour change and generated a gas with a bad smell. [14]

Doreen Rockliff and Nancy Kerr tested commonly used water soluble flame retardants on cotton fabrics with accelerated ageing. They found that the flame retardants were required in a very high percentage (11-15 weight percent of the fabric) which can be stressful for the fibre. Results showed that none of them were ideal for usage on textiles. Immediate effects of a flame retardant containing borax, boric acid and diammonium phosphate appeared as a surface of crystallized material on the fabric. Another flame retardant (FlameGard DSH) based on inorganic ammonium salts caused an increase in the hygroscopic nature of the fabric. The shrinkage of the fabrics was small and probably due to the submersion of the fabric in a water based solution. It even seems as though the flame retardant somewhat reduced the shrinkage. Other changes were loss of stiffness and a small change in Ph. The effect shown after accelerated ageing were some changes in colour of the dyed fabrics. Undyed fabrics became either darker or paler. It also stiffened the fabric which got a crisp feel. [15]

Preservation and conservation

Flame retardants cause a real problem for conserving and preserving textiles. They are not only a problem for conservation treatments, but especially for the preservation of the textiles in general as they cause accelerated degradation of fibres that are not fully reversible, if at all. The best way for long term preservation of a fabric with a flame retardant treatment is to keep it in a stable and good climate, with a good stable temperature and relative humidity and as low UV radiation as possible, and if possible in a pollution free environment. It is still very probable that acids will form no mater what conditions there are in a room or storage. But whereas pollution is a difficult thing to control, temperature and direct sunlight is not.

Since inorganic flame retardants are hygroscopic, a treatment with these on textiles can result in two types of damages. In a dry climate they can act dehydrating and in a humid climate they will dampen the textile. The latter scenario can result in mould growth or fungi attacks.

Application in excessive amounts is required for many flame retardants which changes the character and properties of the fabric. This is especially true of the inorganic flame retardants, which can sometimes require an amount of over 15 weight percent of the fabric. It stiffens and changes the quality of drape and feel and is not suitable for lightweight fabrics that have been chosen for its fine drape or soft feel. Lightweight fabrics have a higher tendency to catch fire and burn and therefore require a higher weight percent of flame retardant than a high dense fabric. [15]

Additive flame retardants are more likely to migrate and contaminate adjacent objects as they are not bound to the textile fibre structure. Therefore they should not be kept close to metal containing objects (unless gold). The same goes for plastics which often have been given a flame retardant additive during manufacture.

Problems in conservation are also health related which needs to be taken into account. Flame retardants are not necessarily more dangerous than other chemicals which are sometimes found in textiles, such as pesticides and fungicides. Any chemical that has been put on to a textile can cause severe health damage to anyone who handles the object. Textile fibres that have come loose from the fabric can easily be inhaled and thereby damage the lungs. Personal protective equipment (PPE) that includes a protective particle mask, gloves, goggles and a white cotton coat is very important. Proper PPE needs to always be worn when dealing with old textiles as they can contain numerous chemicals. PPE is also very important when hanging up or taking down a textile object, for instance a tapestry. It is also important to wear rubber gloves and an apron when washing since the dirty washing water contains chemicals that can be absorbed right through the skin.

It is important to remember all the ways of intake to the human body, orally (through the mouth), dermally (through the skin) or by inhalation (through breathing). It is also important to know that some parts of the body such as the abdomen and below as well as hands, head and upper part of the feet are more susceptible to uptake of chemicals. [16]

Discussion - To treat or not to treat?

Flame retardants should not be used on museum objects. It should not even be used on other fabrics in museums such as decorative fabrics that might come into contact with museum objects. This is because some flame retardants are known to migrate and may contaminate other objects. Textiles in show cases are not likely to be a source of ignition. In case of a fire in the museum it is better to have specific rescue plans for the most important objects.

It is important to consider the values that might be lost or won in the case of flame retardant treatments of textiles. Can treatments of textiles in a room or building enhance the safety in proportions to make it worth the possible degradation of objects? The safety of the lives of humans and the preservation of objects must be weighed against each other. Because all situations are unique there are no general guidelines to follow when deciding whether to treat an object or not. It is also difficult to recommend any specific flameproofing agent, as they all have shortcomings and all cause some sort of degradation. It can be a good idea to try to locate a piece of textile art that has been treated with a flame retardant in the past to evaluate the outcome.

If a treatment is to be done it is of the utmost importance to get an even application. Uneven applications result in uneven damage which can be very disturbing to the eyes and severely diminish the aesthetic value.
It is the conservator's responsibility to inform clients of the degrading effects of flameproofing agents on textiles. A conservator should generally not speak in favour of flame retardants, but there should of course be room for exceptions if the owner thinks it is absolutely necessary or if it needs to be done to meet safety regulations. It is better that a treatment is performed by a conservator for the maximum skilfulness and knowledge rather than by a novice.
Discussion and information in a dialogue between the conservator, the client and the rescue services is crucial. The rescue services are needed to advice on furnishing, on what can be moved or changed. A conservator is needed to inform of the risks taken if a textile is to be flameproofed and other risks. Because textiles are easily damaged there is only one chance to save and preserve them. A destroyed fibre can not easily be mended and therefore a textile destroyed is destroyed forever.

If flame retardants are used in the purpose of saving lives in the case of a fire in a building then there must be other means to go about it. Working fire alarms should be installed in private homes and public buildings in combination with fire extinguishers, fire blankets and maybe even sprinkler systems. Ways to make interior fittings flameproof without chemicals can be to put them high enough for no one to reach it or to put it behind glass or within a showcase. Easily ignited objects are never to be placed along emergency escape routes. Wool can be chosen for interior decorating elements and upholstered furniture. Since wool has great thermal properties it doesn't need a flame retardant finish. A flameproofed lining instead of treating the whole object might be another solution.

Carpets do not usually need a flame retardant finish since they are not easily ignited. Because they lie on the floor they have limited access to oxygen and they don't feed the uprising flame with more material, therefore making the spread of the fire very slow. Curtains on the other hand are more dangerous because they hang in the air and have access to a lot of surrounding oxygen. A fire in a curtain feeds itself upwards along the curtain. The same goes of course for theatre curtains and drapes that are not hung close up against a wall.

Reversibility

Acidity has proved to be a common consequence of flameproofing treatments and textiles with an aged treatment tend to have a very low pH. Acids damage textile fibres, especially those of cellulose. Although the reversibility of a newly added flame retardant with water durable qualities is minimal, there is a greater chance that aged treatments can be removed during water cleaning. Even if they will not wash out completely there is a possibility that cleaning with water can reduce the acidity and make the pH more neutral. As shown in a test flame retardant finishes based on phosphorus create acids when stored for several years. But by laundering it can be possible to neutralize and wash out the acidity. [17] But when it has reached the point where the fibres are severely degraded, cleaning with water can be even more destructible and result in a textile that can not carry its own weight. For an object in use, like curtains in a public building, this will mean the end.

Since there is no fundamental research on the effect of flame retardants on textile materials easily available this is a tricky subject to approach. It is of great importance that conservators and researchers show interest in the subject and start to evaluate the consequences of flame retardant finishes on textiles with the mission to save our textile heritage.

Author

Cajsa Hallgren
Malmögatan 10b
252 49 Helsingborg
Sweden
cajsa_hallgren@hotmail.com

References

1. Lassen, C., Løkke., S. and Andersen, L. I. 1999. *Brominated flame retardants- substance, flow, analysis and assessment of alternatives,* Rapport nr. 494/1999. http://www.rohsguiden.dk/files/brominated%20flame%20retardants_mst1999_494.pdf (Accessed 15 April 2008).
2. Räddningsverket. 2004. *Brandkrav på lös inredning*. http://www.srv.se/Shopping/pdf/21571.pdf (Accessed 23 January 2009).
3. Hindersinn, R. R. 1990. Historical aspects of polymer fire retardance. I: G. L. Nelson (red.): *Fire and Polymers: Hazards Identification and Prevention.* New York: American Chemical Society (ACS Symposium Series 425): 87-96.
4. Collier, B. J. och Epps H. H. 1999. *Textile Testing and Analysis*. Upper Saddler River: Prentice Hall.
5. WHO/IPCS. 1997. *Flame Retardants: A General Introduction*. Environmental Health Criteria 192. Geneve: WHO.
6. Perkins, W. S. 1996. *Textile Coloration and Finishing*. Durham: Carolina Academic Press.
7. Kolare, S. 1995. *Flamskyddsmedel hotar miljön*. Solna: Kemikalieinspektionen.
8. Gohl, E. P. G. and Vilensky, L. D. 1983. *Textile Science*. Melbourne: Longman Cheshire.
9. Gustafsson, B. 2004. *Flamskydd 2003*. KemI PM Nr 2/04. http://kemi.se/upload/Trycksaker/Pdf/PM/PM2_04_flamskydd.pdf (Accessed 23 Januari 2009).
10. Kemikalieinspektionens författningssamling, KIFS 2008:2. www.kemi.se/upload/Forfattningar/KIFS/K08_2.pdf (Accessed 26 February 2009).
11. Halvorson, B. G. 1995. Flame retardant finishes for textiles. *Textile Conservation Newsletter* 29: 20-26.
12. Svensk flamskyddsteknik. Säkerhetsdatablad för Secura Anti-Flame FRT 25. http://195.35.83.106/~xc50513/e-handel/upload/articlefiles//SC%20SDB%20FRT%2025_50.pdf (Accessed 25 February 2009).
13. Finch, Karen. 1969. Note the damaging effect of flame proofing on a tapestry hanging. *Studies in Conservation,* 14(3).
14. Lundwall, E. 2003. *Den ljusskygga textilkonsten: textilkonservering under 1900-talet.* Stockholm: Riksantikvarieämbetet.
15. Rockliff, D. och Kerr, N. 1984. Fire retardant finishes for fiber art: a conservation perspective: preliminary findings. *ICOM Committee for Conservation: 7th Triennial Meeting Copenhagen 10-l4 September 1984: Preprints*. Paris: ICOM: 46-50.

16. Åkerlund, M., Flato, S. and Hellekant, A. 1998. *Från silverfisk till hälsorisk: skadedjur och åtgärder i samlingar*. Stockholm: LT.
17. Leblanc, R. B. 1989. Degradation of Pyrovatex-treated fabrics during storage. *Textile Research Journal,* 59(5): 307-308.

Cold storage as an alternative to mass deacidification

Birgit Vinther Hansen

Introduction

During the 19th century, many production methods underwent a considerable technological development; this was also true for paper production. The old traditional gelatin sized handmade paper made of rags had a permanence that could make it last for thousands of years and we do not yet have to be concerned about the condition of these papers if stored in a reasonable environment. Due to the "development" of papermaking processes in the period 1800-1980s, modern paper may only last a few centuries under normal storage conditions. Libraries and archives throughout the world are therefore challenged because these papers now start to become heavily degraded.

Only when paper is so degraded that it no longer can be handled without it breaking, is it clear to everybody that we face a major challenge. Until now, we have only sporadically seen books or manuscripts, which have degraded to an extent where ordinary handling is no longer possible. From international research it is however evident that over the next decades we will find increasing amounts of objects per year that will reach a heavily degraded stage because acidity combined with age are quietly deteriorating the collections.

The degradation of acidic paper is proceeding with a speed that requires action now. To extend the lifetime of acidic paper the optimal solution traditionally has been mass deacidification. Therefore, in 2004 the Danish Ministry of Culture established a working group to identify the amount of threatened works on paper of national significance in Denmark from the period 1800 to 1985 and to judge whether mass deacidification would be an appropriate method for prolonging the life of our national collections. The Royal Library was represented in this working group together with the National Archives, School of Conservation (The Royal Danish Academy of Fine Arts), The State and University Library and the Library Management Agency. The working group delivered their final report with recommendations for the preservation of the national collections in 2008 [1].

Paper history and degradation

The dramatic change in general paper durability was mainly due to the introduction of acidic alum rosin size as a replacement for the traditional gelatin size and the use of wooden fibers instead of fibers from traditional rag pulp made of flax and cotton. The introduction of alum rosin size happened as the paper machine gained foothold from the 1820s along with an increasing demand for paper. The first paper mill in Denmark was put into operation at Strandmøllen at Mølleåen in 1829 [1] and the use of rosin has been documented in this mill's lists of raw material from 1834 [2]. Use of wooden fibers as "mechanical wood pulp" became commonplace in the 1860s and the resulting high lignin content and lower amount of pure cellulose led to a weaker paper. Also the unstable nature of the acidic lignin leads to accumulation of acids causing further destabilization of the paper.

The combination of alum rosin size, the acidic lignin and the weaker wood pulp turned out to be a catastrophe for the quality of the paper. In the early 1870s experiments began with chemical wood pulp in paper production leading to an increase in fiber strength. Very soon, problems with permanence of these acidic papers were experienced but market forces made it impossible for acid-free papers to compete with the production of acidic papers until the 1970s [3].

In acidic paper the dominant degradation is acid hydrolysis that slits the bindings between glucose units in the cellulose molecules and thus reduces the molecular chain length causing depolymerisation.

Fig. 1. The Danish Collection.

Even a few chain slits may affect the physical strength of the paper. When the paper becomes severely degraded it becomes brittle and can no longer be handled without risk of information loss. The hydrolysis is highly dependent on the relative humidity in the environment and the rate of hydrolysis and the oxidation of the material is related to the temperature. Also air pollutants may affect the degradation.

Collections in the Royal Library

The Royal and National Library´s collections with preservation obligation consist of Danish Collections (The National Collections) created through legal deposit (an obligation by all printers to send to the library one or more copies of everything they produce – see fig. 1.), The Collection of Pamphlets and Corporate Publications, Manuscript Collections and Archives, The Map Collection, Music Collections, Theatre Collections, The Oriental Collection, The Judaica Collection and the Old Collection of Foreign Prints. The comprehensive collections consist of printed and handwritten material mainly in the form of books, archives, maps and pamphlets. The collections are stored in different repositories in and around Copenhagen.

As is the case in similar national libraries, a large part of the Royal Library's collections consists of alum-sized paper produced in the period 1800-1985. These collections represent around 59,600 linear meters (lm) printed material. Of these, about 40,400 lm were manufactured during the period 1800 to 1985. In addition, we have approx. 7,999 lm manuscripts of which 6,639 lm are manufactured during the period 1800-1985. In total the Royal Library holds 46,990 lm paper-based materials, from the period 1800 to 1985, with the obligation to preservation on the long-term. In 2006, this amount represented 69% of the library's total collection covered by preservation obligation from all times. The Royal Library's collections are predominantly arranged in thematic groups. The objects to be targeted for intervention (i.e. acidic paper from 1800-1985) are thus spread over the collections.

The survey

To calculate the amount of acid paper and to estimate the level of degradation in our national collections, surveys were conducted in The Royal Library in 2006, the State and University Library in 2006 and the National Archives in 2005/2007. The survey in the Royal Library consisted of 384 samples randomly selected in the library stocks bringing a level of confidence of 95% ± 5% according

Fig. 2. A copy of the very brittle, Danish newspaper "Information" from 1948.

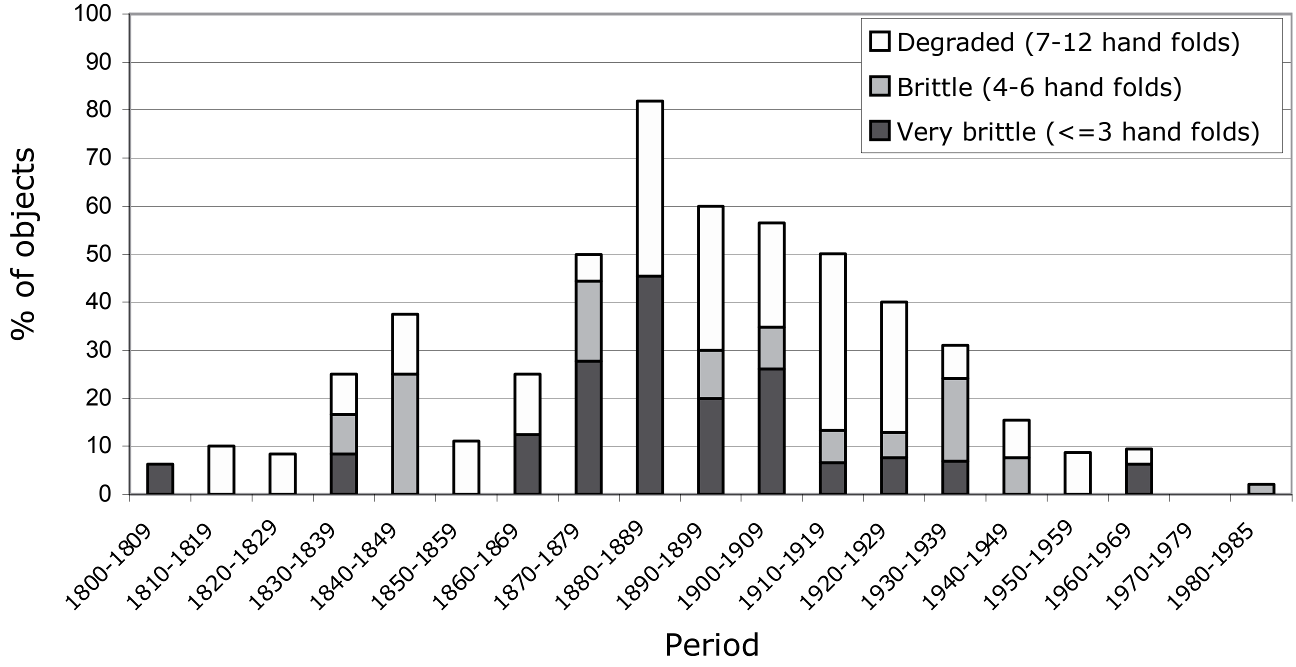


Fig. 3. Proportion of brittle paper in The Royal Library 1800-1985. The columns are subdivided according to hand folds to give a more nuanced picture of the state. We find lignin in the paper at The Royal Library from 1870 and onwards.

to Drott [4]. The results from measuring the individual samples can be used to describe the entire library collection from 1800-1985 because the sample is representative of the whole population. Measured parameters were pH (micro cold extraction), colour (CIELab), brittleness (hand fold), lignin, thickness and weight.

The survey [5] revealed that the total quantity of material from the period 1800-1985 is 1,498 tons of paper corresponding to around 1.3 millions objects. As many as 93 % of the Royal Library's objects from the period are more or less acidic and therefore retain a much shorter life than rag paper sized with gelatine made before the industrialization. This corresponds to what other international studies reports.

About 7 % of the objects from the period investigated are already very brittle (defined as the paper corner breaking in three hand folds or less), and thus at risk by common use. This part of the collections is not subject to mass deacidification as the objects are already too brittle. In fig. 2, a very brittle newspaper is illustrated. To rescue the information in such an object reformatting into another media is required.

In fig. 3 the proportion of brittle papers is presented in relation to their year of manufacture. There are significant differences in the proportion of brittle paper in the different decades corresponding to the materials used in the historical production. Thus, there is no single linear relationship between an object's age and degradation rate.

The figure shows that the proportion of brittle paper up to 1830 is below 10 %, after which it rises up to 40% in the 1840s. In the 1850s the proportion of brittle paper decreases to just over 10 %. After this, there is a strong continuous increase until the 1890s, where the proportion of brittle paper reaches over 80 % of the objects. In the following decades, the proportions of brittle paper fall for each decade until the 1970s, after which virtually no brittle paper is found in the collections.

Lifetime – pH

The rate of hydrolysis dominated deterioration of acidic organic materials is highly dependent on the temperature and humidity. However, it also depends on the pH value of the object. From our survey we know the pH, the age and the level of brittleness of each object. When these data are combined (see fig. 4), it is possible to see the tendency that the older and more acidic the paper is, the more brittle it is. It is even possible to make a correlation between the pH, age and brittleness (3 hand folds or less) if the period 1800-1850 is excluded because of inhomogeneity due to rag fibers still in use.

From this collection's specific correlation (see formula in fig. 4), we can calculate at what age a specific paper in *our* library with a specific pH is likely to become so brittle that it no longer can be handled without risk of disintegration. This stage ("End of Life") is defined as the paper breaking in 3 hand folds or less. A paper with pH 5 will go into "End of Life" 160 years after the year of production. This is close to the results from a survey in Slovenia presented by Kolar [6]. Since we know the pH and the year of production for each of our samples we are then able to estimate the remaining lifetime of all of our books, maps and manuscripts if the environmental conditions in our repositories remain the same in the future as today. As shown in figure 5, it is only 88.6% of the objects from the modeled period 1850-1985, which are acidic. The remaining 11.4% of the objects are not acidic and can be maintained much longer. As many as 26% of our acidic objects will reach an advanced degradation state in 2050 if the collections remain in the environment in which they have been stored until 2006, 80 % in two hundred years (in 2200) and in 2400 *all* our acidic objects will have degraded and may not even be possible to handle in the reading room.

Lifetime prolongation

With the knowledge we have today, there are two ways we can go to about prolonging the life of the collections. The rate of degradation can be lowered if we either neutralize the acid in the paper (mass deacidify) or store the paper in a colder and/or dryer environment as the chemical reactions (hydrolysis and oxidation) are then slowed down with no change of the chemical state. Or both measures can be taken.

Mass deacidification is a chemical treatment neutralizing the acid in the paper on a large scale. Besides neutralization, the treatment deposits a buffer to prevent future acidification, thereby preventing the materials from becoming more brittle. Till now the process cannot restore the paper's original strength – it can only slow down further degradation, but international research has focus on this area. In fig.

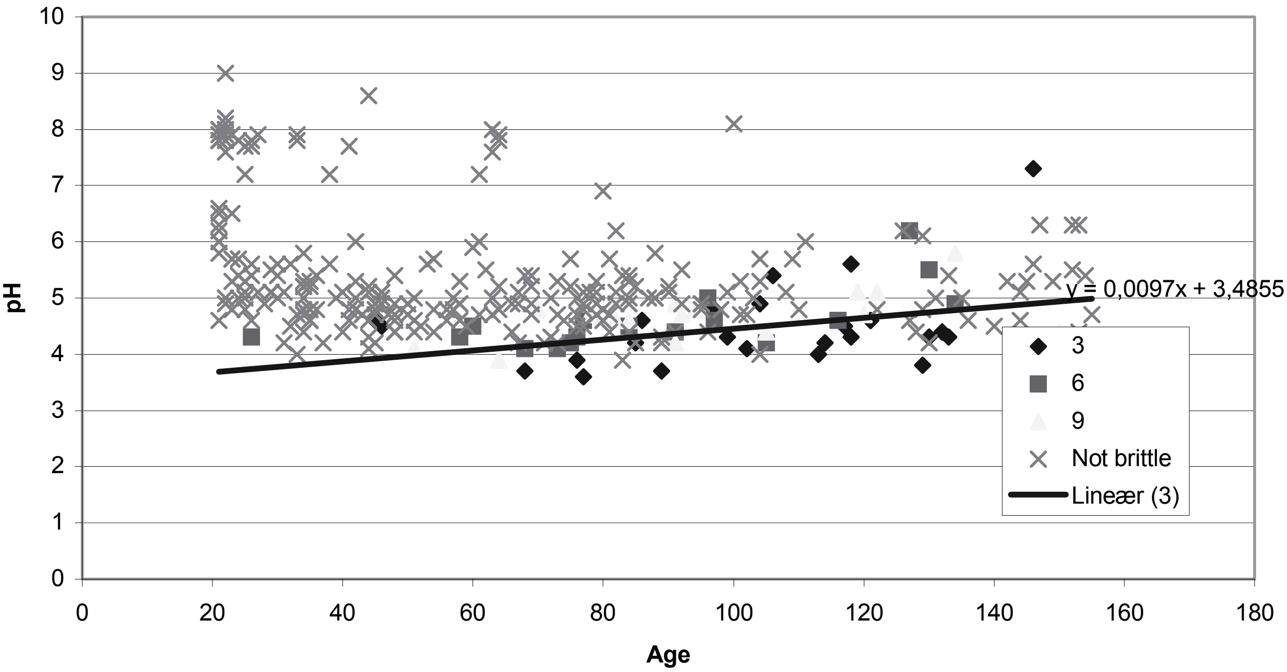


Fig.4. Here the surveys proportion of very brittle objects, which breaks in 3 hand folds or less, from the period 1850-1985 are plotted against pH and age. The line of correlation is y=0.0097x + 3.4855.

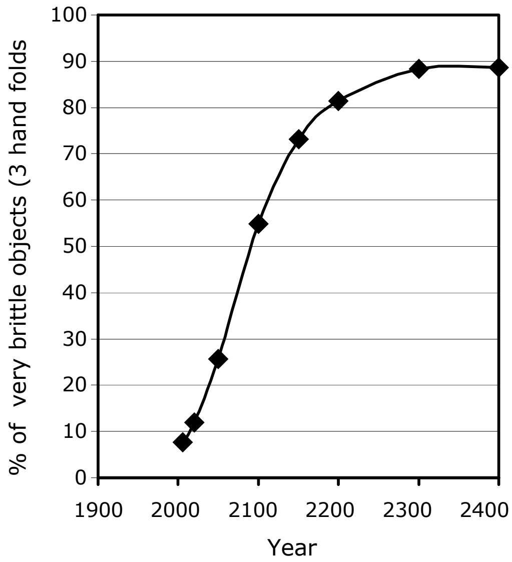


Fig. 5. The proportion of objects in the studied collections from 1850-1985, which will have reached a stage of degradation, where the paper break after 3 hand-folds if the collections are kept stored as until 2006. The part of alkaline paper makes 11.4% of the library's collection from the period 1850 to 1985 and thus makes the acidic part 88.6% to 100% in the figure.

6 and 7 two major mass deacidification systems are illustrated.

The life extending effect of mass deacidification depends on how acidic the paper is. The more acidic, the greater prolongation of the remaining life can be achieved as highly acidic paper has a short lifespan. Each of our collections all has an average pH of about five. The European research project PaperTreat surveyed the achieved stabilisation factors by deacidification at different pH-levels [7]. At pH five, the expected effect of mass deacidification was calculated to a maximum of three time prolonged lifetime. Some objects in the collections will have a lower pH value and may get a higher factor of stabilisation while others will have higher pH and get less out of it. Balasžic *et al* [8] found a factor of stabilisation of 3.3 (+/- 0,9) at the higher pH 6.2 but compared to an environment for the untreated paper at 65% RH which is significantly higher than the recommend RH in repositories with paper.

According to ASHRAE [9] the lifetime of hydrolysis dominated degradation is prolonged by two times if the climate is changed from 20ºC/50% RH to 18ºC/40% RH. If the temperature is further lowered to 12 ºC with RH at 45 %, the lifetime can be multiplied by four. By climatic change it is even possible to multiply the lifetime by 20 if the temperature is lowered to 5 ºC in combination with a RH at 30%. A prolongation of the lifetime by three times gained by mass deacidification can be obtained

Fig. 6. The Bookkeeper mass deacidification treatment takes place in cylinders with a dispersion of perflurocarbon and magnesium oxide.

Fig. 7. In the PaperSave mass deacidification treatment there is no agitation but the batch is going into a deacidification chamber with a solution of magnesium titanium alkoxide and hexamethyldisiloxane.

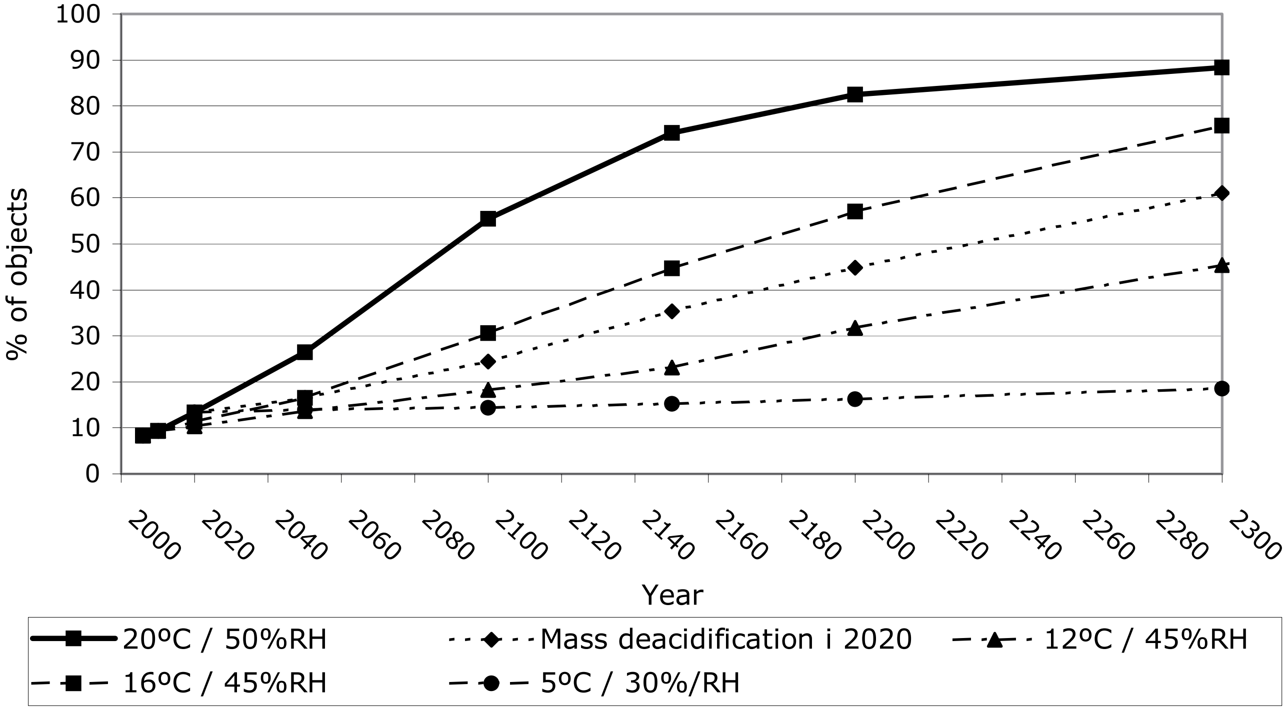


Fig. 8. Lifetime estimations by different means calculated from the age, pH and brittleness of the examined objects from The Royal Library's collections from 1850-1985. The graph shows how big a part of the objects, which in the future will reach the degradation state "3 hand folds".

by lowering of the temperature and humidity from 20 ºC/50% RH to 15 ºC/45% RH.

In Fig. 8, the effect of mass deacidification, with subsequent storage in an unregulated repository, at 20 degrees is compiled with the calculated effect of different climatic scenarios.

In a long-term perspective, there is a great difference in the effectiveness of various measures. As seen in Fig. 6, 82% of the Royal Library's objects will be brittle in 2200 if they remain in the heated, unregulated repositories. By moving the objects to an environment according to BS 5454 [10] (16 º C and 45% RH) the degradation rate is actually halved, and in year 2200 57% instead of 82% of the objects are expected to be degraded. By storing the objects at 12º C and 45% RH, the remaining lifetime is quadrupled, and "only" around 32% of the objects are expected to become degraded in the year 2200. A mass deacidification of paper may prolong life by up to three times, and if we perform deacidification in 2020 (which is the earliest realistic scenario) approximately 45% of our collections are expected to be very brittle in 2200. The last scenario 5° C and 30% RH is chosen from the recommendation in the Danish Ministry of Culture's report on the preservation of cultural heritage, which states that acidic, wood-containing paper should be stored in repositories at about 5 ºC [11] as recommended for unstable plastics. As seen in the figure, this will very effectively slow down the degradation rate so that the number of objects that exceed the three-fold border will only increase with three percent (from 13% to 16%) from 2020 to 2200. Of course, it is also possible to combine mass deacidification with cooling, for example 16 ºC/45% RH, thereby extending the life by up to 5-6 times.

Cost/lifetime

By calculating the cost of lifetime prolongations for both mass deacidification and cold storage (at different levels of temperature and humidity), we can compare the cost for each means.

We have received three international price estimates on mass deacidification of our collections, which all lie in the range of 20-25 euros per kg. Experiences from The National Library in Switzerland [12] show that management, transportation excluded, is about five minutes/unit. The actual cost of mass deacidification will thus be somewhat larger. A mass deacidification of the Royal Library's collections will cost approx. 279 million DKK and in addition costs must be added for selection, administration, transportation, possible development of a national plant etc.

In comparison, the extra energy costs for lifetime prolongations gained through lowering the temperature/humidity in a newly built repository was calculated by the Royal Library's Maintenance Department [13]. From the calculated energy costs at selected lifetime prolongations table 1 can be put up: When comparing the costs it turns out that for the same price we get a greater life prolongation (4 times against 3) by cooling to 10 ºC for a period of around 185 years than it is possible to achieve by mass deacidification even when additional costs for the selection, transportation, management, etc. in connection with deacidification is not included.

It is interesting that the five times greater lifetime prolongation by cooling to 5 ºC compared to cooling to 10 ºC only results in an additional energy cost of 50%. This is because less water is present in the air at lower temperatures thus requiring less energy consuming conditioning.

The decision

Apart from cold storage being the most cost effective means to prolong the lifetime of the collections it has other advantages compared to mass deacidification: we do not have to pick out the acidic object from the big collections where they are spread out (including administration, transport, quality control); there is no material which we will have to sort out because of risk, material composition or condition; there are no side effects or alterations leading to loss of authenticity; all objects, including the non-acidic ones, will gain a prolonged lifetime; it is possible to alter the decision if the premises changes.

Typically, cold storage requires a new building to house the materials. This is significantly more expensive than to build a typical air-conditioned space. It is not just the air conditioning units, but construction techniques, insulation, air locks, and ventilation designs all become more complicated and expensive. Other identified disadvantages are the required consumption of extra energy leading to higher annual maintenance costs and emission of CO_2. This means that future management might decide to raise the temperature to lower the costs, thereby reducing or eliminating the intended benefit.

Lifetime extension	x2	x3-4	x20
Mass deacidification		140 DKK	
Cooling	15ºC/45%RH 0.70DKK/ year	10ºC/50%RH 0.75 DKK/ year	5ºC/30%RH 1.10 DKK/ year

Table 1. Cost of lifetime prolongation of a book (750 g) compared to storage at 20 ºC/50% RH. The calculation is theoretical and does not account for infiltration from expedition, light, impact from the sun on façades, etc., and only count with an average summer and winter situation. Energy price 1.5 DKK/kWh. Future raise in energy prices is not taken into account.

Also conditioning is required to avoid condensation when objects are moved in and out of the repository hereby prolonging the time for expedition. On the other hand, if huge projects on mass digitalization for the next years come into effect, it fits well in with cold storage as the original objects seldom will have to leave the repository. And last but not least, the staff working in the repositories may not feel comfortable if the temperature is low.

From evaluation of the advantages and disadvantages related to cold storage and mass deacidification, the Conservation Department recommends that the library in the future only focuses on developing the capacity to store the collections in a colder environment as mass deacidification neither is an ethical nor economically competitive method. From our cost estimations it is clear that cold storage is by far the most cost effective means to prolong the lifetime of The Royal Library´s collections. The decision to opt out of mass deacidification to preserve large amounts of acidic paper must, of cause, continuously be evaluated as conditions changes.

The Royal Library has already begun on improving the climate in repositories, to extend the lifetime of our collections. In 2007 we started using our new repositories in Njalsgade 112 with an average of 12º C and 45% RH where we expect the remaining lifetime to be quadrupled. And we are now engaged on plans to get a very cold repository when we again will have to expand the number of lm around year 2018.

Author

Birgit Vinther Hansen
The Royal Library, Preservation Department
Lergravsvej 59
2300 Copenhagen S
Denmark
e-mail: bvh@kb.dk

References

[1] ”Bevaring af surt papir i de statslige samlinger”: Netpublikation udgivet af Styrelsen for Bibliotek og Medier, 29. december 2008 på www.bibliotekogmedier.dk/publikationer/

[2] Pedersen, H.P.: ”Kilder til nogle Jydsk-Fynske Papirfabrikkers historie ca. 1795 – ca. 1850”. Konservatorskolen 1996, s. 50

[3] Dąbrowski, J., “Aspects of Technology and Market Forces in the Story of Permanent and Durable Papers.” In IPH Congress –book 15/2004, p. 117-134.

[4] Drott, M.C., „Random Sampling: a Tool for library Research”. College & Research Libraries 30, 1969, s. 119-125.

[5] ”Resultater af masseafsyringsudvalgets stikprøveundersøgelser i Det Kongelige Biblioteks, Statens Arkivers og Statsbibliotekets Samlinger”. Report written by The Royal Library’s Preservation Department, June 2007.

[6] Kolar, J (oral presentation), “Predicting the Future: Estimating Future Conditions from Past Trends” on the conference Advances in paper Conservation Reserach, 23.-24. March 2009 in London.

[7] Kolar, J (oral presentation), “Immediate and Long-term Effect of Deacidification Treatments (thermal ageing)” on the conference PaperDurability II, 7.-9. July 2008 in Slovenia.

[8] Balažic, A.; Habicht, S.; Smodiš, M.; Kolar, J. and Strlič, M, “Extending the Useful Life of Paper – Evaluation of the Effect of Various Preservation Actions” in Museum Microclimatees – Contributions to the conference in Copenhagen 19-23 November 2007, p 39-41.

[9] ASHRAE Handbook - Heating, Ventilating, and Air-Conditioning - Systems and Equipment, Chapter 21, 2007.

[10] BS5454:2000. “Recommendations for the storage and exhibition of archival documents”

[11] ”Udredning om bevaring af kulturarven”,2003. Kulturministeriet, p. 33

[12] ”Papierentsaüerung im Schweizerischen Bundesarchiv” from the conference ” Mass Deacidification. Today’s Experience – Tomorrow’s Perspectives”, 15.-17. February, 2006.

[13] The calculations can be found in appendix to [1]

Preservation of sponsored films

KARIN BONDE JOHANSEN

Introduction

Burmeister & Wain (B&W), East Asiatic Company (in Danish: ØK) and Carlsberg are among the companies, which have deposited their film at the Danish Film Archive. This paper highlights a group of films, which I call sponsored films. They might also be known as industrial films, or non-theatrical films. They often present a company or an organization. They often put forward a certain message, and, directly or indirectly, advertise for their sponsors, however, not in the way of a traditional commercial. Sponsored films have been produced since the beginning of film history, but most are concentrated in the 1940s and 1950s. They are still produced today, primarily for the Internet.

There is today a great focus on digital communication of cultural heritage. In a digitization project soon to be started by the Ministry of Culture in Denmark, moving images will be included. Traditional documentaries will presumably form the main part in this project, but also some sponsored film will be included; probably the non-profit films sponsored by the government or other public institutions (sometimes called propaganda films). These films have been hidden on the shelves a long time but there is now a great desire for communication of these films.
It is important, however, to remember that whether the films are digitized or not, digitization alone is not a durable preservation of the film.

In the following I will discuss problematic film formats and advantages and disadvantages of digitization with a special focus on sponsored film, however, the majority of these problems are also valid for other short films and documentaries.

About the sponsored films

Sponsored films are important historical documents. They represent opinions, places, actions and languages, even though this was not the original intention by the sponsor company. In many cases the film director was just told to put forward a predetermined story. But in some cases the director got free hands, and these films may be of as high an artistic value as many non-sponsored films [1].

The sponsored films have not been given much attention in film history, and they are often treated as second-rate films. That might be due to the fact that they are often a mix of commercials and real documentaries. Traditional commercials (under 1-2 minutes) are not included in this category of sponsored films.
Examples of sponsored films are: Tourist films made by tourist associations, educational films and instructions for manufacturing processes, or films produced by a public organization.

See examples of Danish sponsored films in Figure 1.

- C - a corner of Zealand (C - et hjørne af Sjælland), 1938, directed by Theodor Christensen and Karl Roos. Sponsored by the Tourist bureau of Holbæk.
- 7 mill. horsepower - A film about Burmeister & Wain (7 mill. HK - en film om B&W), 1943, directed by Theodor Christensen. Sponsored by Burmeister & Wain.
- Mayday-mayday-mayday (Mayday-mayday-mayday), 1965, directed by Henning Ørnbak. Sponsored by Ministry of Defense (Forsvarets Oplysnings- og Velfærdstjeneste).
- Guilty – not guilty (Skyldig – ikke skyldig), 1971, directed by Jørgen Vestergaard. Sponsored by The Agriculture Information Office (Landbrugets informationskontor).
- A patient with jaundice (En patient med icterus) 1981, directed by Flemming Arnholm. Sponsored by Leo Pharma (Løvens Kemiske Fabrik).
- The blue Denmark (Det blå Danmark), 2004, directed by Henning Mouritsen and Lars Feldballe Petersen. Sponsored by The Danish Maritime Fund

Figure 1: Examples of Danish sponsored films.

Problematic issues

Collection and registration

Today no overall registration of Danish produced sponsored film exists. Some companies have deposited at the Danish Film Archive, others have not. In the Film Archive the film may be registered, but not necessarily identified as a sponsored film.
One of the problematic issues of preserving sponsored films is to locate originals. In many cases no original negatives or reversal [2] films exist, and a used screening copy might be the only material left. Sometimes the screening copy was only produced in a limited number, which makes the chance of survival even lesser.

Especially in the case of sponsored films, the originals were often located within the company itself. Many companies do not see their film production as important cultural heritage, and there is a big risk that the materials are thrown away or forgotten in the basement.
Analog acetate films on 16 or 35 mm can survive many years in a loft or in a cellar, but a much bigger problem is the survival of the new sponsored films which are only digitally produced. They might be stored on an old computer or on an out-dated tape format.

In Denmark only some companies or institutions have deposited with the Danish Film Institute, and even so it is mostly the oldest material, the nitrate films, which is being deposited.
Besides the collection of originals, some materials and different formats cause particular problems in long-term preservation.

In order to understand the problematic materials and film formats, it is necessary first to describe the preservation methods:

Preservation methods

Analog printing: analog printing is traditional photochemical printing, where an image is exposed from one film to another. Typically, a 16 or 35 mm film, either made of nitrate or acetate, will be printed on new polyester film. Analog printing is the only preservation method which is considered the "correct method" from a conservation point of view. This is because it is the only method where we know for sure that the new film materials can be preserved for more than a hundred years.
Digital scan: transfer of the film stock into digital files of very high resolution, such as 2K or 4K (2K is approx. 2048×1536 pixels and 4K is approx. 4096×3072 pixels per frame). The file can either be saved on a hard disc or on a digital tape. At the Danish Film Archive digital tapes, such as Digital Betacam or HDcam-SR are used. Digital Betacam tapes have an expected lifetime of 10-15 years.

Nitrate film

Cellulose nitrate was the main film material used for all cinema films until 1950. Due to fire risk it was replaced by cellulose acetate. Nitrate films are also called celluloid films.
When a nitrate film degrades, the process is irreversible and devastating [3]. It is therefore important to print the film before the degradation begins. We do not have any "early warning" to tell us when it is time to print a nitrate film, and it is normal practice to make new polyester prints or negatives of all nitrate films. Since the 1960s an ongoing printing of the nitrate films has been taking place at the Danish Film Archive. This printing effort was for many years concentrated on Danish feature films. Sponsored films on cellulose nitrate have been printed over the years as well, but the amount is small and selection was made without a general policy on the subject.

Considering that the registration of the sponsored films is not complete and that the golden-age of the sponsored films (1940s and 1950s) was during the nitrate period, there may still be many non-preserved sponsored films only existing on cellulose nitrate material in the Danish Film Archive.

A & B rolls

In the 1970s a particular method, the A & B rolls, was used when printing 16 mm negatives or reversal films, which, however, gives technical problems today.

In the case of A & B rolls the different scenes of the film is alternately divided on two rolls (in some cases even on three rolls, the C-roll) with black leader in between the scenes. When printing, both rolls are running, but when the first scene from roll A is printed, the light is restrained by the black leader on roll B, and when the second scene from roll B is printed, the light is restrained by the black leader on roll A, etc. This method permits double exposure in printing, and gives the impression of one scene dissolving into another. Furthermore it eliminates the appearance of film splices on the screen.

The method was used for the majority of documentaries starting in the mid 1960s, and peaked in the 1970s until video became common in the 1980s. In the 1980-90s the method was only used to a lesser extent.

The problems with A & B rolls are due to the fact that laboratories and staff members able to handle these films are now decreasing in number. Another problem is high expenses both when is comes to analog printing but especially digital scanning.
To perform a digital scan of an A & B roll it is necessary to scan both rolls separately and after that manually mix the scenes together. Depending on the number of scenes, it can be more than 2 or 3 times more expensive compared to film stock not divided into A & B rolls.

Due to the highly elevated scanning prices for A & B rolls, there might be a risk, that a screening copy is used instead. A screening copy will often be worn with scratches and with missing frames and digital scanning of screening copies also give pictures with fewer details, less sharpness and higher contrasts. The result will therefore be much poorer compared with scan from the original A & B rolls.

What can be done?

First of all, it is essential to establish a general overview of the majority of the sponsored film, and to identify them. Companies may be asked if they have film materials, new or old, which they want to inform about to a common registration guide. Preferable, they can donate the materials to the Danish Film Archive.

The sponsored films already in the Danish Film Archive must be properly identified and catalogued as sponsored films.
When a general overview has been made, film material must be preserved and/or communicated. There may be three possible scenarios:

1: All (or some) sponsored films are printed.
2: All (or some) sponsored films are digitized.
3: All (or some) sponsored films are printed and digitized.

There may also be a fourth scenario, where nothing is done. That is of course not desirable. Some nitrate films will decompose and be lost forever. The A & B rolls will not be lost, but it might be difficult to print these materials in a sufficient quality. The risk that screening copies are used will be even higher with bad image quality as result.

In order to be able to choose the right scenario or perhaps a mix of two scenarios, the cost, advantages and disadvantages for both methods must be taking into account.

Costs

In table 1, prices for printing or scanning of one hour of original film are listed. An extra fee is imposed on handling nitrate film both in the printing and scanning laboratory due to the fire risk and problematic degradation. Printing 35 mm films is more expensive compared with 16 mm films because more film material is needed. One hour of 35 mm film requires 1700 meter film and one hour of 16 mm film requires 680 meter of film.

The prices are valid for printing or scanning of one film; in the case of bigger amounts of film, it might be possible to get a reduced price.

Registration, collection of film and clarification of copyrights are not included in the prices.
The high prices for digital scanning of A & B-rolls is due to the fact that it is necessary to manually adjust together the alternately scenes. This increases the lab time needed. The price for digital scan of A & B rolls highly depends on the number of alternately scenes and is therefore variable.

Table 1: Comparably prices for analog printing and digital scanning. Prices are inclusive of ultrasonic cleaning, 2 hours of preparing, and sound to film or video. Analog printing includes one hour of 16 mm polyester duplicate positive [4] and one release print [5]. Digital scanning includes one hour of film at HDcam-SR-tape [6].

One hour of original material	Analog printing EUR	Digital scan EUR
Nitrate negative, 35 mm	11,650	3,450
Acetate negative, 35 mm	9,600	2,700
A + B rolls, 16 mm	3,900	5,550
Negative or reversal film, 16 mm	3,700	2,360
Screening copy, 16 mm	-	830

The low price for scanning a screening copy is due the fact that it is already graded and no sound mastering is required afterwards. Grading is adjustment of the overall density and color balance. In the case of original negatives every scene must be graded, so the light in the film looks even though the whole film. The sound from a screening copy can be transferred to the tape in the scanning process, where sound to original film materials must be transferred afterwards.

No price is given for analog printing of 16 mm copies due to the fact the image quality will be quite low and it is rarely used.

The prices for printing 35 mm nitrate and acetate negatives are more than three times higher than the price for a digital scan. The price for printing 16 mm negatives or reversal films is one and a half times higher than of a scan, but when it comes to A & B rolls, digital scanning is more expensive than analog printing.

Advantages and disadvantages

When speaking of communication and/or preservation of film, the choice between printing analog film material and digitization is often discussed. In Table 2 some of the biggest contrasts are listed:

Permanence

The most alarming difference between analog printed preservation materials and digitized films is the expected lifetime of the material. 35 or 16 mm polyester film can be preserved for centuries if stored correctly [7]. Long-term preservation of digitized films on the other hand is combined with massive problems. Preservation of digitized films must deal with the durability of tapes (tapes must be converted every 10-15 years), access to and functional play-back machines, updated software and functional and compatible computer hardware.

Costs

In Table 1 prices for both scenarios 1, 2 and 3 are listed. But the prices in Table 1 are only today's expenses.

If the films are only digitized (scenario 2) a preservation plan for the digitized information must be worked out. Preferable, the digitized information must be stored both on tapes and on hard discs. It is extremely difficult to predict the cost for digital storage. Calculations between 6666 EUR (50,000 DKK) and 533 EUR (4000 DKK) for one terabyte (=one hour of film) per year have been suggested [8]. The prices for digital storage also depends on the size of the digital archive, if the data is stored on two geographically separated discs and on backup tapes, how metadata is handled, conversion plans, etc.

In comparison the cost for storing analog film material in cold storage for one hour of film a year is approximate 15 EUR (about 100 DKK) [9].
Whatever the prices for digital storage are going to be, the expenses compared with storage of analog films will be astoundingly high.

Availability

The data in analog film material will always be available independent of technology. The pictures can be seen with the human eye, and it will only require a minimum of engineering skills to screen the film. Digitized films will always demand complex and high-technology play-back machines.

Resolution

Another issue, which is often being discussed in connection with digitization, is image resolution.
Digitization is expensive and it is therefore important to digitize in a resolution, which will also meet future demands.

35 mm negative films are still the media, which have the highest resolution; it is possible to separate 6000 lines in one picture. A HDcam SR tape the number of lines is 1080 [10]. Today, digitization

Table 2. Advantages and disadvantages between analog preservation materials and digitized films.

	Analog film		Digitized film	
Permanence	Long-term preserved, > 500 years in cold storage	☺	Not preserved more than 10-15 years	☹
Costs	High expenses today, but low in the future	☺	Smaller expenses today, but high expenses for conversion and storage of data in the future	☹
Availability	Low-technology Data always available	☺	High-technology Availability of data uncertain	☹
Resolution	Pictures with high resolution	☺	Pictures with lower resolution depending on scan and media	😐
Technology	Out-dated? Analog film material might not be produced in the future	☹	New technology But the future for digital formats is uncertain	😐
Fashion	Not in fashion And not followed by funding	☹	In fashion and followed by funding	☺
Accessibility	None or almost no accessibility	☹	Great accessibility, if distributed on the Internet	☺

using 2 K resolution (2000 lines) is counted on as an acceptable resolution. One hour of a 2 K scan takes up one terabyte.

Technology

Not all conditions, however, are in favor of analog film preservation. The production of 35 and 16 mm film material may simply end, which will close down analog film preservation altogether.
On the other hand, even though digitized films deal with new technologies, there are no guaranties that for example tapes, play-back machines or software will be produced or supported in the years to come.

Fashion and accessibility

Producing analog preservation materials is not fashionable today, and it is hard to get financial support for it. In comparison with digitization it is understandable, when considering the possibilities, which digitized films give. Digitization of film allows for easy accessibility and incredibly wide possibilities for increasing the knowledge of cultural heritage worldwide.

Preservation plan

Scenario 1:

If the sponsored films are printed, they will be preserved in the long term. But they will not be easily accessible and it will only be possible to view the films in the cinema.

Scenario 2:

If the sponsored films are only digitized, we can not ensure long-term preservation of the materials. We will encounter massive problems in dealing with digital storage, preservation of tapes and playback machines etc.

Scenario 3:

In the case of both analog printing and digitization, the films will both be preserved in the long term and accessible. This is the preferable solution, but also incredibly expensive.

If no financial support can be found for scenario 3, a mix of scenario 2 and 3 may be an acceptable solution. The best and most interesting film must of course be printed and preserved on analog preservation materials and they must be digitized and afterwards communicated though the Internet if the copyrights allow it. All sponsored film on cellulose nitrate must be carefully selected and all worthy of preservation must be printed.

In the case of materials of lesser interest, part digitization may be a solution. Examples could be digitized as an appetizer with the possibilities for further digitization and preservation if funding is raised.
It is obvious that if the sponsor company still exists, they might be interested in supporting the preservation of their own films.

A preservation example

In 2008 at the Danish Film Archive a sponsored film was preserved and communicated though Danmarks Nationalfilmografi at the Danish Film Institutes website: www.dfi.dk.

That was the case with the film *Brødrene Dahl Filmen* from 1942, directed by Karl Roos.
Brødrene Dahl is a Danish plumbing wholesaler, which has existed since 1867.

The company contacted the Danish Film Archive in order to investigate the possibilities of transferring the film to DVD. They wanted to use the film for a private company museum and for meetings and conferences.

This film and four other films from the company were donated to the Danish Film Archive in 1972 and 1974.

For this particular film title the archive holds several different film materials.

- Original negative, 35 mm nitrate, black/white, 6 reels.
- Sound negative, 35 mm nitrate, 6 reels
- Copy, 35 mm nitrate, black/white, with sound, 4 reels.
- Original negative and sound negatives, extra materials or cut offs, 7 reels.

The material was collected from the nitrate film archive and examined. It was found that the copy was not complete as reel no. 1 was missing due to degradation.

Therefore, the only complete existing material was the original negative, and it was decided to include the film in the ongoing preservation program at the Danish Film Institute. That means that the original negative including the sound negative was sent to Haghe film in Holland, which is the printing laboratory that performs analog preservation materials for the Danish Film Archive.
At Haghe film three preservation materials were made: A duplicate positive, an answer print [11] and a release print. After return of the materials to Denmark, the release print was sent to Nordisk Film - Short Cut, for digital scanning.

The Danish Film Institute paid for the production of the analog preservation materials, and the company Brødrene Dahl paid for the digital scanning. Brødrene Dahl gave permission to the Danish Film Institute for releasing the film on the website.
In table 3 the time scale and prize for one preservation example are shown.

Table 3 shows that “the full preservation package” cost app. 18,400 EUR (138,000 DKK) for one film at 64 minutes.

Conclusion

In order to ensure long-term preservation of the sponsored film, there are far more advantages in making analog preservation materials compared to digitized tapes or files. But the analog preservation materials are also far more expensive to produce compared with digitized information. On the other hand, the cost for proper storage of digitized information can be far more expensive in the future.

Sponsored films were often produced onto problematic materials and film formats, which may result in loss of films or inappropriate preservation if nothing is done. Nitrate films may be lost due to degradation, and films divided into A & B rolls may either not be printed in a sufficient way or a screening copy with low image quality may be used for digitization instead of the original material. This is due to high prices of digital scanning of A & B-rolls.

The sponsored films must be properly collected and registered, and the most important and interesting sponsored films must both be printed and digitized to ensure preservation and accessibility. Less important films may only be digitized, but afterwards used as an appetizer in order to collect further financial funding for producing analog preservation materials and further digitization.

Sponsored films are cultural heritage and tell histories not told anywhere else. Hopefully, future digitization projects will give new life to the sponsored films together with many other short films and documentaries.

Table 3 "The preservation route" from nitrate film to DVD and Internet.

Date	Action	Price - EUR
February 2008	Application from the company	
March 2008	Going through all film material 8 hours	265
Summer 2008	Included in the preservation program	
	Shipping to Holland	200
	Analog printing. A duplicate positive, an answer print and a release print was produced	15,600
	Shipping to Denmark	200
October 2008	Release print was digital scanned to Digital Betacam tape	770
March 2009	Release to web, 2 hours	65
	Administration	1333
Total		18,440

Author

Karin Bonde Johansen
Danish Film Institute / Film Archive
Naverland 13
DK-2600 Glostrup
Email: karinbj@dfi.dk

References

General information:

Prelinger, Rick (2006) The Field Guide to Sponsored Films, National Film Preservation Foundation, San Francisco, California, 140 pp.

Notes

[1] A famous example is "Danmark", 1935, directed by Poul Henningsen. The film was sponsored by the Ministry of Foreign Affairs, and Poul Henningsen was allowed a free hand in the film production. See more: www.dfi.dk, Danmarks Nationalfilmografi, search for "Danmark" (The webpage for The Danish Film Institute will be changed in Spring 2009, and therefore exact addresses cannot be given).

[2] Negatives and reversal films are both originals. Negatives give inverse images after development, where reversal films are developed to a positive image. Se more about reversal techniques at http://en.wikipedia.org/wiki/Kodachrome or in Matthews, G.E. & Tarkinton, R.G. (1955) Early History of Amateur Motion-Picture Film, Journal of SMPTE 64, p. 105-116.

[3] See pictures of degraded nitrate films: www.dfi.dk, search for "Billeder af nedbrudte nitratfilm"

[4] A special low contrast copy direct from the original negative

[5] The final screening print

[6] See more about different tapes: http://en.wikipedia.org/wiki/Betacam

[7] Read more about the outstanding advantages of cold storage in: Adelstein, P. Z., Reilly, J. L., Nishimura, D. W. & Erbland, J. (1992) Stability of Cellulose Ester Base Photographic Film: Part II – Practical Storage Considerations, *SMPTE Journal*, May, pp. 347-353.

[8] From internal work paper: Teknisk rapport om digitalisering af kulturarven, curator Thomas C. Christensen, Danish Film Institute.

[9] Calculated from power consumption etc. in the Danish Film Archive vaults.

[10] http://en.wikipedia.org/wiki/images_resolution

[11] In this case a copy from the original negative. Answer prints are used to control the printing of the release print.

Modern cultural heritage; an area of research at the Swedish National Heritage Board

Gunilla Lagnesjö

Abstract

The Swedish National Heritage Board conducts research within the area of modern cultural heritage. This recently resulted in the publication of two major projects, one deals with objects made of metals and the other with plastics. Both studies include a historical material and manufacturing survey, analysis of materials and recommendations for preventive conservation.

Introduction

Since the late 20th century the cultural heritage sector has focused on the changes in society making the transition from the last decades of the industrial society towards a more unknown digital future. These processes and new ways of lifestyle are of significant interest and of high priority for the museums, and as noteworthy as the changes in the agricultural society towards the industrial epoch of one hundred years ago. Remains of industrial sites, existing factories and expressions of social life are being documented as well as the objects produced in the industries. The mass-produced household utensils constitute a large group of objects, which has often been overlooked as an important carrier of a variety of different aspects of cultural history such as industrial development, production and everyday life.

Before the industrial revolution, skilled craftsmen produced most metal household utensils manually. Pure metal or well-known alloys and techniques were used. In the middle of the 19th century the production changed in a significant way. New manufacturing processes like casting, pressing and stamping were introduced. Even the mining techniques developed and the extraction of metals was made easier and cheaper and a manifold of new alloys were introduced. Some techniques and alloys were "experimental" and in use for just a short period.

One hundred years later, after the Second World War, a new interesting period for the production of everyday household objects begins. The introduction of plastic objects takes place. Various plastics had already existed for quite some time, but this period marks its real break-through. Due to the wide range of uses the versatile new material plastic now makes its way into practically every home. This early period is also filled with experimental work and unique materials being produced to exist only for a short period of time. Today many of these materials present serious problems with regard to preservation.

Today we find collected objects from these productions in small local private museums as well as in the large national museums. These mass-produced objects, made from metal and plastic, just like many other everyday objects, had received fairly little attention until a group of conservators with responsibility for storage and preservation at the museums in Sweden undertook the initiative to raise the awareness and knowledge about these types of objects.

Among many important missions the Swedish National Heritage Board (Riksantikvarieämbetet) has the opportunity to support, initiate and conduct cross-disciplinary research projects. The aim is to find out more about what cultural heritage communicates and how it develops. Currently the research program focuses on three major subjects; site and tradition, landscape and history, and modern heritage [1].

Two projects dealing with mass-produced objects were proposed under the heading "Modern Heritage".

The scientific committee considered it worthwhile to initiate studies of these often neglected groups of museum objects. The work has resulted in two reports: ”Bevarande av industriellt tillverkade bruksföremål i metall” (Preservation of mass-produced metal utility goods) and “Plast. Morgondagens kulturobjekt.” (Plastic. Cultural heritage of tomorrow). [2]

Preservation of mass-produced metal utility goods

The result of the project is presented in a report which covers the following subjects: metal composition, methods of manufacturing, surface treatment and damage. Recommendations for cleaning and storage of these objects are also summarized.

Metal content in the mass-produced objects

The metal survey focuses on material science and production technique with a certain interest in metal coatings.

Six groups of materials have been examined; electroplated nickel silver [3], metal alloys based on copper [4], tin and lead, zinc, aluminium, iron and steel. Approximately 200 objects were analysed. Their metal content has been identified using a scanning electron microscope equipped with a unit for X-ray microanalysis [5]. The results are presented in well arranged tables where the percentage quantity of the different elements Ag, Cu, Zn, Sn, Pb, Fe, Ni, Cr and Al are listed. It is interesting to note that lead and cadmium, which can be poisonous, are quite frequent in the alloys. It is also clear that it is impossible to judge the metal content from ocular investigations. You have to use an analytical method.

The thickness of the metal coatings [6] has been measured to study differences on individual objects as well as to look for differences related to production period. [7]

Damage on mass-produced metal objects

Different types of damage that are, or tend to be, typical have been identified.

The first critical cause of damage is production. Many processes demand a high technical knowledge about how the metals behave, and mistakes might have occurred when new techniques were introduced. The metal is exposed to several physical and chemical processes from the raw material state on its way to a finished metal object. Typical damages are cracking as result of stress in the material. The cracking can be seen on flat surfaces as well as on projecting parts, such as handles. Another problem is that several parts have often been put together using lead soldering. After many years of use the joints tend to break down. Vessels will leak and the objects will fall apart.

The second cause of damage is inherent factors in the metal. Some metals have impurities that can cause spot corrosion. Tin is sensitive to low temperature and tin pest can be seen in the soldering joints and on objects that have been kept outdoors or in non-heated indoor places during winter. Iron is sensitive to corrosion, which is especially complicated to treat when the iron has some kind of metal coating.

The third cause of degradation is damage related to use and wear. A common phenomenon is “golden” spots on electroplated nickel silver were the silver coating has disappeared through wear. Flaking and cracks in the coatings may be seen. Too much or too little cleaning may also cause damages. Shiny objects have been polished with different products containing various fillers and chemicals. Residues are often left and can initiate corrosion. And finally deformations due to use and improper storage have been seen.

To keep shiny objects shiny

Every proud housewife has traditionally aspired to have a kitchen filled with shiny kettles, vessels and other household objects. To keep them in that condition requires washing and sometimes even polishing. In many museums the objects even today need to be polished before exhibition.

For this reason, an investigation was carried out on 16 different commercial polishing products. The active ingredients were identified and a controlled polishing test was performed. The result differed greatly depending on the product tested. To achieve the same result you needed to "rub" as little as 25 times for the worst product and as much as 900 times for the most gentle.

Storage and care of mass-produced metal household utensils

This part of the report gives useful information to non-professional staff and volunteers in their practical work. The recommendations follow normal guidelines for storage of metal objects in museums. The objects should be clean and kept in a "clean" and dry environment. They must be stored spaciously and handled with care. Advice of what not to do as well as recommendations for the use of carbon cloth and polyethylene plastic bags for certain objects are given. If these recommendations are followed we will be able to preserve a most interesting piece of our heritage reflecting all the "little things" that were produced for domestic use in the era of the industrial revolution in Western Europe.

Plastic, the cultural heritage of tomorrow

The second project dealing with mass-produced objects is devoted to plastics. During the last 50 years plastics has in many ways replaced the metal alloys that were used earlier, in mass-produced everyday products, for the household. Plastics are in many ways a functional and versatile material that can be shaped and formed into almost anything. The project has dealt with the following subjects: history of materials and production, analysis and identification of plastics, state of the museum collections, preventive and active conservation and is presented in a report.

Plastic – an endless variety of monomers and fillers

Plastics can be divided into three main groups; thermoplastics, thermosetting plastics and elastomers. Their behaviour and appearance can be varied through the use of different additives. It is complicated to identify plastics and the monomers of which they are constituted. A few simple tests are recommended which can give a quick classification of the product.

To give an appropriate identification advanced technology is needed, as well as good reference systems. In this study over 600 objects have been examined with an infrared spectrometer, ATR-FTIR [8]. The results have been collected in a database for future use [9]. A review of relevant literature has been conducted and a technical introduction to the most common types of plastics is presented.

Damage to plastic – a complicated issue

The plastic materials that are used in everyday household utensils are seldom designed to have properties that make them last forever. A variety of damages occur, both chemical and structural. Many "new materials" have been tested during the last 50 years, and quite a lot of them are not stable to long-term storage. This is a challenge for the conservators today. The objects are often rare and represent a lot of information about the industrial production from the 20th century. This is a growing problem definitely connected to all industrial mass-production. Today it might be even more complicated to find out how, and of which monomers and fillers the objects are produced, when the factories are often on the other side of the globe.

A special problem in the museum collections is the emission of volatile components that can infect and migrate into nearby objects. Objects that have been in use and are worn have more damage than non-used objects. Composite objects of plastic and metal are often damaged because of the catalytic effect of metals causing deterioration. Damage is also frequent on objects made of polyvinylchloride (PVC), polyurethane (PU) and cellulose derivatives. It is stated that the thermosetting plastics are generally more stable than the thermoplastic.

Storage and care of household utensils made from plastics

Like all museum objects, plastic materials should be kept in a dark, clean and stable environment. However, compared to most objects, plastics need even more attention and care than this.

Generally plastics should be stored at a low temperature (5° to 10° C), and in certain cases even

DSCF 1304
Preservation of mass-produced metal utility goods
Photo; Swedish National Heritage Board

below zero degrees centigrade to slow down chemical processes. Objects that can be expected to emit volatile gases must be kept separate and have good ventilation. Storage in non-oxygen environment can be an option for some types of plastics. This can be accomplished with AgeLess systems or special showcases containing an inert gas.

To sum up, storage of plastics is complicated and demands special knowledge from the storage manager. It is also expensive because of the technical equipment, space and skilled personnel that are needed. We might also establish the fact that it is a rapidly growing problem, since plastics are the most common component in modern objects that are acquisitioned to the collections of cultural history museums.

Conclusion

Collections of household utensils are large and common at nearly all cultural history museums, ranging from local historical houses to national museums. They tell us a lot about everyday life, production systems and changes in society. We may find the same objects made of different material, for example a plate made of wood and another made of metal or plastic, all with similar shape and use, but produced under different circumstances at different times. In many cases they have been so obvious and common that they have been disregarded as having interesting potential for scientific use, and neglected in the collections.

The Swedish National Heritage Board has conducted two projects to raise awareness, as well as assemble and disseminate knowledge about this important part of our cultural heritage. The aim is to provide better requirements for the preservation of mass-produced household utensils. The work has also raised awareness of the extensive problems expected

DSCF 1305
Plastic. Cultural heritage of tomorrow
Photo; Swedish National Heritage Board

in the future for the preservation of objects made of plastic and the need to take part in international research and projects in this field.

Author

Gunilla Langnesjö
Riksantikvarieämbetet /
Swedish National Heritage Board
Box 1114
621 22 Visby
Sweden
gunilla.lagnesjo@raa.se

Notes

[1] För en kritisk & konstruktiv kulturmiljöforskning. Red. Anders Högberg. 2006

[2] “Preservation of mass-produced metal utility goods” Slutrapport för FoU-projektet Bevarande av industriellt tillverkade bruksföremål i metall. Material, tillverkning, skador, rengöring och förvaring. Rapport från Riksantikvarieämbetet 2005:1 Anders G. Nord, Kate Tronner och Annmarie Christensson med bidrag av Hubert Hydman, Kerstin Jonsson och Einar Mattson.
”Plastic. Cultural heritage of tomorrow” Plast. Morgondagens kulturobjekt. Projekt för bevarande av plastföremål. Terminologi, analys, skador, nedbrytning, förvaring. Anders G. Nord och Kate Tronner. Medarbetare: Karin Björling Olausson, Maria Franzon, Mats Johansson, Kerstin Jonsson, Katarina Lampel, Einar Mattsson, Christina Tegnér. Riksantikvarieämbetet 2008
Both reports can be ordered from “bokhandeln” www.ra.se

[3] Nysilver

[4] Koppar, mässing, malm, brons

[5] LEO 1455 VP scanning electron microscope, equipped with a LINK/Oxford unit for X-ray fluorescence spectroscopy

[6] Metal coatings applied with electrolyte techniques. (Försilvring, förnickling, förkromning, förzinkning).

[7] The investigation method is published in Studies in Conservation. Nord & Tronner: Studies in Conservation vol. 45, s 274-279, and Tronner, Nord, Sjöstedt & Hydman: Studies in Conservation vol. 47, s 109-116.

[8] Perkin-Elmer ATR-FTIR Spectrum One

[9] The results are stored in an IR spectra database at Riksantikvarieämbetet, Förvaltningsavdelningen

Developing a policy and procedure for selecting & operating historic objects from the collections of the Science Museum, National Museum of Science & Industry, UK

Martha Leskard

The Ethics of Operation: The Science Museum Perspective

In 1989, Peter Robert Mann, then Curator of Transport at the Science Museum, wrote a paper for the International Journal of Museum Management & Curatorship, vol. 8, entitled "Working Exhibits and the Destruction of Evidence in the Science Museum". The purpose of his paper was "to try to explain why it is that so many curators of technical artefacts, particularly transport artefacts, subscribe to the ethic of the museum profession that their duty is to preserve evidence, yet devote much of their professional lives to the destruction of that evidence."[1] Mann produced a historical survey of the policy and practice of sectioning and operating artefacts at the Science Museum in order to clarify the issues of demonstration. He found that the museum had probably been operating objects longer than any other museum in the world and that sectioning and operating objects had been a deliberate decision; the museum was proud of this *ad hoc* policy and had extended it to include not only objects from the engineering collections but from all areas so that, by 1989, all galleries had sectioned or working objects of some kind. The intent behind this approach was to make the objects more understandable to the public; this interpretive technique was entrenched within the museum. The Science Museum had seen its primary objective as explaining how things work rather than in maintaining an encyclopaedic archive of objects.

The issue as Mann saw it was not with being the "National Museum of How Things Work" [2] but with the fact that the museum had never had a cohesive approach to selecting and operating historic objects from the collections. The choice of objects selected appeared to be a random assortment of new, old and prime objects. Cumulative damage was allowed to occur until any sense of originality or evidential evidence was gone. Objects survived better than might be expected only because of the lack of resources required to operate them more than occasionally and because many decades of operation could be required before significant deterioration would occur. Guidelines governing use had not been written and so curators with individual responsibility for certain operating objects acted independently, making unilateral decisions about which objects should be used and which retired. Mann felt it was time to stop agonising over the ethics of operating objects and concentrate on working out the circumstances in which it was appropriate to operate in order to achieve the objective of the museum. The appropriate balance between medium-term needs of exhibition and the long-term needs of preservation needed to be established and the practical problems dealt with.

The Guidelines for Operation: the Pragmatic Approach

In the early 1990s, Anne Moncrieff, head of conservation for the Science Museum noted that "Industrial collections present a difficult challenge in finding a balance between the ideal and the possible: between the preservation of physical material and function and technology and between conservation and restoration." [3] She based her approach to working objects and the problem of the loss of physical evidence through replacement, restoration and wear on the work done by Peter Mann, amongst others, acknowledging that there was no "nice comfortable middle road, a compromise, on which everyone could agree" [4] but that open discussion, thinking through all the options before any interventive treatment of an object took place, was the responsible way forward. "Ideally all the options should be explored by a team of conservator, curator and if possible a Devil's Advocate."[5]

A restoration approach for some objects, where the gain in information outweighed the loss of evidence or where the evidence was preserved in another similar object, was advocated by Moncrieff and continued by Suzanne Keene, head of collections care. They recommended selecting new objects for operation on a case by case basis, letting the importance and condition of the object and the quality of the evidence for an earlier state guide the decision, with restoration matching the quality of the original. In addition, Keene conducted a survey of the already working machines in the Science Museum and found that, out of 140 objects, only 2 were in such condition that they needed to be removed from operation. It was felt that the rest should continue to be operated; since a decision had already been made historically to compromise the primary evidence, losing the function as well would render the object valueless. A maintenance programme and record-keeping system for the working objects was instituted; unfortunately, as this was only practice recommended but not enforced or carried out by the conservation and collections care section, the practice quite soon drifted to a stop. It wasn't until 2008 that a maintenance manual, training manual and working exhibits database was completed and fully integrated into the responsibilities of the metals conservator at the museum.

By 1997, the pragmatic approach to the conservation of scientific and industrial objects was well-entrenched at the Science Museum. In a paper presented to the Industrial Collections Care and Conservation conference held in Cardiff, 9-11 April 1997, Hazel Newey, now head of conservation, discussed the approach and how it appertained to working exhibits and replicas. While the Science Museum still had no written policy on the appropriateness of operating objects from its collections, the practice had not ceased, even if , in the intervening years, fewer objects than in the past were working exhibits. Poor maintenance, neglect and careless handling were less a factor for the decreasing number than the need for increased resources. "The resource implications of caring for industrial collections becomes higher than anticipated because of the cost of storage, maintenance and display." [6] Objects such as vehicles which required higher levels of maintenance in order to remain functioning as opposed to those such as models of engines gradually became static exhibits.

However, the decision-making process for selecting an object for operation had developed along the lines advocated by Mann and Moncrieff . Whereas once an iconic object might be chosen to be operated, as was the case for the *1888 Benz*, the oldest car in Britain, which was acquired in 1913, fully restored in 1957 and entered in the Brighton Run where it was damaged after running out of petrol and crashing into an MG saloon, the conservation in 1997 of the first petrol-engined motor car to run on British roads, the *1895 Panhard et Levassor,* produced a static exhibit with its original paintwork and engine condition revealed. The assessment of the extent of the 1997 conservation project was undertaken by curator together with conservator with the historic and iconic value of the object one of the primary criteria for final use.

The Guidelines for Operation: the Management Tool

By 2007, there were only 101 exhibits designated as working in the Science Museum at South Kensington. These were often historic models, with a number of full-sized engines, run on compressed air or mechanical drive. But only two vehicles in the collection remained in running order. These two, the 1904 Krieger electric Brougham and the 1958 Dennis F12 pump escape fire engine, stored at the Science Museum's large objects store in Wroughton, had both entered the collection in working order. The Kreiger came in 2003 on loan and the Dennis was acquired straight from owner in 2005. The conservation staff was made responsible for the maintenance and for the operation of the vehicles at the (very) occasional public openings of the site although the donor of the fire engine did arrange to return yearly at his own cost to do the maintenance overhaul and cleaning.

However, there was a certain amount of dissatisfaction at there being only two operating vehicles in the whole of the Science Museum's collection where, once upon a time, many had been operational. The then-curator of Transport had expressed an interest in 2006 in running some of the buses in the collections and senior museum management had requested the conservation manager at Wroughton to investigate the possibilities. A timely attendance at the BigStuff conference held in Bochum in 2007 offered the opportunity to hear from and to discuss with museum peers the current attitudes and approaches to working objects. During the lively proceedings in the workshop "Restoring to working glory; to work or not to work?" [7], Joanna Barr, Principal Conservator, Artlab Australia, gave a summation of her major research project for her master's degree: "The Conservation of Working Objects: Development of a Conservation Management Tool" [8] This conservation management tool had evolved over a number of years; the writing of it had been prompted by a request by the National Motor Museum of Australia for 'mothballing' a motorcycle. "Whilst this seemed to be the most appropriate option for this particular vehicle, Artlab felt that these sorts of decisions should be based on rigorous research, assessment and decision- making processes rather than the 'whim' of the current curator." [9]

The knowledge of this document, which was in the process of being altered from an academic paper to a type of user guide, prompted the decision to develop not only a process for running vehicles from the Science Museum's collection but to review the *ad hoc* approach to the selection and operation of any historic object from the collections and to formalise the procedures within a policy document.

The policy would reconsider the museum's past criteria for selection and operation and bring them into line with contemporary museum practice for exhibit risk management. In addition to taking into account the collection's care needs and the integrity of individual objects, there were the issues of limited resources, health and safety factors, including current regulations, and available skills. In order to assure a consensus of approach within those industrial and technological museums currently revising their own approach towards working objects, it seemed sensible to build on Barr's work, which was already being considered for use by a number of museums. Although unpublished at that point, she had generously shared her research and her document and this has provided the framework for developing our policy and procedures.

The Draft Policy

After reviewing all the conservation management literature cited by Barr as well as other papers already gathered throughout twenty years of conservation practice, researching existing related policies of both the Science Museum and other institutions and exhaustively reading Barr's document, a draft policy was produced. It was realised during the process that the policy of the Science Museum was to operate objects; all else was process for responsible operation and would be itemised in the procedures. So the policy itself was short and to the point:

"The Science Museum holds one of the world's pre-eminent collections in science, technology and medicine. These collections provide an unequalled record of the first and second industrial revolutions and beyond. They contain not only unique icons of international significance, but also the everyday items that show the impact of science on how human lives are lived.

As leaders in science communication and learning, the Science Museum remains committed to operating historic objects, recognising that the high levels of interest and the educational value in "working objects" make a meaningful connection between the museum's visitors and the collections.

The Science Museum's selection, risk assessment, and review processes are based on the tenets of the National Heritage Act, 1983, in order to ensure that working objects are used in a safe, secure and sustainable way, according to best practice, now and for the future, without compromising their physical, historical and technological integrity."[10]

The Procedures

Much of the groundwork for the selection criteria and procedures had been laid out by Mann, Moncrieff, Keene and Newey and the draft has built on this work, setting out the acceptable reasons for selection, the risk factors which must be considered for each proposal, the significance of the object and the use to which it is to be put and the constraints of operation, including resources, health and safety and current regulations. Structure for the procedures was based extensively upon Barr's Conservation Management Tool.

Selecting functions for display, educational and access purposes will be driven by an explicit evaluation of the significance of different functions. Operation will contribute to building individual and meaningful connections with science and technology through:

- adding to the understanding of function, purpose and significance
- showing the sensory aspects of sound, sight, feel and smell
- illustrating technological, social and/or economic change
- preserving significant function
- preserving or rediscovering traditional skills associated with the fabrication, operation and repair of working objects
- inspiring and sustaining an interest in science, industry, engineering, history and/or museums.

Risk factors which must be considered are:

- possible loss of historic information, including significant evidence of use, during restoration to working order
- potential replacement of original parts or alterations of original design for operational or health and safety reasons and regulations or through wear caused by operation
- potential difficulty in determining originality of parts or original appearance
- increasing unavailability of historic materials and craft skills making accurate reproduction of parts or appearance difficult or impossible
- potential deterioration of historic fabric caused by the substitution of modern materials and techniques
- potential deterioration of historic fabric caused by uncontrollable operational environments, particularly outdoors, or through accident, inappropriate use or abuse or insufficiently trained operators
- resources required to restore an object to working order may be insufficient to complete the project through underestimating needed allocation, escalating costs or project shortfall
- resources required to maintain and demonstrate the working object and to train the operators may exceed the return in benefit to the museum in terms of public interest or educational value.

An object may be proposed for operation through one or more of the museum's three functional streams - Creative Offering, Visitor Experience or Corporate Services - as all are stakeholders in the museum's vision to become the best place in the world to learn about and enjoy science. Proposals may also come from outside the museum, from other institutions, special interest groups or individual researchers.

Each proposal will be considered for:

- the object's cultural significance, which is the aesthetic, historic, scientific, social or spiritual value that it has for past, present and future generations. Objects which are considered icons, of incomparable significance, nationally important or rare will not be considered for operation as use is mutually incompatible with preservation of the whole.
- the significance of the object's function(s), including its alterations, repairs and modifications, if any. Any new use of an object will be compatible with original function with minimal change to fabric, respect of meanings and associations and continuation of practices which contribute to the cultural significance of that object.

- the object's current condition and state of preservation, the likely impact of wear to significant parts, the need to update to current safety standards and the requirement to remove hazardous materials and/or functions. Objects which are beyond their economic life (i.e. in a state of accelerated wear) will not be chosen for operation unless physical integrity is deemed insignificant in relation to significant function.
- the benefit to the public and to the museum, in order to inspire innovation, engage understanding, motivate learning or preserve the collections. The opportunity for potential research collaboration into aspects such as the history of technology, future industrial developments, deterioration of materials or methods of preservation will be explored.

Publicity, direct revenue generation, sponsorship attraction or special interest group gratification may be considered as supplemental reasons for proposal for operation but are not acceptable motivations on their own.

- the resources required for maintaining the functionality for both the short and long term. Money, time, facilities, equipment and skilled staff are required for treatments, maintenance and repair programmes. Thorough documentation including photography of all processes from decision-making to maintenance logs and handling requirements must be kept and be made accessible. Where resources cannot be committed to the long-term maintenance, repair and replacement programme, an object shall not be selected for operation.
- museum need in terms of frequency of operation and number of objects operating
- restrictions of museum context (available space, exhibit design, health and safety requirements).

The selection process itself closely follows the conservation management model produced by Barr with a curatorial, conservation and museum resource assessment, a written statement of significance which will be retained as part of the historic record of the object, preparation of conservation objectives which will best preserve the important features defined in the statement of significance and a treatment plan. The treatment plan will determine all the means required, including skills, equipment, materials, space, and present and future financial resources and will be entered as part of the conservation record of the collections database for the object. The approved treatment will also be retained as part of the historic record, as justification for the treatment may be required in the future. An Operating and Handling Guideline and an Inspection and Maintenance plan will be included in the Working Objects Database (WOD), developed while at the Science Museum by Efstathios Tsolis, now conservator at the National Railway Museum.

Responsibility for maintaining the entries in WOD will remain with conservation. Periodic reviews of each working object will be undertaken to determine whether an object will continue to be operated, whether the operation should be modified or whether the object is no longer suitable for operation.
Operation of an object will not be modified or altered without review.

The Guidelines for Operation: The Future

At present, the policy and procedures are still in draft form. They have been circulated to curatorial, conservation and documentation units at the museum and feedback has been collected. During the next two months, it is anticipated that a redraft will be written; there will be some reformatting as a result of the feedback. However, there will be very little content change - not totally surprising as much of the document reflects the past twenty years' considerations of the Science Museum's curators and conservation and collections care managers - but gratifying, none the less.

The redraft will be submitted to the Collections Group of the NMSI (the corporate organisation of the Science Museum, the National Railway Museum and the National Media Museum) and the Collections Development Committee for final review and sign-off. Once presented to the Board of Trustees of the Science Museum, it will be implemented; a review using the policy and procedures should then be made of all objects presently being operated before additional candidates are considered. This review will be used to evaluate the process, including the selection committee structure and the responsibility roles, and to determine whether the Working Objects Database is configured appropriately to support use. Current resource implications - money, time and personnel - will be defined by this review and that information used to inform future proposals for operational historic objects from the Science Museum's collections.

Author

Marta Leskard
The Science Museum at Wroughton
Redbarn Gate
Wroughton
Swindon
Wiltshire
UK
SN4 9LT
marta.leskard@sciencemuseum.org.uk

References:

[1] Mann, Peter Robert; "Working Exhibits and the Destruction of Evidence in the Science Museum"; *The International Journal of Museum Management and Curatorship* (1989) 8; pp. 369-387
[2] Mann; *op cit*
[3] Moncrieff, Anne; "Conservation of Industrial Collections" unpublished proceedings from "Standard Threads" workshop, International Institute for Conservation- Canadian Group (IIC-CG); May 1992
[4] Moncrieff; *op cit*
[5] Moncrieff; *op cit*
[6] Newey, Hazel; "Conserving Scientific and Industrial Heritage: A Pragmatic Approach"; *Industrial Collections Care and Conservation*, proceedings of the conference hosted by The Council of Museums in Wales and The United Kingdom Institute for Conservation (UKIC); 9-11 April 1997, pp.159-165
[7] Hallam, David et al; "Workshop 6: Restored to working glory; To work or not to work?"; Big Stuff '07 International Conference Industrial Heritage Management; www.bigstuff07; 11-14 Sept. 2007
[8] Barr, Joanna; "The Conservation of 'Working Objects': Development of a Conservation Management Tool"; draft; barr.joanna@dpc.sa.gov.au; 2006
[9] Barr; *op cit*
[10]Leskard, Marta; "Policy and Procedures for Selecting and Operating Historic Objects from the Science Museum's Collections"; draft; Science Museum; 2008

Polymers in watches manufactured in the Jura region, Switzerland

The necessity of an anthropological approach for the conservation of a new heritage

Agnès Gelbert Miermon

Introduction

Since the 18th century Switzerland's world famous watch and clock industry has been concentrated in the Jura Mountains, between Geneva and Schaffhausen (fig. 1). This industry has given rise to an important heritage that is promoted through the "Watch Valley" concept developed since the year 2000. The region is associated with the image of traditional and luxury objects such as high-class mechanical watches manufactured from precious materials. The Jura watchmaking industry abounds in ingenuity and aesthetic treasures. The constant endeavour to conserve this heritage is illustrated by the rich collection of the Musée International d'Horlogerie (MIH) (International Watchmaking Museum) in La Chaux-de-Fonds, which to date houses the largest collection of watch and clockmaking related objects in the world. Private companies have even developed their own museums recently. These institutions also focus on exhibiting exceptional watches manufactured from traditional materials.

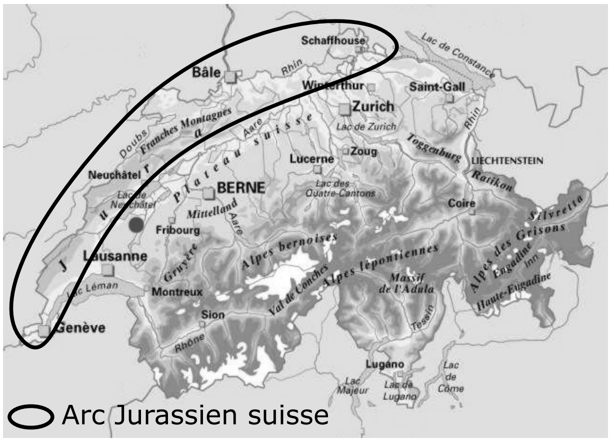


Figure 1. Map of the Jura region of Switzerland

Figure 2. Girard-Perregaux quartz movement (1978 or 1979). Only the battery support and the printed circuit are made of plastic.

However the Jura region, particularly the Neuchâtel Mountains, has been set apart for more than 200 years by a diversified watchmaking industry, combining prestigious watches with low-priced popular watches featuring all types of materials. From the 19th century onwards, polymers have gradually been introduced to the watchmaking industry for all ranges of clocks and watches – including coatings, cover layers, wire insulation and electric coils, watch faces, cases and mechanical components. Except for the balance, spiral and barrel, all parts of a watch can contain plastics (fig. 2).

To explain this essential facet of the Swiss watchmaking industry, the Applied Research and Development division of the Haute école de Conservation-restauration Arc (HECR Arc) examined the conservation of plastics used in timepieces. Through a research project named

Figure 3. View of La Chaux-de-Fonds

CROHP [1],[2],[3], carried out between 2006 and 2007, a multi-disciplinary team investigated these materials to explore their patrimonial interest and to consider their preservation. Results highlighted the need to combine research in conservation with both history and ethnography, particularly in respect of industrial objects, the primary value of which often goes unnoticed by the public or professionals working in the cultural field.

After briefly placing the region in context, we will try to evaluate why plastics are not recognised in the watchmaking heritage of the Jura region. On the basis of the results of the CROHP research project we will then discuss the importance of these materials at a technical, economic, social and cultural level and the necessity of preserving them as key anthropological markers despite the technical difficulties they present to conservators.

Regional context

The Swiss clock making industry developed in Geneva from the 16th century onwards, under the impulse of goldsmiths and thanks to the know-how of “Huguenots” fleeing from France [4]. The history of horology in the Neuchâtel Mountain region begins only in the 17th century and develops further in the 18th century [5]. Historians attribute the emergence of the watch and clockmaking industry in this mountain region to a number of social and economical factors, particularly the huge workforce “of odd-job men” who were in fact Jura farmers able to adapt to the various tasks involved in clockmaking [6] and the system of “établissage” [7],[8]. Horology thus spread to the mountains, initially as a cottage industry, then gathered pace in cities that were organised around this activity, such as La Chaux-de-Fonds (fig. 3) and Le Locle. In these watchmaking centres, economic life, town planning, culture and architecture developed for and around the clock industry. During the 20th century, this industry employed up to 50% or more of the active population. These urban centres bore the imprint of the watch and clock industry, so much so that today an application has been filed for their official recognition and inclusion on the UNESCO World Heritage list. Over recent years the canton has oriented tourism towards this heritage, particularly as a result of the Watch Valley concept promoted since the year 2000 (http://www.watchvalley.ch).

Plastics: a rejected heritage

Cultural and tourist institutions of the Jura region communicate a very partial image of the Swiss watchmaking industry. A glance at the MIH catalogue [9] reveals that the objects on show are almost solely exceptional artefacts manufactured from precious materials. When incorporated in prestige watches, plastics remain hidden. When used in popular watches, the timepiece itself is generally not exhibited. In this context, the use of plastics appears to be a real taboo. Several factors can explain this rejection of plastics.

Generally plastics have a poor image in our society [10]. Is it because they are omnipresent in our lives and are thus trivialised [11]? Is it because they are synthetic [12], often disposable [13], [14] or mass produced? In all events, the negative representations associated with plastics are reflected in the field of horology, and plastics are associated with downmarket products. Today, Switzerland and in particular the Jura region, wishes to promote the view of an area devoted entirely to a traditional, prestige industry. Like many great industrial areas, the Neuchâtel Mountains identified itself with its clockmaking activity and elevated it to a national symbol: "Horology indeed remains a showcase, the brand image and quality symbol of Swiss products all over the world." [15]; "There is a clockmaking patriotism, pride taken in fine workmanship." [16]. The Neuchâtel Mountains built their history and their identity around the clockmaking industry and little by little created a veritable mythology which today becomes confused with the region's real history [17]. Thomas Perret writes that the changes which marked the clockmaking industry from the end of the 19th century and particularly during the 20th century served only to reinforce the population's attachment to this tradition: "In response to these economic and social transformations which call into question the image that Neuchâtel's clockmaking society has of itself, there emerges an historical discourse with the clock industry as its subject, which very often takes on the appearance of a genuine search for identity." [18]. The author refers thus to the appearance of legendary "heroes", such as Daniel JeanRichard [19], and of the emblematic figure of the "peasant watchmaker" [20]. The image is conveyed of "mountain dwellers" who are "predestined for the clock industry" [21] and whose qualities explain the industry's establishment in this area [22].

The population identifies itself with the clock industry and with the manual, intellectual and even moral qualities associated with it: "work, patience, modesty, unselfishness, an obsessive quest for improvement" [23]. In this context, one can understand better why Jura people wish above all to convey "an artistic and artisanal view of clockmaking carried out in small workshops, as opposed to the image of an industrial activity." [24]. This view is reflected directly in the conservation and exhibition choices of horology-related objects and in the image they have abroad. In this perspective, plastic, a material associated with mass-production, automation and the consumer society, has no place.

Another factor that can explain the lack of patrimonial interest in plastics used in clockmaking is the nature of these materials and their properties. Plastics quickly degrade and conservators do not know enough about their composition to propose adequate treatments that could slow this process down. In the absence of effective conservation treatments, professionals today concentrate on preventive measures of environmental control for storage and exhibition. One could of course argue that other organic materials causing equivalent problems are given special attention. For example, leather used in watch straps benefits from extensive research. Plastics incorporated in timepieces can degrade to the extent that they are no longer fit for purpose. This is particularly true of plastics used as wire sheaths in electric clocks from the 19th century onwards. However, most of the time, and because of the small number of conservators specialising in this field, the restoration of watches and clocks is entrusted to traditional restorers with basic training in the repair of clocks and watches (in the Canton of Neuchâtel the training involves a Federal Certificate of Capacity-CFC in horology followed by an Ecole Supérieure-ES diploma in complication/

clockmaking restoration). These professionals with knowledge of the most complex mechanisms seek to restore the timepiece to working order in accordance with traditional know-how [25]. For presentation to the public, objects are restored to working order and given a pleasing appearance. Plastics with their poor mechanical strength easily fall victim to clock and watch restorers, who very often decide to replace damaged polymer parts. Their choices, often opposed to those of conservators who prefer to sacrifice the "use value" of an object if the repairs called for are too extensive [26], [27], [28], risk sacrificing a fundamental cultural dimension and an essential part of an object's authenticity. To evaluate this risk, it is necessary to explore the patrimonial value of plastics from all angles (technical, aesthetic, historical, symbolic, economic, etc) because it is the value given to a cultural object which "generally decides how it will be conserved." [29]. In the context of conservation of an industrial heritage one should thus measure the importance of historical and ethnographic research to reveal the patrimonial value of ignored objects or materials.

Plastics: a fundamental heritage

Plastic is an essential material because it is eminently representative of the watch and clockmaking industry of the 20th and 21st centuries. According to art historian Claude-Alain Kunzi, it is regrettable that in the field of horology it is primarily the scarcity of an object that determines its patrimonial value and its place in a collection, eclipsing "the concept of the pre-eminence of representativeness" of the low-priced timepieces that form "part of our history" [30]. In terms of representativeness, historical research shows that plastics should have a key place in collections because they have been used since the 19th century in clocks and since the 1960s have slowly been introduced into almost all parts of timepieces [31], [32].

In fact, there are two phases involved in the introduction of plastics [33], [34]. The first phase (1860 – early 1960s) corresponds to a discrete but significant appearance of plastics in timepieces (fig. 4). According to historians it is difficult to document precisely when

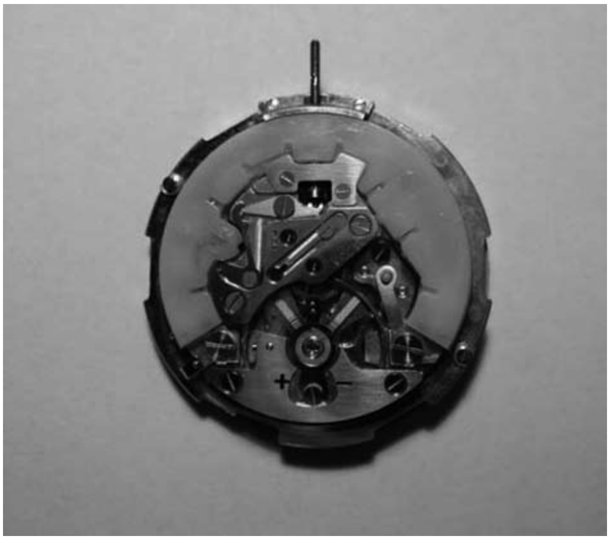


Figure 4. The Landeron 4750 electro-mechanical movement (1960). The motor's electric coil is overmoulded with plastic .

the first plastics appeared in timepieces from the end of the 19th century and there is very little information in specialist literature. The oldest polymers were used for isolating electrical parts of clocks. There is more precise information from the 1930s about the use of polymethyl methacrylate (PMMA) for glass replacement. Then, in the 1940s-1950s, various plastics were tested for making joints and circles, such as polyvinyl chloride (PVC), acrylonitrile butadiene (ABS) or polyurethane (PU). The second phase (1960s to the present) is characterised by the increasingly visible use of plastics in the watch and clock industry (fig. 5). The first watch cases made of polymers were developed in the 1960s

Figure 5. The "Symbol" Watch, one of the numerous models of the 1960s and 1970s. Except for the movement, the entire watch is plastic 33x43mm.

Figure 6. The Astrolon Watch "Idea 2001"

(manufacturers of alarm clocks already used ebonite or phenoplast for cases half a century earlier [35]). In the 1970s polymers were introduced in movements until watches were almost completely made of plastic (except for the balance, spiral and barrel). Two watches thus marked the history of the clock industry: first, in 1971, the Astrolon watch, from Tissot (fig. 6), the "first mechanical watch made of plastic" which was a technical success but a commercial failure; and then of course, in 1982, the well known Swatch watch (fig.7).

Even if they were and are still used in all product ranges, plastics remain associated with down-market watches. It is for this reason too that these materials have a fundamental cultural value, because they are associated with the democratisation of watches and the sociological changes to which they testify. Claude-Alain Künzi thus underlines the historical interest and the social and symbolic impact of cheap watches: "in the 19th century, making it possible for workmen to own a watch meant giving them a way to control working time, by exercising control over hours deducted by the owner." [36]. It is thus a true "countervailing power" which was often commented upon by Marx and Engels [37].

Clockmaking in the Neuchâtel mountains was always characterised by a variety of products, including the "economic" watch, optimising value for money and the cheap watch sometimes sacrificing quality for price [38]. J.-M. Barrelet describes a heterogeneous production often of low quality and quite removed from the image one has of a prestige industry [39]: "The absence of corporation in the Mountains allowed great creative freedom. Anything could be produced: large volume clocks, simple systems and relatively cheap pocket watches, as well as more refined even luxurious pendulums, automata, etc (…). Anything appeared on the market, including the best and (often) the worst, to the great chagrin of upholders of tradition who called for firmer regulation of the profession and its commercial and technical standards" [40]. Therefore the strength of the Swiss watch and clock industry, in addition, was that it developed in each period a range of low-priced watches, from Roskopf's Proletarian (fig.8) in 1867, to the famous Swatch of the 1980s. Historians have recently become aware of this: "The objects also embody these deep-rooted changes. Luxury or cheap watches, charms or works of art, they express the potential of the Neuchâtel watch and clockmaking system as much as its limits" [41].

Plastics played a major role in technical developments which accompanied watch and clockmaking, testifying to this industry's dynamism which, contrary to the conservative image that one might have, was always at the cutting edge of innovation. Thus, from the 19th century, Neuchâtel clock and

Figure 7. A model of a Swatch watch

Figure 8. The Rosckopf's Proletarian, 1867

watch makers learned how to modify their means of production to counter foreign competition, particularly from America. They developed the mechanization of production, in spite of the reservations of "some partisans of tradition" [42]. The clock industry took time to integrate scientific innovations, believing for a long time that it needed only "brilliant craftsmen". Little by little it understood that it also needed engineers and scientists [43], as attested by the creation of the Laboratoire de recherches horlogères (Laboratory of horology research) in 1924 [44]. The 20th century was particularly rich in innovations with the advent of the wristwatch, followed by the development of battery watches (with motor balance, diapason tuning fork, quartz, etc) bringing with them new production methods for integrated circuits, movements, etc.

Plastics also have a strong anthropological value because, as the results of the CROHP project show, the introduction of plastic brought about a complete transformation in industrial organisation and the social and economical context of production. During the first phase, the field of horology appeared to be only slightly affected as plastic parts were outsourced. Historians even speak of a "non-event" [45]. Since the 1950s however, the use of plastics has gradually increased and changes have occurred at various technical, economic, social and cultural levels constituting a real revolution [46], [47]. Technically, plastics are useful for insulating electrical parts in quartz watches, especially micro-motor coils. Even if the manufacture of quartz watches does not require plastics, these materials supported the development of this technology in the 1970s by bringing down production costs. They also allowed the creation of wristwatches with a digital display (without moving parts) at an incredibly low cost compared to metal. Plastics also helped to rescue Switzerland during the major crisis of the 1970s. In the face of competition from Asia and its production of quartz watches (appearance and large-scale distribution on Western markets of Seiko watches in the early 1970s), the creation of the Swatch in 1982 rescued Swiss watchmaking from the threat of bankruptcy [48], [49]. The massive introduction of plastics in the watch and clock industry had a huge impact at a technological level. It led to outsourced production [50], the development of new know-how [51], changes in production and tools [52], changes in social organisation [53] as well as in the profession and education [54].

Finally, the increasing use of plastics from the 1960s coincided with a major change in the social function of watches and in cultural representations associated with them. From the 19th century, "the Swiss knew and wanted to make every kind of timepiece on the market, and [they] understood that not everyone wanted a watch for the same reason" [55]. Two categories of watches then emerged in the second half of the 20th century: high-end and bottom-of-the-range. The first is precious and valuable and rejects plastic, while the second is cheap and is treated as an accessory, governed by the influence of fashion and the mass market – plastic is not only accepted but is also a major selling point. These two categories respond to different social goals and convey different representations of the watch itself and of plastics. The Swatch Company played a major role in this transformation by giving a new symbolic status to watches with new marketing concepts. Swatch introduced its watch as a fashion accessory, associated with a particular lifestyle. Swatch watches must be up to date, frivolous, futile, consumerist and trendy [56]. This change of status of the watch is obvious in advertisements [57]. As the "heritage watch" is linked to life events and is used as a gift at specific times in people's lives (communion, birthday, anniversary, wedding), Swatch is associated with social as opposed to individual events. From the watch given as a present for the first communion we have moved on to special editions created for the Olympics, Mother's day, Valentine's day, etc.

Conclusion

Michel Leiris made famous the comment by Marcel Mauss: "A can may, for example, characterizes our societies better than the most sumptuous jewel or the rarest stamp. One should not be afraid therefore of collecting the most humble and scorned things […]" [58]. Applied to horology, this sentence gives full meaning to the preservation of plastic watches and of plastics used in watches. It is a question of saving and revealing to the public the worth of a heritage of undeniable historical and cultural value. Plastic conquered the world of watch and clockmaking, imposed new rules of production, offered new challenges, modified the organisation of work and our relationship to the object. It constituted a genuine revolution in terms of production and consumption.

The plastic revolution that took place in the 1960s was not the monopoly of the watch and clock industry. Cheap and ephemeral products multiplied and became archetypical of the consumer society [59], [60]. This change was evident not only in the economic sense, but also in the artistic world, with New Realism (Martial Raysse, César, etc) and was contemporary with the American Pop Art movement (Claes Oldenburg, Allen Jones, etc) [61].

Like all artefacts made of polymers, plastic clock and watch components raise specific issues for conservators. Degradation phenomena are not always well understood and appropriate treatments have not yet been developed for all materials [62], [63]. Historical and ethnographic research carried out as part of CROHP projects highlight the need to face up to these issues by pooling resources with numerous other research studies devoted to the conservation of plastics.

Acknowledgments

We would like to thank the Haute Ecole Spécialisée de Suisse Occidentale (HES-SO - The University of Applied Sciences of Western Switzerland) for their financial support for the CROHP project, which was the source of this presentation. We would also like to thank all the research teams at the Haute école de Conservation-restauration Arc, the Ecole d'Ingénieurs et d'Architectes of Fribourg, the Institut d'Ethnologie of Neuchâtel and the Musée International d'Horlogerie of La Chaux-de-Fonds, which took part in the project. Thanks to Annick Vuissoz (HECR Arc) and Christian Degrigny (HECR Arc) for the translation.

Author

Agnès Gelbert Miermon
Haute école de Conservation-restauration Arc
Rue de la Paix, 60
2300 La Chaux-de-Fonds, Switzerland
agnes.gelbert@he-arc.ch

References

Note: quotations are the author's translations.

[1] "Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19ème siècle. Approche pluridisciplinaire". Project leader: Annick Vuissoz

[2] Gelbert Miermon A. 2007 *Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19ème siècle. Approche pluridisciplinaire (CROHP). Rapport scientifique*. Online http://www.he-arc.ch/hearc/fr/ima/IMA_galerie/crohp_rapport_scientifique_final.pdf

[3] Gelbert Miermon A. et Vuissoz A.. The Conservation of Polymers used in Horology since the 19th Century. In Brenda Keneghan and Louise Egan (eds) *"Plastics: Looking at the Future & Learning from the past"*. Papers from the Conference held at the Victoria & Albert Museum, London, 23-25 May 2007. Archetype Publications in association with the V & A, London, 2008, p. 36-44.

[4] Landes D. L'heure qu'il est. Les horloges, la mesure du temps et la formation du monde moderne. Paris, 1987, pp. 337-338.
[5] Bujard J. and L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*. Les Editions de la Chatière, Chézard-Saint-Martin, 2008.
[6] Barrelet J.-M.. Permanences et mutation de l'horlogerie suisse. In: C. Cardinal; F. Jequier. J-M Barrelet and A. Beyner (dir) *L'homme et le temps en Suisse. 1291-1991*. Institut l'homme et le temps, La Chaux-de-Fonds, 1991, p. 147
[7] Définition de la Fédération de l'Industrie Horlogère, citée par Blanchard 2008: 18): "Mode de fabrication de la montre et/ou du mouvement consistant à en assembler les divers éléments constitutifs. Il comporte généralement les opérations suivantes: réception, contrôle et stockage des ébauches, des parties réglantes, ainsi que des autres fournitures du mouvement et de l'habillement, remontage, posage du cadran et des aiguilles; emboîtage; contrôle final avant emballage et expédition."
[8] Blanchard P. Une production éclatée. In: J. Bujard and L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*es. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, p. 18.
[9] Cardinal C. et Piguet J.-M. *Catalogue d'œuvres choisies du Musée International d'Horlogerie*, La Chaux-de-Fonds, 1999.
[10] Chapatte, J. and Wenger, D. Rapport VSH2: Volet ethnographique, In: Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle. Approche pluridisciplinaire. Unpublished internal final report. Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007, pp. 50-52.
[11] [12] Dagognet, F. *Des détritus, des déchets, de l'abject: une philosophie écologique*. Institut Synthélabo pour le progrès de la connaissance (Les empêcheurs de tourner en rond), Le Plessis-Robinson, 1997.
[13] Beaune, J.-C. *Le déchet, le rebut, le rien*. Éditions Champ Vallon, Seyssel, 1999.
[14] Norman, D. A. *The psychology of everyday things*. Basic Books. Inc. Publishers, 1988.
[15] Barrelet J.-M.. Permanences et mutation de l'horlogerie suisse. In: C. Cardinal; F. Jequier. J-M Barrelet et A. Beyner (dir) *L'homme et le temps en Suisse. 1291-1991*. Institut l'homme et le temps, La Chaux-de-Fonds, 1991, p. 223.
[16] Barrelet J.-M.. Permanences et mutation de l'horlogerie suisse. In: C. Cardinal; F. Jequier. J-M Barrelet and A. Beyner (dir) *L'homme et le temps en Suisse. 1291-1991*. Institut l'homme et le temps, La Chaux-de-Fonds, 1991, p.223.
[17] Perret T. Une horlogerie mythique. . In : J. Bujard et L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, pp.336-345
[18] Perret T. Une horlogerie mythique. In: J. Bujard and L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, p. 337.
[19] The legend tells that this self-taught watchmaker was the founder of the watch-making industry of the Neuchâtel Mountains region. Marti L. *L'invention de l'horloger. De l'histoire au mythe de Daniel JeanRichard*. Éditions Antipodes & Société d'Histoire de la Suisse romande, Lausanne, 2003, p. 37.
[20] Perret T. Une horlogerie mythique. In: J. Bujard and L. Tissot (dir) Le pays de *Neuchâtel et son patrimoine horloger. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, p. 337.*
[21] *ibid, p. 337*
[22] *Barrelet J.-M.. Permanences et mutation de l'horlogerie suisse. In: C. Cardinal;* F. Jequier. J-M Barrelet and A. Beyner (dir) *L'homme et le temps en Suisse. 1291-1991*. Institut l'homme et le temps, La Chaux-de-Fonds, 1991, p.148
[23] Perret T. Une horlogerie mythique. In: J. Bujard and L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, p. 339.
[24] ibid, p. 338
[25] Broto O. Résurections au MIH. *Wtch around* N° 003, Autumn 2007.

[26] Bergeon, S. Ethique et conservation: la valeur d'usage d'un bien culturel', In: C. Chahine, F. Daniel, F. Flieder et al. (eds), *La Conservation: une science en évolution. Bilans et perspectives*. Actes des troisièmes journées internationales d'études de l'ARSAG, Paris, 21–25 April 1997, pp. 16–22.
[27] Bertholon R. Cours en ligne: R.Bertholon (FinValeurRiegl.doc) version dated 23/10/07. http://epi.univ-paris1.fr/servlet/com.univ.collaboratif.utils.LectureFichiergw?ID_FICHE=5112&OBJET=0008&ID_FICHIER=17212, 2007.
[28] Ducatel, N. Conservation et fonctionnement: de la déontologie des conservateurs-restaurateurs au compromis et à la conservation déléguée, In: *Conférence annuelle de la SCR ' Entre conservation et fonctionnement*, Zug, 5 May 1999.
[29] Bertholon R. Cours en ligne: R.Bertholon (FinValeurRiegl.doc) version dated 23/10/07. http://epi.univ-paris1.fr/servlet/com.univ.collaboratif.utils.LectureFichiergw?ID_FICHE=5112&OBJET=0008&ID_FICHIER=17212, 2007.
[30] Künzi C.-A. Luxe et pacotille. In: J. Bujard and L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, p. 121.
[31] Châtelain, P.-Y. *Rapport VSH1-2: Etude historique', in Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle. Approche pluridisciplinaire.* Unpublished internal final report. Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007.
[32] Châtelain P.-Y. Les matières plastiques dans l'horlogerie. Aperçu historique. *Chronométrophilia* N°64, Hiver 2008, pp.27-44
[33] Aguillaume, C. Rapport VSH1-1: documentation technique/étude historique. In: *Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle. Approche pluridisciplinaire*. Unpublished internal final report, Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007.
[34] Châtelain, P.-Y. Rapport VSH1-2: Etude historique', in Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle. Approche pluridisciplinaire. Unpublished internal final report. Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007.
[35] Laboratoire suisse de recherches horlogères. *L'habillement de la montre*. Cours pour cadres techniques [unpublished], chapter "Boite", 1975, p. 52.
[36] Künzi C.-A. Luxe et pacotille. In: J. Bujard and L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, p. 111.
[37] Ibid, p. 111.
[38] Winter-jensen A. La montre économique. In: C. Cardinal;F. Jequier. J-M Barrelet and A. Beyner (dir) *L'homme et le temps en Suisse. 1291-1991*. Institut l'homme et le temps, La Chaux-de-Fonds, 1991, p. 313.
[39] Barrelet J.-M.. Permanences et mutation de l'horlogerie suisse. In: C. Cardinal; F. Jequier. J-M Barrelet and A. Beyner (dir) *L'homme et le temps en Suisse. 1291-1991*. Institut l'homme et le temps, La Chaux-de-Fonds, 1991, p. 148.
[40] Ibid, p. 149.
[41] Bujard J. et L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, p. 11.
[42] Barrelet J.-M.. Permanences et mutation de l'horlogerie suisse. In: C. Cardinal; F. Jequier. J-M Barrelet and A. Beyner (dir) *L'homme et le temps en Suisse. 1291-1991*. Institut l'homme et le temps, La Chaux-de-Fonds, 1991, p. 149.
[43] Perret T. L'affinement d'un patrimoine. In: J. Bujard and L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, p. 211.
[44] Barrelet J.-M.. Permanences et mutation de l'horlogerie suisse. In: C. Cardinal; F. Jequier. J-M Barrelet and A. Beyner (dir) *L'homme et le temps en Suisse. 1291-1991*. Institut l'homme et le temps, La Chaux-de-Fonds, 1991, p. 150.

[45] Aguillaume, C. Rapport VSH1-1: documentation technique/étude historique. In: *Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle. Approche pluridisciplinaire*. Unpublished internal final report, Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007.
[46] Chapatte, J. and Wenger, D. Rapport VSH2: Volet ethnographique, In: *Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle. Approche pluridisciplinaire.* Unpublished internal final report. Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007.
[47] Gelbert Miermon A. and Vuissoz A. 2008. The Conservation of Polymers used in Horology since the 19th Century. In Brenda Keneghan and Louise Egan (eds) "Plastics: Looking at the Future & Learning from the past". Papers from the Conference held at the Victoria & Albert Museum, London, 23-25 May 2007. Archetype Publications in association with the V & A, London, 2008, p. 36-44.
[48] Carrera, R. Swatchissimo. Antiquorum Editions, Geneva,1992.
[49] Aguillaume, C. *De la Bêta à la Swatch. La mutation horlogère suisse dans l'œil de la presse*. Degree dissertation. University of Neuchâtel, Switzerland, 2003.
[50] Chapatte, J. and Wenger, D. Rapport VSH2: Volet ethnographique, In: Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle. Approche pluridisciplinaire. Unpublished internal final report. Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007, p. 14.
[51] Ibd, pp. 14-18
[52] Ibid, pp. 18
[53] Ibid, pp. 29-31
[54] Ibid, pp. 31-34
[55] Landes D. L'heure qu'il est. Les horloges, la mesure du temps et la formation du monde moderne. Paris, 1987, p. 380.
[56] Chapatte, J. and Wenger, D. Rapport VSH2: Volet ethnographique, In: Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle. Approche pluridisciplinaire. Unpublished internal final report. Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007, p. 86.
[57] Perret T. L'affinement d'un patrimoine. In: J. Bujard and L. Tissot (dir) *Le pays de Neuchâtel et son patrimoine horloger*. Les Editions de la Chatière, Chézard-Saint-Martin, 2008, p. 223.
[58] Mentionned in Jean Bazin, "N'importe quoi", In: Marc-Olivier Gonseth, Jacques Hainard & Roland Khaer (eds), *Le Musée cannibale*, Musée d'ethnographie, Neuchâtel, 2002, pp. 273-287
[59] Bertolini, G. Homo plasticus: les plastiques, défi écologique. In: *Les dossiers de l'écologie*. Paris: Sang de la terre, 1991, pp. 267–70.
[60] Chapatte, J. and Wenger, D. Rapport VSH2: Volet ethnographique, In: Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle. Approche pluridisciplinaire. Unpublished internal final report. Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007, pp. 22.
[61] Ibid, pp. 71-74
[62] Gelbert Miermon A. and Vuissoz A. 2008. The Conservation of Polymers used in Horology since the 19th Century. In Brenda Keneghan and Louise Egan (eds) "Plastics: Looking at the Future & Learning from the past". Papers from the Conference held at the Victoria & Albert Museum, London, 23-25 May 2007. Archetype Publications in association with the V & A, London, 2008, p. 36-44.
[63] Vuissoz, A., Schenkel, T., Beck, J. and Ducatel, N. 2007 Rapport VT1: Etude des objets du corpus, In: *Conservation-restauration des polymères utilisés dans l'horlogerie depuis la fin du 19e siècle.* Approche pluridisciplinaire. Unpublished internal final report, Haute école d'arts appliqués Arc, La Chaux-de-Fonds, 2007.

Gramophones and Records - the first widespread commercial standardisation

George Brock-Nannestad

Introduction

Gramophone records, and before them cylinders, were at the same time industrial products and carriers of cultural expression. To be useful they were entirely dependent on other industrial products: gramophones (and phonographs). Together these constituted a system. Standardisation was necessary to a degree, and this opens up the question of authenticity. Historically, some companies used strict in-house standardisation, which meant that the most satisfying results would be obtained by the use of specific reproduction equipment. Other companies gave a much wider margin for home reproducing equipment. The present paper does not discuss how to obtain maximum quality sound from a record.

When components in the system become the focus of attention today it is important to view them in their historical context as well as in the context of their present use for documentation and exhibits. The present discussion concentrates on the commercial disc record and the system it was a part of. The purpose is to give an overview in order that a restoration activity may be placed in the right context.

Industrial products are the results of industrial manufacture, which is characterised by a widespread division of labour: the various components are manufactured in departments or individual firms that specialise in them. Each such subsupplier contributes to lowering of cost by concentrating on one type of work and also ensuring quality control by having to master essentially only a few processes. Assembly then occurs at the factory that eventually sells the combined product. Industrial manufacture would not function without agreement on the properties of the component delivered, and to create a common frame of reference, standardisation was introduced. Such standardisation is always contingent on detailled instructions for measurements. Based on industrial history some will claim that standardisation was first introduced in small-arms manufacture, others will claim that standard threads for nuts and bolts was first, but in both cases, these are fairly simple standards for staple items. A related field of the present, that of cinematography, was also quite early, but this was in a narrowly professional field. The recorded sound industry, on the other hand, had to rely on so many individual components, from dimensions known from clock-making to sacks full of slate dust. This created a need for in-house standards, first and foremost, and as the industry expanded, de-facto-standards that ensured the compatibility between makes. This was a requirement for commercial penetration.

At the time of manufacture, all the components had to cooperate synergistically; otherwise the product would not be accepted by the market. In conservation practice usually only individual components are handled, and it is important to realise the context that these elements were placed in. The term component is here used quite broadly to indicate not only the mechanical components of a reproducing unit, the gramophone, but also the material that went into a gramophone record or the processes that were used to convert a recording into a commercial gramophone record.

In order to be able to design a physical restoration process, it is important to have precise knowledge of the industrial processes that went into the manufacture of records and gramophones, respectively. Gramophone and record manufacture was dominated by a handful of companies, but they had factories in several countries, and partly for historical reasons the processes were different in the various locations. However, there was also independent local manufacture in most countries, in some cases even small staple components were manufactured locally.

Records were manufactured by industrial processes similar to those used in e.g. the rubber and plastics industry[4], but the presses and temperatures were developed specifically for records. The thermoplastic material was composed of ca. 80% filler and 20% shellac-based binder, which was frequently exchanged for cheaper ingredients. Further industries supplied heat-tolerant printing inks for the labels. However, the quality of the finished record was also dependent on good quality galvanotypic processes. A given record provides information about many of the processes used in its manufacture. The shellac record system was in use from 1894 - ca. 1955, when it was gradually replaced by the vinyl, slow-revolving Long Playing record, which was mono until ca. 1960 when stereo records had been introduced. However, technologically there was no essential difference caused by the introduction of stereo records.

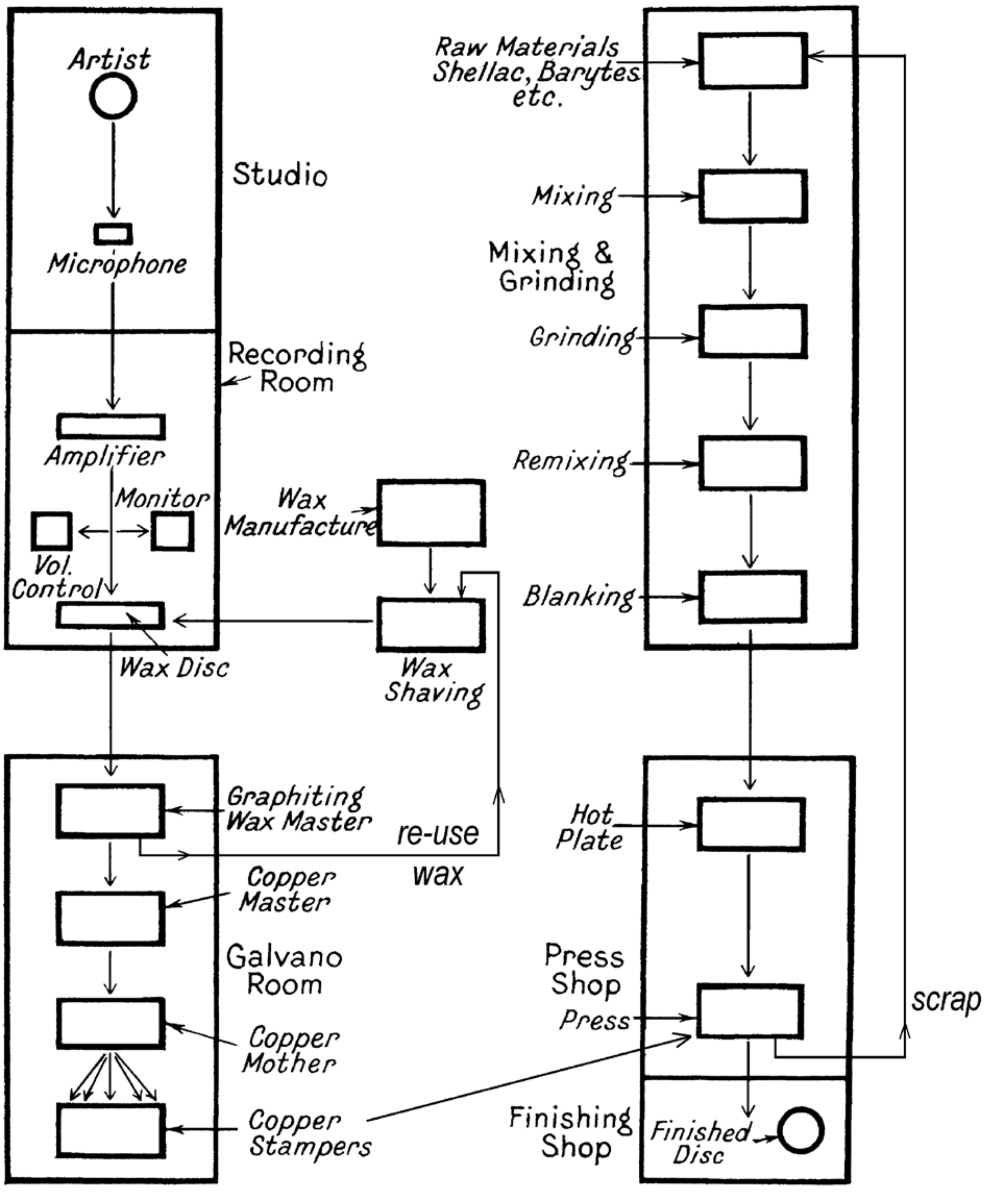
Gramophones were mainly machinery, and processes and materials known from clockwork and motor manufacture were used. Electrical pickups (1926-) used processes and materials known from the telephone industry, and the amplifiers and loudspeakers used were known from the radio set manufacture that sprang up at the same time.
We shall look at the various components of the industry and how they interacted. And note that we are not discussing cylinders and phonographs, nor tape recorders and magnetic tapes.

Historical beginnings

The basic principle only requires recording of a groove and a needle and soundbox for reproduction. The first mechanical gramophones and records invented by Emile Berliner were just that: a zinc plate was covered in beeswax, the recording stylus scratched a wavy line; when dipped into chromic acid the zinc was etched in the bottom of the line, and a zinc record was obtained. The groove was instantly available for reproduction, and the whole thing was hand-cranked. However, this was not industrial production. The desire to obtain this was intimately linked to the use of electrotyping, which was already known in printing and could provide a high quality. The original zinc plate was galvanotypically copied, and the result was a negative in copper. This could be used to press grooves in a thermoplastic material, and at first ebonite (hard rubber, Vulcanite) and guttapercha were used. The cost was high, and a cheaper material was found in semi-products for clothes-buttons: a material consisting of mineral material and cotton flock bound by a matrix of shellac. This type of material was almost universally used in the period 1895-1955, with variations determined mainly by economic considerations. However, the fairly soft copper stamper became worn thereby, and further copies had to be made.

A period of fairly uniform industrial manufacture

From 1900-1945 commercial recording used a master termed a wax, although the main constiuent was of the class of metal soaps. After recording by cutting a modulated groove the wax was metallised, and a series of negative and positive impressions were obtained galvanotypically. The final negative in the series was chromium-plated and reinforced by a steel plate ("backed-up") and this stamper was used to press records in a suitable shellac-based compound. Actually, two record sides were pressed at the same time in the press. Before placing the requisite amount of compound in the press, each stamper had been provided with a paper label in the centre. When the thermoplastic compound flowed due to steam heating of the stampers, the stampers made impressions in the material, and the paper labels were embedded in the record. Subsequently cooling water was provided to the stampers, and the finished record could be removed when the press was opened. The flash or spew (exuded surplus of compound) was removed and the edge was polished. Subsequently the record was put in a paper sleeve. Later, at least in Scandinavian record shops, the paper sleeve was replaced by an individualised sturdy carton cover carrying advertisements for the shop. Typically one record in twenty was picked out for playing on a factory gramophone to check



Record manufacturing process 1925-1950. Adapted from Courtney-Bryson 1935 for defects. Also, from each new stamper a number of records were played repeatedly to determine the number of reproductions this particular record would tolerate before its quality became unsatisfactory. For many years the absolute minimum was 50 playings[1,2,9].

The wax was manufactured in an industrial plant or in a dedicated department of large record companies. The raw materials were stearic acid, metal salts, and alkaline solutions, and the materials were boiled in a similar way to soap manufacture. To the molten mixture were added various natural waxes, such as Montan and Carnauba wax in order to improve the interaction with the cutting stylus during recording. The molten mixture was poured into circular cans and left to cool; due to shrinkage the cast wax could be easily removed. The top surface was finely shaved to obtain a mirror-like surface. The recording took place in a recording machine which was essentially a vertical lathe, in which the cutting tool (the cutting stylus) was transported across the surface and at the same time vibrated by a cutter-head. The vibrations were representations of the sound. The groove was given a cross section that experience had shown would give a good interface to the steel needle later used for reproduction in the finished record. The swarf (chips) was sucked off so that it would not get entangled in the machinery.

The recorded wax had a very delicate surface, and it was carefully carried or shipped to the record factory galvanotypic department. The surface of the wax was made conductive by careful brushing with graphite or by vacuum sputtering, and a negative was created by electrodeposition of copper. In order to obtain a fine-grained (small crystal) deposit on the modulated grooves, the current was low at first, but then increased to have a fast growth of thickness. The copper and wax were then separated, and the negative (the father) was given a semiconductive release layer and a copper positive (the mother) was formed galvanotypically from that. The release layer ensured that the original negative could be separated easily and be retained as the original. It was frequently silvered or nickeled. The wax was shaved again (refacing) for later re-use. The original thickness of the wax of ca. 40 mm could be reduced to ca. 20 mm with no adverse effect on its cutting qualities. From the mother a series of stampers (sons) could be similarly formed, and whereas copper was used in the beginning, nickel and chromium plated nickel became the norm to increase durability[13]. 2-10 thousand records could be pressed from one stamper before it was worn so much that the quality suffered. Polishing of the original negative was only rarely performed, because it obliterated the high frequencies that were recorded.

The record material was provided to the presses in the form of “biscuits” of material that was pre-heated on a hot-table. The compound for the record material consisted of ca. 80% mineral filler, mostly a mixture of natural minerals, such as slate dust or barytes, or fillers obtained industrially, such as barium sulphate. As opposed to concrete manufacture, where a wide distribution of particle dimensions is important, in record manufacture which is dependent on the wetting of the particles by the binder, uniformity is aimed for. This is obtained by comminution and screening. The binder was shellac with addition of resins and waxes, all depending on the actual properties of the batch of raw materials used. A further constituent of the record material was record scrap, i.e. the material left over from manufacture and old records received back (this was prevalent during the two world wars). All constituents were ground and then mixed on rollers or kneaders (masticators) and rolled hot in the form of slabs. The slabs were cooled, broken up, and then ground to a uniform powder that was hot rolled to make up the biscuits. It was important to maintain a very low moisture content, because the heat of the presses would otherwise generate steam. All machinery was subjected to heavy wear, because the record material was abrasive[3,6].

An alternative to the shellac compound record was the much cheaper phenolic record, which had a commercial life from ca. 1931-35. “Hit-of-the-Week” and Durium were single-sided reddish carton sheets impregnated with a dark brown phenolic resin that was cured as it received the impression of the stamper. Two recordings were on one side, and apart from popular tunes, several language courses used this format.

Gramophones

The reproducing machine (a gramophone) had a turntable with stable main bearing and rotated at constant rpm by means of a motor drive. A pickup or soundbox held a needle that was vibrated by the undulations of the record groove, and the vibrations were transmitted either to a diaphragm or to a magnetic or piezo-electric system. The diaphragm was placed in a soundbox with an outlet to an acoustic horn. The tonearm that carried the soundbox was part of the horn, and the joint that enabled the tonearm to swing across the record from beginning to end was air-tight. The horn radiated the sound into the listening room. The volume could essentially only be controlled by using different needles.

The pickup also held a needle, but the vibrations changed the properties of a magnetic circuit so that a voltage from a coil was induced at the terminals. This voltage was taken to an amplifier (frequently the low-frequency part of a radio set) that amplified the signal sufficiently to drive a loudspeaker. The volume could be controlled by a volume control. From the late 1930s piezoelectric crystals were used to convert the vibrations to voltage. These crystals were made of Rochelle salt which was very hygroscopic, and although they were coated by waxes or rubbery compounds they deteriorated after a few years.

The needle was made in carbon steel and was available in several thicknesses. A thick needle gave a strong sound. The needle wore the record and the record ground sharp-edged flats on the steel needle. This was a necessity, because the specific pressure on the record material should not exceed a certain breakdown value, and grinding facets on the tip of the needle increased the contact area. For this reason a small amount of grinding material was included in the record material. This also meant that the needle had to be changed for every record side played. When the flats became pronounced as the needle moved towards the centre of the record its ability to trace the short wavelengths associated with high frequency disappeared, and the end of a record hence tended to sound dull and distorted. For this reason the professional use of records for sound-on-disc cinematography was to cut records from the inside out. This meant that the flats would develop when all wavelengths were about twice as long near the outside of the record[3].

In 1917 a new type of needle was developed by the Victor Talking Machine Company in the US, the Tungstyle or TungsTone. This was a short piece of tungsten (W) wire clamped in the end of a steel needle. The diameter was such that the wire would fit comfortably inside the groove, but the steel needle did not touch the record. This type was semi-permanent and would tolerate up to 100 playings.

Due to complaints that records played in apartment houses sounded too loud, various types of fibre and thorn needles were developed and eventually received a cult-like status among some collectors of (mainly) classical records. One type was a triangular cut bamboo sliver that was sharpened after each use by cutting the end at an angle by a special sharpener that would work even when the needle was in the soundbox. All types of straight needle were made to have an angle of ca. 60 degrees to the horizontal in the soundbox[6,10].

With the advent of microgrooves (for LPs and singles) and the advances of the manufacture of artificial gemstones from ca. 1950, sapphire (and to a lesser extent diamond) became the material of choice for pickup stylii. Sapphire was cut into minute rods, which were tumbled with diamond dust to create the rounded tips. They were then mounted at the ends of flattened minute aluminium tubes that transmitted the movement to the generating part of the pickup.

The soundbox was a shallow tin with a membrane or diaphragm on one face and a hole connected to the horn in the other. The diaphragm was supported at the rim by rubber gaskets and at the centre it was connected to one end of a lever with a knife-edge bearing at the periphery of the soundbox. The other end of the lever had a screw clamp for the needle; in order to accommodate both cylindrical steel needles and triangular bamboo needles the hole was frequently triangular. The diaphragm in most cases was made as a thin sheet of mica, but from 1925 corrugated aluminium diaphragms were used.

The motor was clockwork, and it was more heavy-duty than other uses of clockwork that was normally made for discontinuous motion. For this reason the spring was very strong, and frequently several springs were connected in series. The thing that set gramophone motors apart from other clockwork was the centrifugal governor (or rather, *brake*) for the speed, which used friction of leather on a rotating disc rather than the well-known air brakes. As the gramophone was a piece of fine mechanical construction, it was attempted to save on materials where it might not matter. For instance, soundboxes were frequently made of nickel plated zinc alloys (”pot metal”) with the well-known re-crystallisation problems.

Professional recording machines were frequently of the same basic design as gramophones, only much more strongly built. The power source was mostly a weight (e.g. 20 kg) hung in a steel wire wound around a drum. The need for power to cut a wax at an outside radius of e.g. 15 cm was appreciable[8].

Home recording

A spin-off from the commercial gramophone production was the manufacture of stronger domestic turntables for home recording use. In this case the record was a one-off, cut directly onto a disc master in a special lacquer. The lacquer record had a carrier, most commonly absolutely flat aluminium, but in times of war glass, zinc, or even cardboard was used. The manufacturers of the disc masters were not record companies but came from the paint and lacquer industry. Each record made was unique, but they could be played on most commercial gramophones. In this respect they adhered to the technical de-facto standards used for commercial gramophone records. However, in order not to damage the soft record material, special bent “trailing” needles were used - they had an angle of ca. 40 degrees to the horizontal in use. The lacquer master records later (1945-85) became the standard master material for commercial record production, but cut on professional recording lathes.

Restoration considerations concerning components of a sound recording and reproduction system.

Apart from the considerations required by the context of the system, the various components and subassemblies as found in conservation practice also need a specific, if brief, mention. All restoration or preservation activities should be controlled by the basic consideration: what is the goal? Repair of function or repair of appearance? Old new stock or replica original parts (or even replacements in better materials?)[12].

The components encountered in practice are primarily 1) records, and 2) machines to reproduce them. Records are primarily of 3 kinds:

- “78s” or “shellac records” that will not tolerate alcohol or other organic solvents but certainly brief contact with water and anionic surfactants (however, the label must not be wetted).[15].

Played with steel needles, bamboo or other fibre needles, tungsten-tipped needles (historically), sapphire or diamond tips (very modern, but Pathé used a sapphire sphere as a permanent tip as early as 1907!)

- “vinyl”, LPs, “singles” which are mainly made in a PVC alloy, although polystyrene and alloys with cellulose acetate are known. Tolerates water, alcohols.

Played with sapphire or diamond stylii in lightweight pickups.

- ”lacquer records” (avoid the populist term ”acetates”!!), which are thin lacquer layers of a nitrocellulose lacquer (not flammable in this form) with castor oil or camphor as plasticiser and used as masters or one-off records. If the surface is not crazed it will tolerate water, but no organic solvent. Aluminium and glass substrates will permit correct adhesion for a long time, but zinc substrates shed the lacquer irreversibly due to oxide formation on the metal surface.

Played with ”trailing” steel needles (historically) or sapphire or diamond stylii in lightweight pickups.

Pickups (and cutterheads) are very delicate electromechanical mechanisms that need the care of delicate scientific instruments. They have moving parts and supports and dampers made in rubber-like compounds that originally had very specific mechanical and rheological qualities.

Machines (i.e. gramophones) are clockwork driven (wind-up) (1897-1960) or with an electromotor (in most cases a universal AC/DC motor) (1921-1950), both types using a centrifugal governor. From ca.1950 an asynchronous motor or transistor-controlled low-voltage motor was used. All machines must be correctly lubricated to run. Modern motors have sintered bronze bearings with permanent lubrication (however, I recommend a minute drop of molybdenum disulphide suspension). Drive belts and rubber idler wheels are prone to deterioration[5,11].

The clockwork uses just one spring in a barrel or several barrels in series. Each spring is tightly compressed inside its barrel (danger!) and lubricated with graphite-loaded grease. A gear train increases the speed to the ca. 78 rpm needed for the record and the ca. 1000 rpm needed for the governor. The whole gear train must be well lubricated as must the leather pad for the adjustable centrifugal governor. All weights for the governor must be present and the carrying springs must not be broken[10].

The universal electromotor uses a helical gear to obtain the gear ratio, and the adjustable centrifugal governor is fitted to the main motor shaft, because it already has a sufficient rpm. Everything has to be well lubricated, and the carbon brushes have to fit and not be worn down. The voltage for the motor must be correct. Humidity may have corroded bearings and broken down the insulation (danger!).

Reflections on the record as document and it place in the system.

Modern users of the records have to take several aspects into consideration: one is the physical restoration of original record and original equipment in order that the two may meet to generate a sound that is close to the sound at the time these industrial items were modern. Will this generate an authentic sound? What will it be used for? Several sophisticated modern methods of reproduction exist, and they all break the system and they give different sounds. Should the characteristics of the original reproducing equipment be simulated in the modern equipment?[14]

Author

George Brock-Nannestad
Patent Tactics
Resedavej 40
DK-2820 Gentofte
pattac@image.dk

Notes and references:

[1] Henry Seymour: The Reproduction Of Sound. Being a description of the Mechanical Appliances and Technical Processes employed in the art, London: W.B. Tattersall Ltd. n.d. [1918]
(this was the semi-professonal handbook of the first, acoustic period, dealing with everything regarding recording, including cylinders)

[2] H. Courtney-Bryson: The Gramophone Record, London: Ernest Benn Limited 1935
(this was the industry handbook of the 1930s, dealing with everything concerned with records, but not the mechanics of gramophones)

[3] P.G.A.H. Voigt: Getting the Best from Records. Part IV: The Record Has the Last Word, Wireless World, Vol. 46, No. 7, pp. 242-245 (May 1940)
(a very thoughtful discussion - in the words of a shellac record - relating to a number of record manufacturing and reproduction fundamentals)

[4] Emil R. Riegel: Chemical Machinery. An elementary treatise on equipment for the process industries, New York: Reinhold Publishing Corporation 1944
(a very good introduction to the type of equipment that was used in the period of interest)

[5] Harry Mileaf: Servicing Record Changers, Slough: Foulsham-Tab Limited 1973

(this is a handbook that caters for many 1950s constructions of gramophones. British edition. Originally from Gernsback Publishing in the US)

[6] Several papers in the Journal of the Audio Engineering Society Vol. 25, No. 10-11, October 1977 (”Centennial Issue”) as follows:
J.C. Ruda: Record Manufacturing: Making the Sound for Everyone, pp. 702-711
L.S. Burt: Chemical Technology in the Edison Recording Industry, pp. 712-717
S.K.Khanna: Vinyl Compound for the Phonographic Industry, pp. 724-728
J.H. Kogen: Record Changers, Turntables, and Tone Arms–A Brief Technical History, pp. 749-758

[7] Erling Benner Larsen: Electrotyping, Copenhagen: School of Conservation, Royal Danish Academy for Fine Art 1984
(a modern and very detailled reference work in the field)

[8] George Brock-Nannestad: The EMI recording machines, in particular in the 1930s and 40s, The Historic Record & AV Collector No. 43, pp. 33-38, April 1997.
(using archive material and inspection of surviving artefacts, it is pointed out how the commercial records themselves can identify precisely the type of recording machine used)

[9] George Brock-Nannestad: “The Objective Basis for the Production of High Quality Transfers from Pre-1925 Sound Recordings”, AES Preprint No. 4610, 103nd Convention 1997 September 26-29, New York.
(despite the title the preprint contains a wealth of detail on acoustical sound recording and record production. Very much archival material is quoted)

[10] Eric L. Reiss: The Compleat Talking Machine. A Collector’s Guide To Antique Phonographs, Chandler, Arizona: Sonoran Publishing LLC 1998 (Third edition)
(this is a handbook covering both cylinder and disc phonographs (gramophones) and their repair and restoration)

[11] Andrew Emmerson: Electronic Classics. Collecting, Restoration and Repair, Oxford: Newnes 1998
(a good introduction to the electronics involved in modern electronic equipment, using valves (electronic tubes) and transistors, and their artefact status)

[12] George Brock-Nannestad: The Rationale Behind Operational Conservation Theory, in ‘Conservation without limits - IIC Nordic Group XV Congress’, Ed. R. Koskivirta, Helsinki 23-26 August, 2000, pp. 21-33.
(the information content and structure in an object is both of a scientific and of a perception nature. The balance between the two types changes over the service life of the object. Systematic information analysis provides a firm background for responsible decisions on preservation and restoration)

[13] George Brock-Nannestad: How is discography related to the physical object, paper presented at the seminar ”Dokumentation av 78-varvsepoken i Skandinavien”, arranged at the Swedish Ljud- och Bildarkivet SLBA, Stockholm 12-13 February 2005. 6pp.
(the physical object the disc record carries a number of very distinct marks that are related to the manufacturing process. The paper provides a sequence of steps in the manufacture and an alphabetical list of the terms used for identifying the steps; describing and classifying the markings)

[14] George Brock-Nannestad: The Development of Recording Technologies, in Cambridge Companion to Recorded Music, Cambridge University Press, forthcoming 2009.

[15] Cleaning and restoration of shellac records under the stereo microscope was taught at the School of Conservation in Copenhagen 1991-98 by the present author as an exercise in fine-motor manipulation. This formed part of courses in Media for Sound, Moving Images, and Data.

USS *Monitor* conservation: preserving a marvel of 19th century technology

Eric Nordgren, David Krop, Erin Secord, Elsa Sangouard,
Michael Saul, Gary Paden and Gerry Hanley

Abstract:

The American Civil War ironclad USS *Monitor* (1862) is one of the most significant ships in naval history. The *Monitor*'s innovative design featured armor plating; a vibrating side-lever steam engine; the world's first ship-mounted, steam-driven rotating gun turret; and numerous other advances that influenced the technological development of all subsequent naval ships. Even with these new technologies, the *Monitor* was built in just over 100 days due to the efficient cooperation of a large number of ironworks, shipbuilders, and other manufacturers. In a real sense, the *Monitor* is not just a historic ship but also a prime example of mid-19th century industrial production and the engineering genius of its designer, John Ericsson.

Though the *Monitor* had a large impact on naval history, its working life was short. It sank in a storm off the coast of Cape Hatteras, North Carolina, on December 31, 1862, and was discovered in 1973 at a depth of 240 feet (approx 73m). Following rediscovery, the United States National Oceanic and Atmospheric Administration (NOAA) established the *Monitor* National Marine Sanctuary and manages, protects, and studies the wreck. Over 200 tons artifacts from the *Monitor* have been recovered from the wreck site by NOAA and the US Navy, including the rotating turret, guns, gun carriages, engine, condenser, and many smaller mechanical components such as the steam-driven Worthington water pumps and ventilation engine.

In 1987, The Mariners' Museum (TMM) in Newport News, Virginia, was designated the official repository of all artifacts and archives from the *Monitor* site. As such, TMM is charged with the conservation, curation, and display of *Monitor* materials. The large size and weight of the artifacts combined with their long immersion in seawater present significant challenges and require specialized conservation facilities and techniques for storage, handling, and treatment. The scale and industrial nature of the large components of the ship often require solutions which are in part adapted from modern industrial facilities and practices.

This paper will describe the work of the USS *Monitor* conservation project and its efforts to preserve the vessel's industrial steam technology. The research and conservation of the *Monitor*'s mechanical components such as the Worthington pumps, ventilation engine, and propulsion assembly will be described in case studies which illustrate specific challenges related to preserving marine-recovered industrial artifacts. TMM conservators face issues of scale (the engine weighs approximately 30 tons [27 metric tons]), the practicality and process of disassembling and reassembling complex composite artifacts, the benefits and problems associated with using modern technology to study and treat historic industrial technology, the adaptation of standard treatment methods to unique objects, and decision-making regarding the safe and effective display of complex technology.

Introduction

The American Civil War ironclad USS *Monitor* (1862) is an icon of naval history and a technological marvel. *Monitor*'s innovative design featured armor plating; a vibrating side-lever steam engine; the world's first ship-mounted, steam-driven rotating gun turret; and numerous other advances that influenced the technological development of all subsequent naval ships. The *Monitor* sank in the Atlantic Ocean off Cape Hatteras, North Carolina, on December 31, 1862, only nine months after engaging the Confederate ironclad CSS *Virginia* (1862) in the Battle of Hampton Roads. In 1973 researchers discovered the remains of *Monitor* in 240 feet of water. After extensive research and planning, the National Oceanic and Atmospheric Administration (NOAA) and the US Navy began excavating and recovering the significant components of the *Monitor* for treatment at The Mariners' Museum (TMM) in Newport News, Virginia.

This paper will describe the USS *Monitor* conservation project and its efforts to preserve the ship's industrial technology. The history of the design and construction of USS *Monitor* is providing valuable insight into the technology employed and, as a consequence, guiding the approaches adopted by conservators when dealing with the large objects and sophisticated engineering of the period. Case studies of the Worthington bilge pumps, ventilation engine, and propulsion assembly conservation treatments will highlight the aforementioned issues.

Deterioration in Marine Environments

The preservation of historic industrial materials from marine archaeological sites is significantly different than those excavated from terrestrial burial or those preserved in non-archaeological contexts. Depending on the material type and the salinity, water depth, pH, oxygen availability and other environmental factors artifacts may be relatively well preserved, or suffer severe deterioration in the time they lay submerged on the ocean floor. [1] The presence of chloride salts in seawater is particularly detrimental to metal artifacts as they promote corrosion. Metals, particularly iron, form a thick surface layer called concretion composed of corrosion products, calcium, sediments, and marine life. While concretion formation is part of the deterioration process of marine metal artifacts, it can also be beneficial in that it can slow down corrosion rates and preserve other artifacts, including organic materials, which may become incorporated into the concretion matrix.

The process of archaeological recovery also affects the preservation of marine material. While it affords the opportunity for thorough conservation and successful stabilization, it also disrupts the artifacts' physical and chemical equilibrium and exposes them to higher levels of oxygen than were present in the submerged burial environment. In the case of metal artifacts, this can lead to higher corrosion rates and further loss of material unless preventive measures such as controlled aqueous storage conditions and cathodic protection are taken.[2] The recovered artifacts required controlled aqueous storage as a pre-treatment to prevent rapid deterioration upon excavation.

Treatment Goals

The primary goal of the USS *Monitor* conservation project is stabilization of the artifacts recovered from the wreck for display and study at The Mariners' Museum. The marine archaeological context of the *Monitor* material necessitates the removal of sediments and concretion, desalination, dehydration, and storage in controlled environmental conditions for all artifacts. In the case of complex mechanical assemblies such as the Worthington pumps and ventilation engine, artifacts are disassembled whenever possible to allow more extensive treatment and effective desalination of all surfaces. The recovered artifacts would require controlled pre-treatment storage indefinitely and would deteriorate over time, in some cases quite rapidly, without these steps. Mechanical components then require re-integration and re-assembly following stabilization treatments in order to present as clear a picture as possible of the appearance and function of the original object.

Thorough documentation of the objects before, during, and following conservation and a detailed description of the conservation treatments used is one of the most important aspects of the conservation process. Documentation includes the recording of any details of the materials used, manufacturing techniques, and evidence of the working life of the object. Analyses such as material characterization and metallography performed in order to guide conservation treatment also yield important information on the materials and industrial processes used to produce the artifacts.

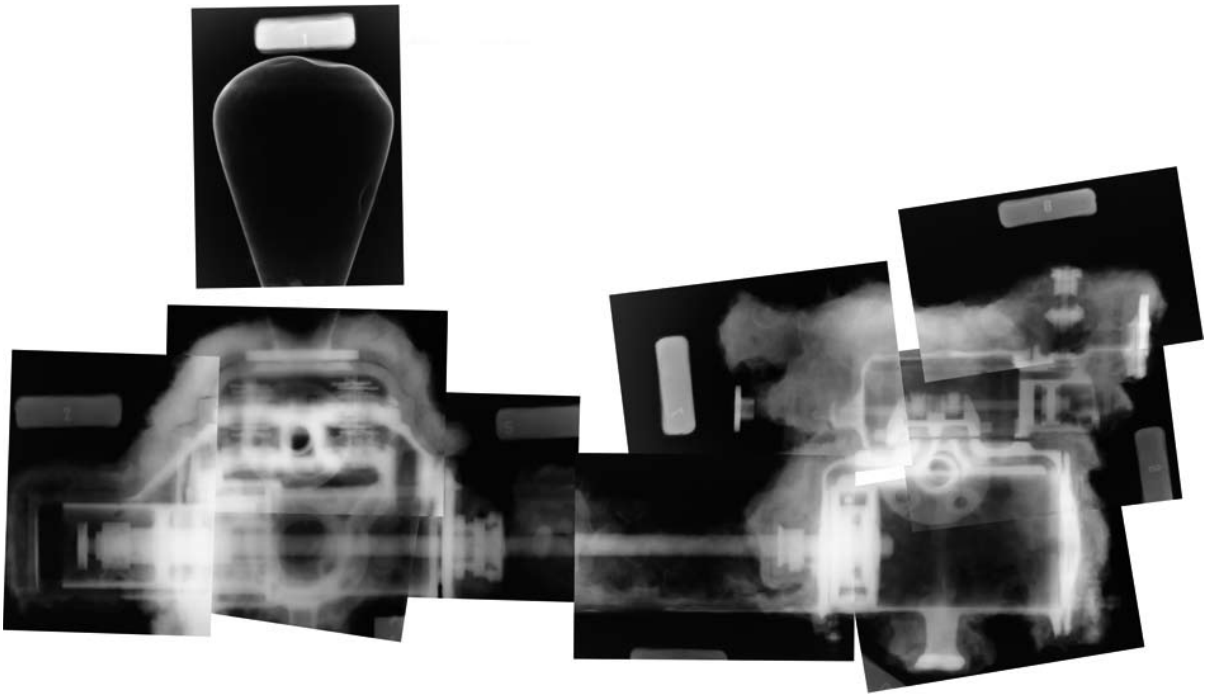


Figure 1: X-radiograph mosaic of USS Monitor port side Worthington pump.

Worthington Pumps

The Worthington direct-acting steam pump was a distinctly American invention patented in 1844. Its primary advantage was compactness and lightness of weight when compared to the then customary beam and flywheel pumps. Henry R. Worthington established manufacturing facilities in New York which were located close to the USS *Monitor* construction site. Two of these pumps were installed in USS *Monitor* and we believe them to be "off-the-shelf". The pumps were mounted port and starboard in the engine room. They pumped boiler feed water, served for firefighting, cleared the bilge, and had other uses. They likely are the oldest surviving examples of a Worthington design. [3]

The pumps were initially stored in a pH 12 sodium hydroxide solution upon recovery to prevent corrosion before active conservation treatment began in 2007. Investigation of these components began with documentation and x-radiography of the port pump. Visual examination determined that the pump body casting had cracked during the wrecking event and had rotated 90 degrees around the pump shaft, but the condition of the pump and internal components beneath the concretion layer was otherwise unknown. X-radiography with an 8 MeV linear accelerator was performed at Northrop Grumman Newport News Shipbuilding yielded excellent penetration and high quality images (Figure 1). All of the internal components such as the steam piston, slide valves, water plunger and poppet valves could be clearly seen, as well as the differences in density between the graphitized cast iron body and the well preserved copper-alloy components. The x-rays were invaluable in planning the deconcretion and disassembly of the

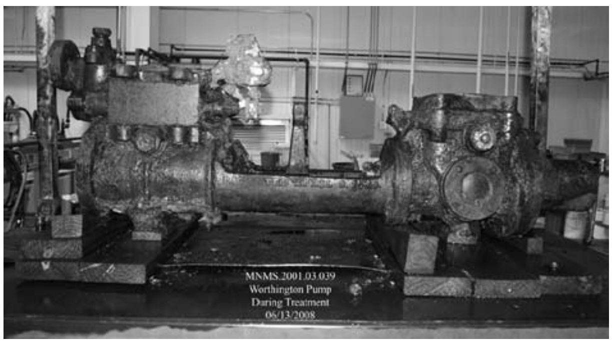


Figure 2: Starboard Worthington pump during deconcretion. Note the patent date of April 3, 1849 on the side of the cast iron cradle.

Figure 3: Disassembled pump components awaiting electrolytic reduction.

port pump, as it was possible to judge the exact depth of concretion to remove before reaching the original surface of the object, and to better understand the configuration and location of internal components.

Deconcretion and disassembly of the port pump was accomplished using a variety of hand tools such as hammer and chisel, scalpels, plastic and hardwood modeling tools. Pneumatic air-scribes were used to break up and remove concretion. Flame deconcretion was also used to remove concreted sediment from copper alloy and some iron components. [4] During deconcretion, conservators uncovered manufacturer's casting marks on the pump cradle that identified the maker, model number, and patent number. Although the preservation of original shape and casting details was excellent, the surface had become very soft due to loss of metal. Marine-recovered cast iron loses much of its strength due to the process known as graphitization, in which iron in the outer surfaces is lost to corrosion, leaving behind a soft graphite matrix. [5] As a result, great care was taken in handling and cleaning the surface of the pump's iron castings (Figure 2).

In many cases the wrought iron fasteners had completely corroded away, allowing components such as cover plates to be removed by carefully separating the plate from the rubber gasket with a scalpel or long saw blade and removing the component. In areas where copper alloy fasteners were used, the preservation of the bolts and threads was much better, and could be unscrewed as originally intended using off-the-shelf or custom-made tools padded with rubber, foam or cloth to prevent damage to the original parts.

Disassembly challenges varied with the design, type of alloys involved, condition of fasteners, and the presence and condition of rubber gaskets or sealing material. Parts which had become firmly adhered to each other, particularly due to galvanic corrosion at interfaces between iron and copper alloy components, were much more difficult to separate. In some cases, limited pressure was applied using ratcheting rigging straps to gently pull components apart. The weakness of the graphitized cast iron was an important consideration during disassembly. Visible cracks and loose fragments indicated that there was a limit to the amount of force which could safely be applied to loosen and separate components. The disassembly of mechanical parts is often easy when their condition is poor and much more difficult when their condition is good. This paradox must be addressed on a case-by-case basis when making decisions about disassembly. Despite these challenges, conservators and technicians disassembled the pump into 57 component parts that were individually documented and catalogued prior to further treatment (Figure 3).

Following disassembly, the port pump components were placed in an electrolytic reduction (ER) treatment which, when carefully applied, has been shown to be very effective in treating marine-recovered metal artifacts. [6] Electrolytic reduction serves three functions in the treatment of marine recovered metals; to reduce corrosion products, to loosen concretion and sediment, and to increase the diffusion rate of chloride ions out of the metal. [7] A 1.0% sodium hydroxide (NaOH) solution in de-ionized water at pH 12 was used as the electrolyte, with an expanded mesh 316 stainless steel anode. Artifact connections were made by using stainless steel bolts threaded into original threads in the castings, or by using undersize bolts through non-threaded holes secured with stainless steel washers and nuts. A potential of -0.950 V vs. standard hydrogen electrode (SHE) was initially applied which produced some hydrogen evolution useful for removing fine amounts of remaining concretion and corrosion products. As the treatment progressed, the potential was reduced to -0.750 V. vs. SHE to continue chloride extraction

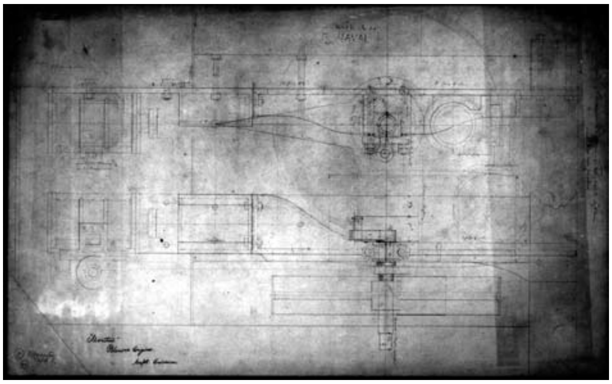


Figure 4: Detail of ventilation unit from USS Monitor. [10]

without hydrogen bubbling. Chloride concentrations in the solutions were measured with potentiometric titration and ion-specific electrodes. The solutions were monitored regularly and exchanged for fresh NaOH solution and the solution changed when a consistent concentration was reached the chloride concentration stabilized. After approximately 1 year in treatment and many solution changes, the chloride levels were consistently at 10 parts per million (ppm). This extraction level was acceptable and indicated that the port pump components were nearly ready for rinsing, final cleaning, dehydration, coating, and reassembly. The cast and wrought iron parts of the pump will be coated with tannic acid [8] followed by coating with Acryloid B44 clear acrylic resin with a matting agent. Copper alloy components such as the connecting rod will be coated with Incralac. [9] Some components, such as the copper alloy air-flask, have already been fully conserved. The starboard Worthington pump has been treated in a very similar way, with the exception that conservators made greater use of electrolytic reduction to loosen concretion and help separate components during the disassembly process.

Ventilation Engine

Ericsson is widely credited as the first designer to apply a forced draft system to a steam vessel. He designed two forced-air ventilation units to draw air from the deck and into the engine compartments. This measure was intended to improve both crew conditions and engine efficiency. Each unit was composed of a centrifugal fan powered by a small auxiliary steam engine (Figure 4) for an original drawing of the ventilation unit. The fan is shown at the right of the drawing while the auxiliary steam engine is shown as a cylinder at the left of the drawing.

Archaeologists recovered one auxiliary steam engine and part of its wall-mounting frame. Much like the Worthington pumps, the ventilation engine was heavily concreted. This hard layer adhered to the artifact and obscured the original metal surfaces. The artifact was stored in a pH 12 solution of tap water with sodium hydroxide for many years before hands-on treatment started. The engine weighs at least 600 pounds and cannot be moved without mechanical assistance. To minimize risk of damage from handling, a galvanized steel platform was constructed to provide support during lifting while still allowing conservators complete access to the ventilation engine. Conservators use a 5-ton overhead crane with lifting straps attached to the steel platform, rather than to the artifact, to move the whole assembly.

Conservators planned on documenting the ventilation engine with similar techniques used on the Worthington pumps. However, x-ray images provided insufficient detail even at the maximum voltages and exposures available (300 kV). Conservators therefore used visual assessments of

Figure 5: Ventilation engine before and after deconcretion.

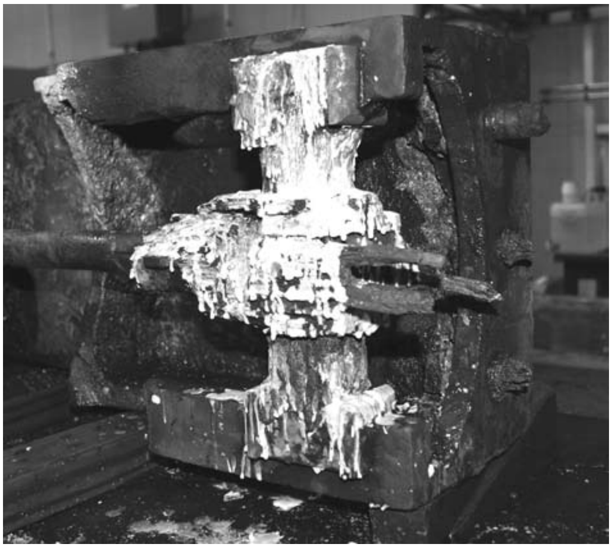


Figure 6: Cyclododecane wax applied to the wrought iron crossbar of the ventilation engine.

the artifact and original drawings instead of X-ray images to locate original surfaces.

Hand tools such as chisels, flat-head screwdrivers, micro spatulas, Popsicle sticks, scalpels, hammers, and hand-held pneumatic scribes were used to remove hard concretion and soft sediment (Figure 5). The condition of the ventilation engine was consistent with that of the Worthington pump; cast iron components were structurally stable but fragile and graphitized, wrought iron parts were deteriorated with little to no original surface remaining, and copper alloy parts were in very good condition. A preliminary study determined that the density of the remaining cast iron is around 6.2 g/cm^3

Conservators observed that even slight water movement could disturb the tenuous hold between strands of wrought iron. To prevent this loss, liquid cyclododecane wax at 60^{o}C was applied to friable iron with brushes and disposable pipettes. Cyclododecane is a volatile organic wax that is applied as a melt to the friable metal. The solidified wax has been successful at preserving the remaining material since it was applied in October, 2008 (Figure 6). Cyclododecane wax can be completely removed through sublimation at atmospheric conditions or through application of warm or hot air. [11]

Once significant amounts of concretion were removed, the ventilation engine was connected to an ER circuit powered by a direct current rectifier. The artifact connection provided acceptable electrical conductivity throughout the iron casting with internal resistance around 20 ohms. Platinum-niobium coated copper wires were used as anodes for the ER circuit. The wires were cut into lengths of 1 meter and sheathed in perforated 1.5” PVC piping to prevent electrical shorts. The anodes were suspended from the platform frame with monofilament lines and steel hooks and positioned near the surface of the artifact. Conservators used their judgment to place the anodes in a configuration that would provide maximum coverage to the artifact (Figure 7).

Chloride diffusion into solution is monitored regularly and, as of February 2009, is around 2 ppm per day of immersion. The concretion and sediment removal due to ER has proven incredibly beneficial during disassembly.

As with the Worthington pump, the treatment goal is to disassemble the engine into as many components as safely possible for desalination and concretion removal. Initial disassembly attempts were futile due to adherent concretion and sediment. At first, only the frame end could be removed from the main casting. The fasteners between the two were completely corroded and the joint had no rubber gasket, allowing for simple disassembly. Other joints were tightly bonded due to intact fasteners, adherent gaskets, and sediment. Threaded fasteners often require modified tools for safe removal; standard crescent wrenches were filed down to fit a bolt head, wrenches and

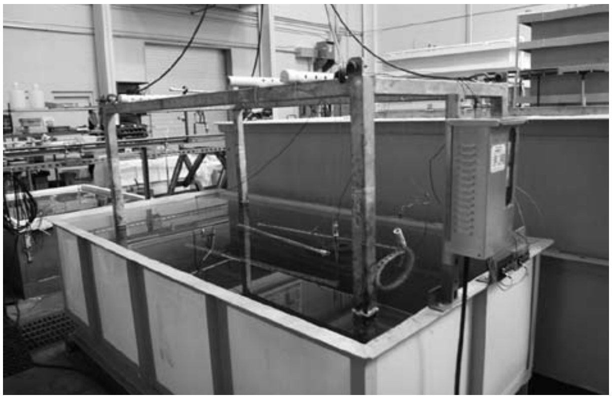


Figure 7: Electrolytic reduction setup for ventilation engine.

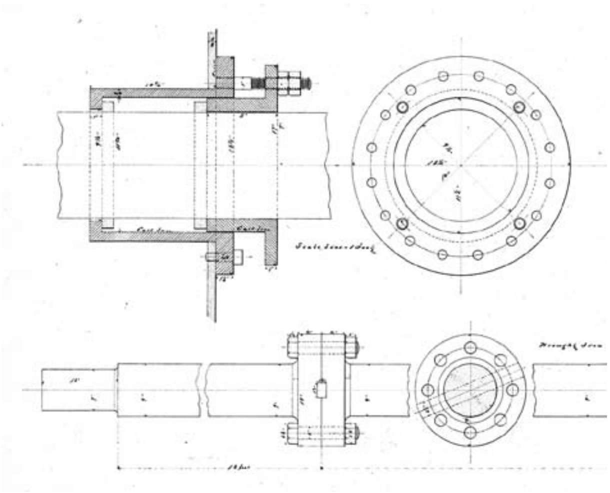


Figure 8: Detail of Monitor's packing seal and propeller shaft. [13]

fastener heads were padded to prevent damage, and unique wrenches were fabricated for unusual fittings.

To date, four components and seven fasteners have been removed from the ventilation engine. Components are removed as they become loose and are immediately treated. A specific disassembly goal is to separate the copper alloy components from the iron materials to prevent further galvanic corrosion. This has proved difficult despite the excellent condition of the copper alloy parts. The major treatment roadblock is the safe disassembly of components. Future work will focus on methods of removing corroded wrought iron fasteners from cast iron substrates and separating surfaces joined by rubber gaskets. End-point considerations such as replacement fasteners and fit tolerances will also be addressed before re-assembly is started.

Packing Seal

A complex 30-ton side-lever steam engine was the heart of *Monitor*'s propulsion system. It directly powered a wrought iron propeller shaft and 9-foot diameter cast iron propeller. The packing seal, also known as a gland seal or stuffing box, is a lesser known but important feature of the propulsion system. The packing seal was a water-tight sleeve around the shaft that prevented large volumes of water from leaking into the hull while allowing the propeller shaft to rotate freely. NOAA and Navy salvage divers recovered a ten-foot section of *Monitor*'s wrought iron propeller shaft including the packing seal assembly in 2000.

Figure 9: Packing material and aft packing ring revealed by crack in cast iron.

Monitor's packing seal (Figure 8) consists of two ¾-inch diameter metal packing rings and a currently unidentified fibrous packing material, possibly oakum. [12] The rings and packing material are housed within two overlapping cast iron sleeves. The aft-most cast iron sleeve was originally fastened to *Monitor*'s hull with sixteen ¾-inch diameter bolts and overlaps the forward cast iron sleeve. The forward sleeve is bolted to the aft sleeve with four one-inch diameter bolts and four sets of double hex nuts. *Monitor*'s crew would compress the packing material within the sleeves by tightening the nuts. The packing seal section of the shaft packing seal assembly surrounds the aft-portion of recovered propeller shaft, which is composed of two 9-inch diameter shaft sections that are flanged and fastened with eight 2-inch bolts. The flanges surround a 19" x 2-1/2" x 1-1/2" wrought iron key, which prevented the bolts from fretting due to heavy torque and likely indicated flange and bolt alignment.

Upon recovery in 1998, conservators used mechanical methods, including hammers, chisels, and pneumatic hand tools, to remove concreted sediment from the surface of the packing seal assembly. The combination of these methods was successful at removing the majority of concretion, and the process revealed details about the physical condition of the assembly. The 9-inch diameter wrought iron coupled shaft was visibly bent, approximately a few degrees off centerline. This likely occurred as a result of

Figure 10: 11-3/4" bolt removed from shaft flange.

the wrecking process, during which the *Monitor* slammed stern-first into the seafloor. The majority of the deformation is aft of the bolted flange and in close proximity to the packing seal. In consequence, a 6-inch x 8-inch section of the aft cast iron packing sleeve fractured, revealing the aft packing ring and some packing material (Figure 9). The packing material is heavily impregnated with iron corrosion products and concreted sediment.

Conservators have also utilized electrolytic reduction on the packing seal. The assembly currently rests in a 1.0% sodium hydroxide solution in de-ionized water, pH 12. The artifact is wired to a rectifier with stainless steel connections including threaded rods and alligator clips. The rectifier is also hooked to platinum-niobium wire anodes. An initial potential of -0.978 V vs. SHE proved effective at surface cleaning and reducing corrosion products. The artifact remains in electrolytic reduction, and chlorides continue to be released into the solution.

Conservators opted to partially disassemble the shaft coupling. Prior to disassembly, conservators documented and reproduced the wrought iron nuts by molding them with an algae-based dental molding material. This material proved highly effective because it sets in a warm, wet environment, provides detail, and cures quickly. Conservators then used a commercial gypsum material to create casts of the individual nuts. Modern pipe wrenches and a chain wrench with rubber and canvas padding were used to remove the eight wrought iron nuts that secure the bolts to the flanged shaft assembly. The threads were well preserved even though the surfaces of the fasteners were highly corroded. Removal of a single bolt revealed well preserved inner metal surfaces that appeared unaffected by 138 years of immersion in salt water (Figure 10). Conservators decided not to separate the coupling because of the tight tolerances between the two joined surfaces and the remaining fasteners, and they also opted against removing the cast iron packing gland because of the fragility of the graphitized cast iron. Treatment of the packing seal is now in its final stages of desalination before drying, surface coating and re-assembly.

Conclusion

Mariners' Museum conservators have expanded their knowledge insight into the treatment of large industrial artifacts by documenting and treating the Worthington pumps, ventilation engine, and packing seal assembly. This process continues to provide insight into the materials and fabrication techniques used by Ericsson and other shipbuilders to expand the art of shipbuilding in the 19th century while laying the groundwork for the next stage in the conservation of *Monitor*'s large mechanical components, including the condenser and vibrating side-lever steam engine.

The general treatment method for large marine-recovered artifacts from *Monitor* includes many steps. Metal artifacts are stored in corrosion inhibiting solutions such as sodium hydroxide. Each object is then examined, documented, and investigated to better understand their composition and condition. Active treatment begins with manual and electrochemical removal of concretion and corrosion, followed by disassembly of component parts. Thorough desalination through chemical and electrochemical means is followed by dehydration, and application of protective coatings prior to re-assembly and museum display.

Experience in the treatment of these large marine-recovered industrial artifacts has demonstrated that a multitude of skills such as rigging, welding, plumbing, fabricating, electrical work, engineering, metallurgy, photography, and x-radiography are necessary to support the conservation effort. Substantial facilities are also required, including large volumes of chemicals and de-ionized water, rugged and flexible workspaces, cranes and rigging equipment, storage and treatment tanks, and artifact storage areas. The combination of these factors and good treatment practices are necessary when conserving large industrial artifacts.

Authors

Eric Nordgren, David Krop, Erin Secord, Elsa Sangouard, Michael Saul, Gary Paden and Gerry Hanley
The Mariners' Museum
100 Museum Dr.
Newport News
Virginia, 23606 USA
Email contact for the corresponding author: enordgren@marinersmuseum.org

Endnotes

[1] MacLeod, Memet.
[2] Memet, 166.
[3] Hanley, 2.
[4] Carpenter 31-2.
[5] Memet, 162.
[6] Degrigny, Degrigny and Lacoudre, Hamilton, North.
[7] Degrigny.
[8] Pelikan.
[9] Acryloid B44 with the addition of Benzotriazole and UV light absorbers.
[10] Peterkin, 67.
[11] Rowe and Roziek, 21.
[12] 'Tarred hemp or manila fibres made from old and condemned ropes which have been unpicked.' Kemp, 610.
[13] Peterkin 339.

References

Carpenter, Jon. A review of the Physical Methods Used to Remove Concretions from Artefacts, Mainly Iron, Including Some Recent Ideas. *Bulletin of the Australian Institute for Maritime Archaeology*, 14(1): 1990 pp. 25-42.

Degrigny, Christian. Du dégagement des canon part électrolyse à la consolidation réductrice des plombs altérés. *Journées des Restaurateurs en Archéologie.* Cahier technique de l'ARAAFU. 2000. pp 32-35.

Degrigny, Christian and Lacoudre, N. Les techniques électrolytiques. In: H. Meyer-Roudet, Ed. *A la Recherche du metal Perdu*, Errance, 1999. pp. 114-127.

Hamilton, Donny L. *Basic Methods of Conserving Underwater Archaeological Material Culture*. Legacy Resource Management Program, U.S. Department of Defense, Washington, D.C. 1996.

Hanley, Gerald S. The USS *Monitor* Worthington Steam Pump, Design and Operation. Unpublished report, The Mariners' Museum, 2009.

Kemp, Peter ed. The Oxford Companion to Ships and the Sea. London, Oxford University Press, 1976.

MacLeod, Ian. A new corrosion mechanism for iron shipwrecks in seawater : A study of the Fujikawa Maru (1944) in Chuuk Lagoon, Federated States of Micronesia. In: *Preprints of the 14th Triennial Meeting, The Hague, 12-16 September 2005*. James and James, 2005.

Memet, Jean Bernard. The corrosion of metallic artifacts in seawater: descriptive analysis. In: Dillman, P. et al (eds.). *Corrosion of metallic heritage artifacts, Investigation, conservation, and prediction for long-term behavior*. Woodhead Publishing, 2007, pp. 152-169.

North, Neil A., Conservation of Metals, in C. Pearson, Ed., *Conservation of marine archaeological objects*, Butterworths, 1987, 207-252.

Pelikan, J. B. Conservation of Iron with Tannin. *Studies in Conservation* 14(3): 1966 pp.109-115.

Peterkin, Ernest W, Capt. *Drawings of the USS* Monitor. USS *Monitor* Historical Report Series, Vol. 1 No. 1. National Oceanographic and Atmospheric Administration, 1985.

Rowe, Sophie and C. Rozeik. "The uses of cyclododecane in conservation." *Reviews in Conservation.* Number 9, 2008. pp 17-31.

Case Study of a Ducretet Inductor Coil: Conservation Problem or Visual Wonder?

Sharon Penton

The paper explores the issue of conserving industrial objects in pristine/working condition or maintaining them as they are. The decision process is explored via a case study of the National Science Museum's decision to preserve a 19th Century Ducretet inductor coil in a deteriorated state. The conservation of the Ducretet inductor coil is an example of how by considering alternative ways of preserving and presenting industrial objects we can retain more than just the physical object. The physical alterations in the appearance of the inductor coil leave a profound impact on the observer and thus altered the object's value, returning it to its original state would destroy this unique item. The object's function, originally one of an instrument representing early scientific technology, has changed with it becoming a unique oddity with a strong visual impact.

The function and value of an object can change. This is discussed drawing on examples from other areas of cultural heritage. The approaches to conserving these examples are compared with that of the inductor coil and reflect how 'experiencing' the object becomes an important part of its value. This value influences how conservation will be carried out.

Introduction: the value of industrial objects

When it comes to deciding on how best to treat cultural heritage, it is a challenge for conservators to incorporate differing values. Values like the function, historic significance and the aesthetic quality of cultural heritage are difficult aspects to pin down and define. Due to the very nature of industrial objects these issues become even more complicated. Function is key to understanding most industrial objects. Museums and other institutions display such materials to educate the public about how the objects work and the roles that they played in industry [1].

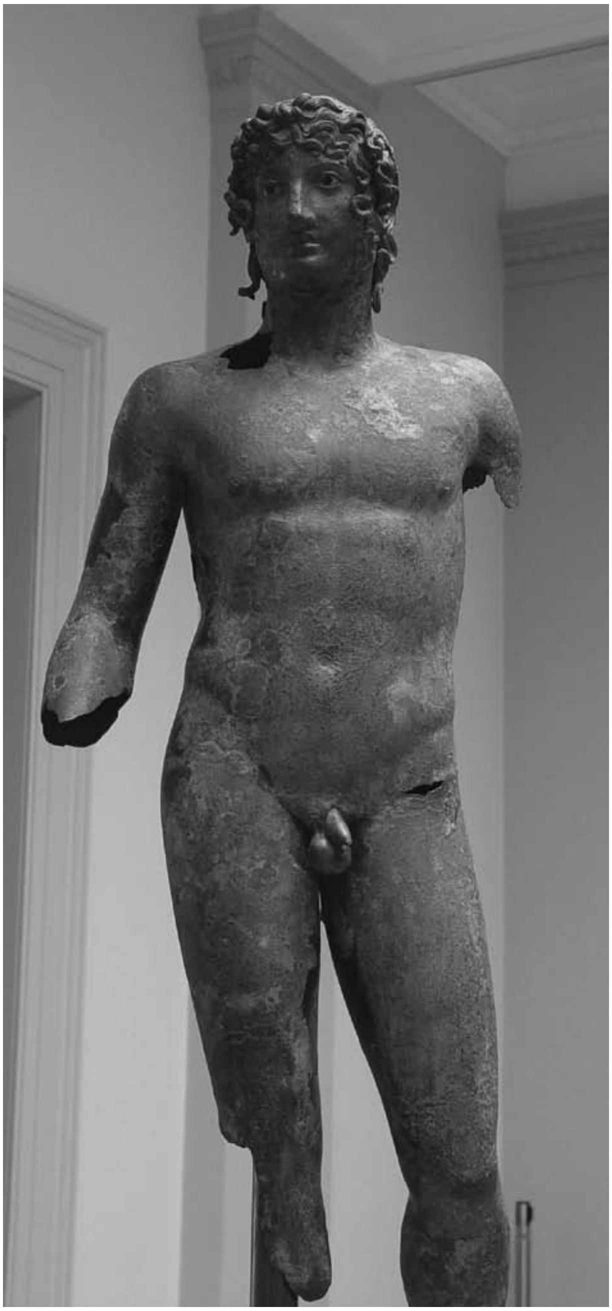


Figure 1. 1st Century B.C. bronze statue of a young man. Found in Egypt and on display at The British Museum.

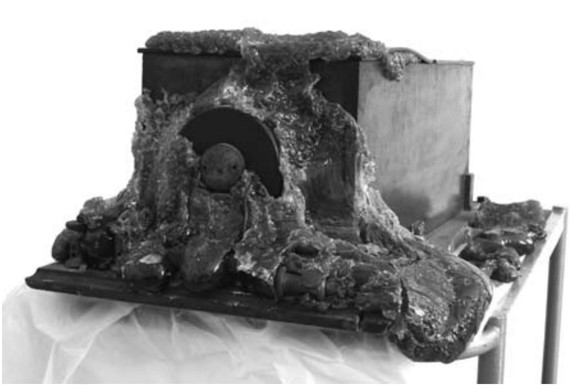


Figure 2. The Ducretet inductor coil from the National Science Museum, London.

These machines and instruments were designed to perform a function. To understand that function society has traditionally expected the object to continue to carry out that function to some extent and to appear as it did when it was in use, if not new.

Retaining objects in working condition is not always realistic and can result in wear and tear leading to replacement of components [2]. Consequently the question of how extensive restoration affects authenticity must be considered [3]. To overcome these obstacles the conservator determines what is acceptable change and how invasive the conservation treatment should be. While some changes are negative and are considered damage, change can also enhance an object's value and is desirable [4]. When conserving a painting a conservator might choose to leave in place old discoloured varnishes because audiences expect the piece to have a certain look of age. A patina on classical bronze statues, shown in figure 1, increases its value and so is left in place; originally this statue would have been polished bronze.

With industrial objects therefore the problem is to determine if and how much change is acceptable when the objects function becomes affected. Thus the curators and conservators of industrial objects have to make compromises and struggle to achieve a balance that keeps the best for the object in mind while still incorporating the wants and desires of stakeholders. This paper presents an object whose physical appearance was so greatly affected by deterioration that its function changed from an industrial object to visual oddity (figure 2). Recognising the importance of this impact and the 'experience' when seeing the object, the conservators involved sought a compromise between preserving the historic integrity of the object while still retaining its aesthetic impact. Through a discussion of the decision-making processes involved for this Ducretet inductor coil this paper aims to present the challenges of balancing the various values placed on industrial objects and explains how their functions can change. A comparison is made with how functionality and value was incorporated into the treatment of other materials from two different areas of cultural heritage and reflects how these challenges are not unique to industrial objects.

A Ducretet inductor coil

This Ducretet inductor coil is part of the Wellcome Collection, a vast collection of objects and instruments pertaining to medical science [*5*]. The object was one of a group on permanent loan to the National Science Museum (NSM), London since the 1980s. In 2006 it was called to the attention of the conservation department because of its remarkably altered state. Visual examination clearly reveals that the object has suffered structural damage resulting in the breakage of its base and the seepage of a resinous insulating material which is obscuring much of the object's front (figure 2 and 3).

Condition aside, this inductor coil presented an unusual problem for the conservators and curators at the NSM by blurring the lines between what is a historic object and what is an aesthetic or artistic one. Not only has the function of this object changed

Figure 3. The Ducretet inductor coil viewed from the side.

but so has its physical appearance and value. These new attributes would have to be considered in the conservation treatment.

A systematic decision making process was employed and can be summarised in four stages.

1. Information: Gathering information involved searching through historic records and patents to learn about the objects origin, followed by further research into the history of inductor coils. In addition, an analytical investigation was needed to identify the various materials from which the object is made.
2. Condition assessment: Though the physical condition of the object was obvious an assessment of its stability was needed to determine if the materials were in immediate danger of further deterioration.
3. Establishing significance: Defining the object's value as a historic object and its relation to the museum's collection.
4. Conservation treatment: A conservation treatment was needed which was appropriate to the needs of the object and how it would be used within the collection.

Stage 1: Information

Background research concluded this coil was built by Eugene Ducretet (1844-1915). Ducretet was a manufacturer of scientific instruments in Paris, France [7]. The most probable construction date for this particular instrument is the early 1890s. Ducretet's inductor coil is typical of French designs at the time, consisting of a large rectangular box and filled with some kind of resin to act as an insulator [8] (figure 5). Analytical results determined the box to be constructed of mahogany with brass, bone and vulcanised rubber fittings and an iron core. The resin was identified using FTIR as poor quality shellac combined with pine rosin. This is also supported by the historic information gathered and explains the higher glass transition temperature observed for the material.

The first inductor coils were created in the mid 1800s to transform low voltage electricity into high voltage electricity. In its most basic form, an inductor coil consists of two coils of wire, a primary and a secondary, wrapped around an iron core. An electrical charge of high current and low voltage is passed through the primary coil which induces a low current but with high voltage in the secondary coil [9].

Stage 2: Assessment of Condition

Based on the information gathered it was concluded that the inductor coil was in no immediate threat of further deterioration. The cause of the damage to the base of the object was linked to improper handling when it was lifted from its packing crate. Furthermore, the cause of the resin seepage was discovered to be that the object was stored on its end while in the crate.

There are no signs of corrosion on any of the materials nor do they pose any harm to surrounding objects. The investigation concluded that what damage there is has already taken place and, except for the continuing flow of the resin, the object is in stable condition.

Stage 3: Establishing Significance

The historic significance of the object is fairly obvious. This machine is an example of early electrical engineering and represents part of the life and accomplishments of Eugene Ducretet, who aided the mass production of scientific instruments for wider use. However, it had also become apparent that due to its physical alterations this object had taken on a new function as an aesthetic entity whose visual impact was appreciated by audiences.

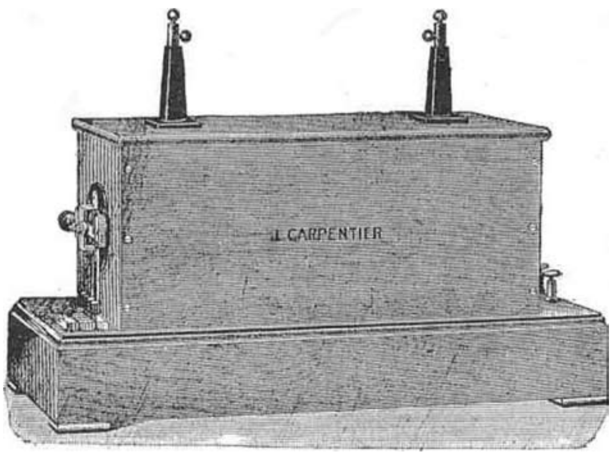


Figure 4. Illustration of a typical 19th century French manufactured inductor coil, from Armagnat 1908.

During its time in storage at the NSM and after the seepage was discovered, the inductor coil received a lot of attention. This included staff who came to call it simply the 'oozing object'. People were interested in the coil because it was so unusual and visually spectacular. A visiting author who came upon the coil during a tour of the museum's stores was even inspired to write a short story about it. In Hill's story 'Impossible Things' he gives a mystical depiction, explaining that the leaking resin is a living being and bestowing upon it magical healing powers (figure 6 and 7).

When deciding on how to precede the conservators would have to take into consideration the newly found fame and appreciation the inductor coil had acquired.

> *"'People say it is living and that it will cure the one who owns it.'*
>
> *'Cure them of what?'*
>
> *'Of many things...'*
>
> *'...Then you expect me to believe this is something people put their faith in. Is that it? But I have no proof that it is anything other than an interesting piece of medical equipment, and in rather less than fair condition. Why on earth should I believe it is anything more?'*
>
> *'So it is a mystery'" [6]*

Figure 5. Excerpt taken from Hill's story 'Impossible Things'.

Stage 4: Conservation Treatment

When it came time for the conservators to decide on a course of action as to the object's treatment three options were explored.

a) Attempt to remove the resin and place it back inside the box then repair the damage to the base
b) Remove the resin entirely so a more thorough examination of the interior could be made and repairing the base or
c) To maintain the coil in its current condition.
The head of the department in conjunction with the director of the museum decided to leave the object in its current condition.

The reasoning was that there were other inductor coils in the collection which represented the same period and which were not affected by any alterations. It was felt the historic integrity of the object was retained. The coil's value as an example of early electrical engineering and scientific history and its significance as part of the life and achievements of Eugene Ducretet was saved through the act of investigation and the production of more in-depth documentation about the object. In fact many of the sources consulted are now out of print and difficult to access, had the object not come to our attention until a later date then the information may have been lost altogether and with it the better understanding gained about the other coils within the collection.

In this altered state the inductor coil provides an 'experience' and might even be appreciated as an aesthetic object. The other inductor coils within the collection are large wood and metal boxes which offer little visual stimulus or insight. The inability of these objects, and so many industrial objects like them,

Figure 6. Image of the inductor coil from Hill's story 'Impossible Things'.

to easily communicate their meaning to audiences is a problem that has confronted many curators of industrial collections [10]. Yet, this Ducretet inductor coil stops people in their tracks and makes them ask questions, it piques their curiosity and imagination.

The approach of NSM to maintain the 'experience' is bold and innovative; keeping the interests of the object in mind while attempting to explore new ways of understanding cultural heritage and its significance. Impact and experience have been identified as primary aspects of the inductor coil's value. The decision on treatment reflects these values. There are other instances where impact and experience of objects or places have influenced the way things were conserved. The following section presents two examples of very different types of objects, in one case a building, where the conservation approach was directly influenced by the experience the objects provided audiences.

Comparison with other types of cultural heritage

First, the monumental carillon clock by Isaac Haberecht, displayed in the British Museum (figure 8). The approach to conservation chosen by The British Museum in relation to this piece focused on the aesthetic value and experience had when viewing this object, yet it required a very different conservation treatment than that chosen for the inductor coil. In this instance, the technological quality and artistic meaning behind the clock, is not completely appreciated unless seen in motion. Every hour it plays *Vater Unser* ('Our Father'), written by Martin Luther, as Christ and Death represented on the first tier strike the hour. The other tiers represent the four ages of man and the Madonna and child followed by a procession of angels.

Unlike Ducretet's inductor coil, the mechanical function of the clock is necessary to achieve the full impact of the object and what it represents. In this case the original function is still intact, the artist intended to combine our senses of sight and hearing to convey a message about mortality and spirituality. For this reason the museum maintains the clock in working order and risks the eventual wear and deterioration of the mechanisms involved.

In archaeology we also see issues arising about changes in function and value. Few archaeological ruins start out as deliberate monuments [11]; they have a function for which they were built; for example to provide protection and defence. However, over time they have deteriorated and lost their original function only to be attributed with new ones perhaps because and in appreciation of the aesthetic value or the sense of place they invoke.

One such example is Wigmore Castle (built c. 1068). English Heritage spent one million pounds on a conservation project for the castle in 1999 [12]. The

Figure 7. Isaac Haberecht's monumental carillon clock, Stroudsburg (1583). On display at the British Museum.

Figure 8. Wigmore Castle after conservation. Photo by Jeffery L. Thomas 2002.

significance of this project was that the castle was consolidated as it was in a ruined state. Like the inductor coil the function had changed and this was incorporated into the conservation treatment. After conservation the site looked little different than it did before the project started (figure 9). This approach was decided because the 'romantic ruins' of the castle were such an integral part of the landscape and the experience had by visitors.

This experience is important as people feel a connection with the past [13]. There are other examples of castles from this period which are presented in a state of restoration yet the experience had is not the same. A fully restored structure lacks the sense of decay that some find desirable and also a sense of discovering a place seemingly untouched by the modern day. Thus, it was the goal of English Heritage to prevent the ruins from collapsing while preserving not only the material fabric but also the sense of place it created.

Conclusion

Some objects need to be seen performing their intended function in order to be fully appreciated and experienced. Yet function is not simply a mechanical concept; it can go beyond the physical material. An object's function can also be to give a sense of nostalgia, an experience of discovery, or they can act as portals into the unknown. Simply put the experience is part of an object's function; therefore this value must be incorporated into the conservation of the place or object.

In the case of this Ducretet inductor coil the function and value of the object have gone from that of a scientific instrument, to an example of industrial innovation from times gone by, to that of a visual oddity appreciated for its aesthetics and impact on the senses.

What is so innovative about this approach of leaving the coil in a deteriorated state, is the way it attempts to deal with the ever increasing demands being put on heritage institutions. Both the public and professionals want greater access to objects [14, 15] and wider interpretation. People expect more from museums than to just be a repository for objects; they go because they want to be provided with learning through demonstration [16]. They also want to have a connection with the past and with objects through experiencing and interacting with them [17].

Currently the inductor coil is back in storage at the NSM but discussions have begun for an exhibit to be focused on conservation and decision-making. The inductor coil would be a centre piece in such an exhibit. The exhibit would be a chance to assess people's reactions to various forms of conservation treatment and ask them for their opinions about how cultural heritage is treated. Perhaps even ask whether they think the right decision was made about the inductor coil or if they would prefer to have it restored? However, I believe the object in its current condition has the potential to stop people in their tracks and makes them ask 'what is that?' People suddenly become engaged and transfixed by the object which causes them to want to learn more about it. Through this change in value and function the Ducretet inductor coil has been given a second life.

Author

Sharon Penton,
Preventive Conservator
The British Museum
Great Russell Street
London, WC1B 3DG
UK
e-mail: spenton@thebritishmuseum.ac.uk

Acknowledgments

I would like to express my gratitude to all the staff at the National Science Museum who helped with the research on this object and especially Jannicke Langfeldt, Head Conservator, for getting me involved in the project. Finally, I would like to thank Dean Sully, Lecturer at UCL, for his encouragement and enthusiasm during work on this object.

References

[1] Butler, S. (1992), *Science and Technology Museums*, Leicester University Press, Leicester.

[2] Keene, S. (1994), 'Objects as Systems: A New Challenge For Conservation', in *Restoration: Is it Acceptable?*, The British Museum Occasional Papers 99, A. Oddy (ed), The British Museum, London, p. 19-25.

[3] Mann, P. R. (1994), 'The Restoration of Vehicles for Use in Research, Exhibition, and Demonstration' in *Restoration: Is it Acceptable?*, The British Museum Occasional Papers 99, A. Oddy (ed), The British Museum, London, p. 131-138.

[4] Ashley-Smith, J. (1995), *'Definitions of Damage'*. Available at http://palimpsest.stanford.edu/byauth/ashley-smith/damage.html accessed on 20 February 2008.

[5] McEwen, N. , *Ducretet and Roger, Paris France: An Unusual Spark Key ca.1915-1919*. Available from http://www.telegraph-office.com/pages/DuCretet_and_Roger_key.html accessed on 25 March 2007.

[6] Hill, T. (2003), 'Impossible Things', in *The Phantom Museum: and Henry Wellcome's Collcection of Medical Curiosities,* Profile Books, Ltd, London.

[7] *Wellcome's World.* Available at http://library.wellcome.ac.uk/node620.html accessed on 18 September 2007.

[8] Armagnat, H. (1908), *The Theory, Design and Construction of Inductor Coils*, McGraw Publishing Company, New York.

[9]Hare, A. (1900), *The Construction of Large Induction Coils,* Methuen & Co., London.

[10] Butler, S. Ibid.

[11] Munoz Vinas, S. (2005), *Contemporary Theory of Conservation,* Elsevier Ltd., Amsterdam.

[12] Williams, R. (1999), *Wigmore Castle*. Available at *http://www.castlewales.com/wigmore.html* accessed on 20 February 2009.

[13] Lowenthal, D. (1985), *The Past is a Foreign Country*, Cambridge University Press.

[14]Henderson, J. And P. Manti (2008), 'Improving Access to Collections for Sampling' in *Conservation and Access : Contributions to the London Congress 15-19 September 2008,* eds. D. Saunders, J. H. Townsend and S. Woodcock, IIC, London, p. 115-119.
[15] Keene, S. Ibid.
[16] Butler, S. Ibid.
[17] Schouten, F. F. J. (1993), 'The Future of Museums', in *Museum Management and Curatorship,* Butterworth-Heinemann Ltd, Amsterdam, p.381-386.

Considering the changes of appearance of iron and steel objects during conservation

Karen Stemann-Petersen

Introduction

The "state of the art" in choosing protective coatings for iron and steel in collections of newer history and industrial heritage will be quite briefly presented. Objects containing forged iron, steel and cast iron alloys are in the following all designated as iron.

Possibilities and limitations for the use of clear and semi-transparent coatings should be judged and compared with protection of surfaces with several paint layers. The choice is between protected, painted surfaces looking very much as the original by means of artistic retouch in the top layer or considering whether a clear coating is protective enough and can present and reveal an original metal texture or ornamentation beneath. Clear coatings can actually change an object's looks just as varnish layers do on paintings.

Both the conservation and ethical values involved will be discussed. Thereby many aspects will be covered quite briefly and picture examples will not be fully debated. Discussion, with illustrations in colour, will be part of the conference presentation.

It has not been possible to divide the following text as in scientific articles. The starting point is sections on: 1) *Corrosion rates according to climate condition and iron surface,* 2) *General aspects of protecting iron with coatings* 3) followed by a case-story with more considerations on display and conservation: *Testing a decision-making model.* The last section: *Conclusion* is short, relying on the hope that the presented information will nourish the debate between conservators together with historians and conservation scientists.

The conservator and historian's standard ethical values for preservation and conservation are easy to maintain if historical iron only needs a light cleaning to remove dust from use or storage and is to be displayed or stored at low relative humidity. For unprotected iron placed at higher humidity and for iron with actively corroding surfaces, the same professionals will, of course, wish to protect the objects from rusting away, either by treatment or removal from corrosive surroundings. For display reasons, changing a sad and rust-stained object's appearance to something more presentable, may also be considered. Taking the first step in a treatment of iron and steel surfaces by removing rust layers however allows more access for oxygen to the corrosion zone and makes the metal surface more instable. Follow-up treatments become necessary.

This paper deals with conservation considerations for unstable iron objects that can not be placed at low relative humidity and rust-coated, sad-looking ones that are to be displayed.

Corrosion rates according to climate condition and iron surface

The corrosion rate of iron depends on climate conditions as well as the condition of the metal surface. The information in this section combines of general knowledge of corrosion science, conservation and experience. In preparation of the paper, there has not been time for a new literature review.

Conservators, as well as corrosion scientists, must consider the changes in stability of iron if it is moved to an area with a different climate or its surface is treated. Conservators can sometimes be involved in some cleaning of iron surfaces without facing the facts or having the necessary discussions with the involved curator or institutional customer. Before actions are taken on either large or small historical iron objects, a decision-making model should be applied so that all the facts are considered.

The instability of iron when subjected to wet surroundings is commonly known. Metallic iron will rust when in contact with oxygen and water vapour at both moderate and elevated relative humidity (RH). Water molecules from the atmosphere will be able to attach to the surface. Unprotected iron will deteriorate to form the minerals much as those from which it was extracted. The dry conditions needed for the stable preservation of iron depend on several factors. Very clean, evenly composed and polished steel surfaces (on polished tools, etc.) can stay rust-free longer than uneven or dusty ones under the same conditions.

Uneven access to oxygen over a metal surface causes local differences in potential and corrosion rate. Corrosion can thereby first be noticed in an iron construction's narrow caps or in cracks (crevice corrosion). It is the same situation when an iron angel of a knife corrodes more towards the wooden handle than on the visible areas. It is also important to consider if the iron is in contact with other metals (galvanic corrosion) or contaminated with salts, such as chloride.

Fig. 1 Some tools from workshops and farming are products of early industrial times and are exhibited in unheated houses at the National Museum's Open Air Museum. Ten years ago, the blade of the scythe seen above was de-rusted, painted with very thin layers of paint and retouch to look very much like steel. The otherwise stable surface now shows slight rust-stains at the sharp edge. This, however, is not obvious on the picture. In the middle is a carpenter's drill. A 10-year-old clear coating (maybe an alkyd lacquer we used then) hasn't completely prevented rust in the damp conditions. Notice that with its shiny clear coating it is not very natural looking. The plastic look is obvious even though it is not thick enough on the edges to prevent corrosion. The lower saw blade has now been conserved and treated with four coats of paint and retouched after an old clear coating had failed. As will be discussed later, my impression is that when viewed from a distance as museum visitors do, the two painted tools (the scythe and saw blade) look most natural, as when used.

Where there is rust, compact even layers can shield while pit-corroded and partly scraped-off surfaces can be very corrosive. The even, compact corrosion crusts will delay the electrochemical processess and thereby lower the corrosion rate. In contrast, a mechanically de-rusted iron surface gets very corrosive if the corrosion layers and chloride are not fully removed. The active corrosion zone will be directly on the metal surface and in any pits contaminated with chlorides. A fully cleaned iron surface is therefore more stable than a partly cleaned one. If one is not willing to follow up with complete cleaning and coating, an iron object, it has to be kept at low relative humidity.

The practical techniques for removing rust by electrochemical or chemical means or these combined with mechanical treatments and rinsing are not the subject of this paper.

General aspects on protecting iron with coatings

Information in this short section on protective coatings is based on old lectures at the Danish School of Conservation combined with new information from articles and personal experience, including some earlier tests conducted along with conservation colleagues [1]. Not referred to here (but being presented elsewhere) is my colleague's present ongoing, systematic studies comparing coatings for iron at the National Museum of Denmark [2].

Throughout time products of iron must have been finished with more or less durable coatings – from a coat of thin oil to several paint layers. This is necessary to keep cleaned iron acceptably stable in normal indoor and outdoor climates. Iron objects from collections of newer history and, thereby, also industrial heritage, can be expected to be displayed or assembled in one of following environments:

a) Unsheltered outside
b) Sheltered (under a roof) or inside under unheated conditions

c) Indoors at normal room temperatures
d) Or, seldom, in dry, special climate-controlled areas.

Thin or thicker non-polar coatings on iron will at best form unbroken film coatings that act as a shield for some time and prevent the polar water molecules from settling. The protectiveness of a coating depends therefore on how completely it coats and penetrates to give water-displacing properties. It should also have good adhesion and withstand penetration over time. The film adhesion and stability is, of course, dependent on the preparation quality of the iron beneath.

The ability of various clear coats to cover uneven surfaces is described by several authors. Very uneven metal surfaces and edges are difficult to protect evenly with some types of coating [3]. Layers can turn out to be very thin on edges (more and less sharp ones) as is mentioned about the scythe in figure 1. For protecting outdoor iron it has therefore sometimes been necessary to even out and blunt edges before coating.

The properties of new oil products, waxes, lacquers and paint that industrial scientists wish to develop for coating iron are much the same as those the conservator seeks. The scientists mostly develop coatings for clean metal surfaces. Zinc oxide compounds are often used as electrochemical protection in paint primers while lead oxides now are being abandoned. Furthermore inhibitors now seem to be an important part of primers, clear and semi-transparent coats. They can, at best, delay the anodic and/or cathodic reactions of corrosion. Coatings are developed for either long-time protection or for short-term, such as for overseas transport of machines and weapons. For our use, we would also like to have products that are protective on top of corrosion layers. Unfortunately, at least some polymer films are sensitive to some metallic corrosion products causing weaknesses and then breakdown.

Another consideration in choosing coatings involves removing them later. Some tend, over time, to crosslink and discolour. Partial mechanical removal with scalpels, as paint conservators do, will often be considered too time-consuming and expensive for iron objects. Immersion in a tank for electrolysis or else steam and heat treatments are other possibilities. These methods are without health hazards for staff, but will take away, for example, preserved older interesting paint remains and harm attached wooden parts. Therefore not all objects are suited for these treatments. Removal with solvents can become a safety risk when dealing with large surfaces, although newer paint remover products should be less harmful. In removing the conservator would have to consider saving parts of the original paint etc. for later documentation or research by taking samples.

A coating's protection of iron against vapour penetration can be judged just by immersing a test piece in water. Although accelerated, this test is reasonably reliable for comparing products. Outdoor exposure tests on panels in sheltered or un-sheltered locations will, on the other hand, give the conservator an impression of protection time. A general rule says the thicker the film, the better the protection. This, of course, also has limits because a coat's expansion and contraction at changing temperatures is greater, than that of the metal to which it is applied. Coatings containing pigments produce thicker layers than clear ones.

The tendency of coating to yellow and crosslink has to be tested by exposure to light. Modern standard tests combine several factors.

Contamination such as dust, dirt and microbial growth (lichen) on coatings will keep the humidity high and thereby accelerate failure as illustrated in figure 2.

To prevent time-consuming frequent repair and renewal of coats on iron, it is practical to have some guidelines. Following are mine in climate conditions a-d (as noted above) until news from ongoing tests is ready:

a) Unsheltered outdoors iron should be completely cleaned and coated with several layers of paint. One picks a paint system for outdoor iron with correctly applied primer and subsequent coats. The recommended light sandblasting of the metal surface beforehand gives the best result. Sharp object edges, as mentioned, must sometimes be rounded. A

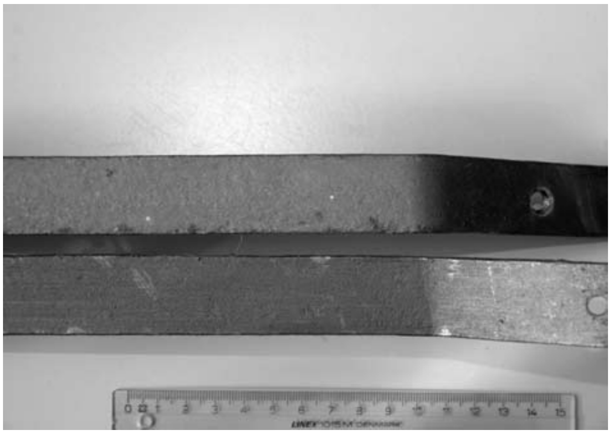


Fig. 2 Rust stains on the too-thinly painted iron were seen on upward facing surfaces that became dusty on display. This is shown at the top with the corresponding back side below it. In the failing conservation treatment (done by craftsmen for our Open Air Museum some decades ago) only two layers of paint had been applied: a primer with lead (and maybe also iron) components and a topcoat with graphite. In 2008, the parts were completely cleaned and then four layers of paint were applied.

metallic zinc coat can also be applied as a first layer (galvanised in one of several ways). Choice of the subsequent paint system thereby becomes different. Where complete rust removal is not possible, some conservators start with old-fashioned oil paint with red lead as primer. There seems to be a few alternative newer paint products too. My recent comparison of three 3-layer paint coatings and a clear coating on a clean steel panel is described below. If iron has to be covered with layers of paint, one should remember beforehand to describe any special surface details such as the fabrication marks illustrated in figure 3.

b) Sheltered (under a roof) or indoor under unheated conditions iron objects are either to be treated and painted as un-sheltered iron or with a very efficient semi-transparent coating. Figure 1 showed three examples of iron after older and new treatment: The upper and lower objects with paint layers and the one between with a clear coating. Possibilities for their preservation in the Open Air Museum's damp houses, as when outdoors, seem to start with complete removal of corrosion layers. Until now, only paint-protected surfaces of several layers and a semi-transparent coating seem to have lasted for more than a decade. Years ago Danish conservators started using Rustilo 160 from Castrol Ltd. as a

Fig. 3 Details as fabrication marks on the iron should be well documented before coating with several layers of paint. Two end parts of scythe blades are shown. Good documentation and/ or sampling is also need if objects have to be stripped of remains of original paint layers.

semi-transparent coating for this purpose. The iron was first cleaned pretty well, then treated with a tannin solution to react with rust remains, dried, brushed lightly and then coated. Experience showed that nearly cleaned iron with applied tannin (in this way) is a slightly better base for coats than without it. The mentioned coating seemed to protect better than the microcrystalline wax conservators had used before that (the product later changed its name to Rustilo 2000). Many have tried this yellow, slightly drying oil that long remains sticky/tacky.

c) Indoors at normal room temperatures the treatments mentioned above can be applied to the iron or we can pick among the clearer coatings. Hopefully both storage and display areas can be kept at acceptable RH, so even rust-coated iron will be reasonably stable in a lightly-restored state for many years as with the bicycle shown in figure 4. When the object is protected from high relative humidity, it thereby seems possible, with minimum loss of stability, to save parts of the original surface untreated. Remains of original paint layers and remains of metallic coats on the iron such as tinning, nickel, chrome and galvanizing (Fig. 5) can be left visible.
d) Iron objects from newer history are in a few cases put in dry special climate-controlled areas. Iron is so reactive that many special items should be preserved this way. Depending on RH, protective coatings can also be used.

When working on the objects from the Open Air Museum's houses it was obvious to test protection of our painting procedure where the topcoat has to give the illusion of old iron surface. Graphite alkyd paint coatings look much as old iron when mixed and retouched with shades of black alkyd paint, but would a topcoat with likewise shiny aluminium/zinc spray (or a spray with stainless steel particles) function better? For the quick test (Fig. 6A-B) our procedure of 4-5 layers was minimised to three, to give a worst-case situation. To compare with these the lower right corner got a layer of clear acrylic coat product from Cortec (Cortec VCI 386).

The steel panel for the quick tests seen in figure 6A, was first lightly sandblasted on one side. (Sandblasting is standard procedure before application of paint systems for outdoors.) Three sections of the panel were painted by brush with a layer of zinc-containing primer, Rust-Oleum 1080, and then the following different paints were applied in two layers:

- Top left: a coat of Rust-Oleum 7500 was then applied, because it is known to seal well when used as top coat, and over that again the graphite-containing alkyd paint.
- Bottom left: only an extra coat of the primer was applied and then the graphite-containing alkyd paint.
- Top right: the Rust-Oleum 7500 was applied and then a spray paint from the same company containing both aluminium and zinc. (Its shiny appearance could always be altered with black.)

Horizontal lines have been scratched through the coatings with a scalpel blade so their later protection when physically altered could also be seen. After one month's exposure outdoors, the clear coated corner is starting to deteriorate, while the painted regions are stable – even where the paints are scratched through (Fig. 6B).

Encouraged by the paint's abilities, three full panels were coated and sent for accelerated weathering tests (being supervised by the mentioned colleagues for their tests). Following this the same types will also now be included in the connected long-term outdoor tests. We decided merely on two differences to the above-described procedure. The steel panels were only degreased, as were the panels they here will to be compared with. The top spray paint from Rust-Oleum now used contained stainless steel particles (which resembles iron more) instead of Al/Zn. When ready, the final results and comparison to evenly applied clear coatings will be published.

Testing a decision making model

Hopefully the ongoing tests at the National Museum of Denmark will help us to make more confident choices for protection of cleaned iron and maybe even to protect rusty or partly de-rusted iron. Museum staff in the future should be able to make reasonably realistic predictions of a treatment's protection time, and in choosing, be aware of costs of any needed follow-up maintenance. Making decisions is important and requires systematic judgment.

As of now, if you only wish to partly remove rust layers and are not willing to fully clean and coat iron (oil, wax or paint products) the object has to be kept at very low relative humidity. It may be desired to save remains of original paint layers or iron may be an integrated part of a composite construction that cannot be treated separately. In these cases iron can be embedded so that rusting mostly happens where it is unseen and least treatable. Decision-making for iron conservation is not easy because there are several important issues:

1. The main conservation factor is the object's preservation and, thereby, chemical and physical stability – The iron surface has to be quite stable even if the surrounding RH is not very low. Large metal objects are sometimes submitted to more physical handling than museum staff generally considers. The coating's strength, therefore, is also an issue.

Fig. 4 Some bicycles in use and in storage have not always been properly taken care of. This one had to be conserved and exhibited among others in the Museum's new display of industrial heritage. It was only treated to withstand a controlled room temperature situation.

Fig. 5 Galvanized steel will also eventually start rusting in use and/or later exhibition in the Open Air Museum's houses. Here the low bucket parts have been damp and its steel band is rusting. Both conservation and preventive conservation (lifting it slightly) were needed for future preservation.

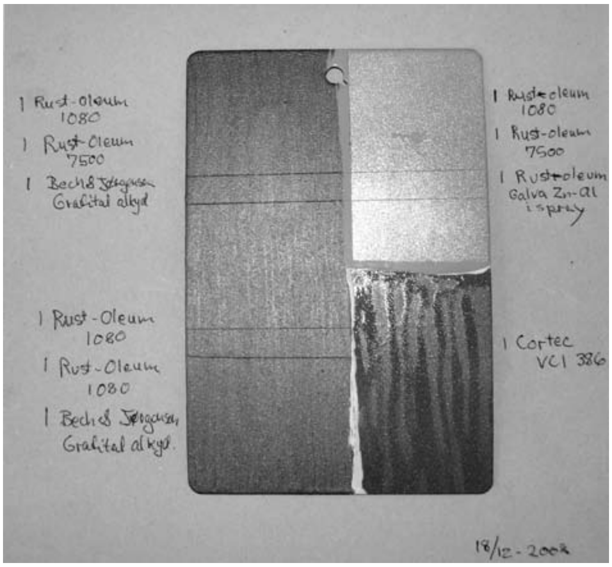


Fig. 6A For a quick outdoor comparison, a standard steel test plate was sandblasted on one side and coated with three different build-ups of three layers of paint each as explained above. On the lower right corner, a clear coating was spead that we yet have little experience with. Here it was applied with a too narrow brush that made the surface uneven. Two horizontal scratched lines through the coat layers are made on each test area. The panel curves slightly because of the one-sided sandblasting.

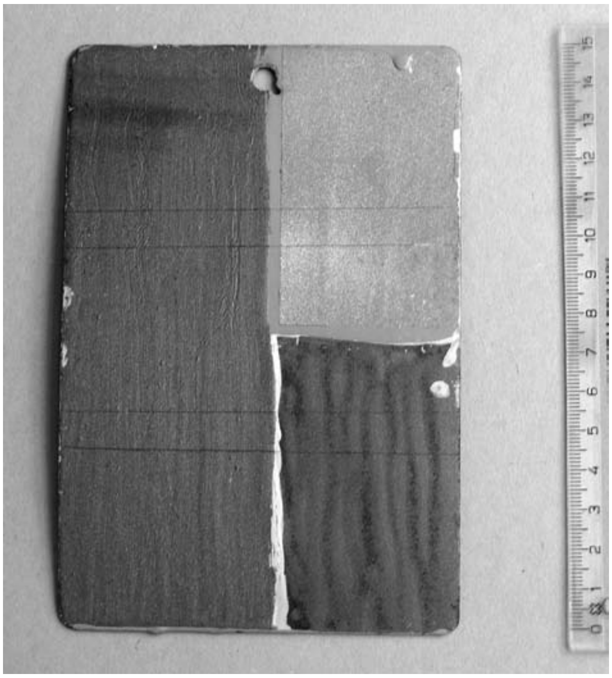


Fig. 6B This picture shows the test panel after exposure outdoors (hanging on a cloths-line near Brede) in the cold snow and rain from Jan. 16^{th} to Feb. 25^{th} 2009. On the thickest parts of the clear coating, as well as in its scratches, pitting-corrosion is starting causing the coating to look brown. (Be aware that this coating as mentioned was uneven and look instead at the big comparative tests when ready.) (Small, light paint smudges reveal that the panel's backside was painted after the front.) Untreated edges of the panel are also corroding. This continuing outdoor test will be presented at the conference in May 2009.

2. The factor of scientific value after applying a conservation treatment – An object's original surface treatments can have great interest and value for visitors, education in the museum collection and research. Samples of the original surface can be taken, or in some cases, it can be safe enough to leave areas untreated or select a coating with some reversibility.
3. The aesthetic factor – Iron to be displayed in open-air museums or as outdoor (sheltered or unsheltered) industrial heritage is often required to look much as it did when in use. Neither a full re-paint nor layers of modern clear coating seem absolutely truthful in the display of historical iron. As illustrated in figure 1, painted surfaces can look more realistic than lacquered when surfaces are viewed from a distance, as museum visitors do. Waxy coatings are however less shiny than thick layers of lacquer can be.

Having no published decision-making model specifically for items in cultural history collections for metals, for this purpose we tested the one used for modern art [4] on a farm implement. The threshing machine (Fig. 7) for the National Museum's new permanent exhibition is the subject for this short example:

1. *Data registration*: A threshing machine, museum no. 157/1988, NM, DNT, was produced by Dronningborg Machine Factory in Denmark. The company produced many similar and slightly larger machines for Danish farmers of that time. Further data are available in the exhibition. The machine consists of a painted wooden body, steel mechanical parts and thin sheet iron painted with some texts and lines. The rotating parts are connected by leather and textile straps.
2. *Condition*: The wood and painted wood parts are quite well preserved even though it has faded. The surfaces of the mechanical steel parts are evenly rusted but the axles were to some extent protected by lubricant. The thin sheet iron with its even rust layer seems quite mechanically stable but is looking more mistreated than the rest. The painted text and line ornamentation on it is damaged by rust but

Fig. 7 The threshing machine had been in the museum's collection since 1988 and been stored at an acceptable RH and room temperature. It had to be cleaned and assembled for display.

is best preserved where it has been stained with lubricant from rotating parts.
3. *Meaning*: The machine represents a quite well-preserved piece of equipment from the start of industrialism in farming. The materials used in the machine are traditional and thereby valuable for showing that simple systems also work. The quality and importance of the machine for the farmer is underlined by the paint decorated wooden body and line ornamented sheet iron. The red painted text information on the sheet iron has served a practical purpose.
4. *Possible discrepancy between condition and meaning*: (The model's subsections as 4a-d are here described in one). Rust damage and fading of the painted areas shows that the equipment is old and real. The fading paint on wood is therefore very acceptable. The mechanical parts are functional. The exhibition climate planned will be at moderate RH as has been its storage conditions in the museum for two decades. The remaining paint on the sheet iron will over time be lost as rusting continues. A planned treatment should be effective in conservation for controlled indoor climate and not too time-consuming. The machine must not be dangerous for visitors of the exhibition, so rotating parts must be blocked.

5. *Conservation options*: Preserving the thin iron sheet metal and its text and line ornaments are important for the machine's general appearance. Even though best corrosion resistance of the iron would be obtained by full removal of rust and repainting much genuine look would be lost. As it is to be displayed indoors, protection is not so critical but the general appearance of the rusty iron parts is important to the rest of the machine.
6. *Weighing conservation options / Considerations*: A minimum conservation done on the machine's iron will preserve its authenticity. Both oil and wax-like coatings will, however, reveal and brighten the painted parts. The coating should not be too shiny since the painted wood parts have lost brightness over time. A clear, waxy coating for iron available to us, Dinitrol 4010, seems not to have been tested on rusty iron, but has performed very well on outdoor bronze [5]. More or less transparent coatings brighten the appearance of rust-look. A later analysis of the painted iron after applying the clear coating seems possible. The mechanical parts do not need extra lubrication.
7. *Proposed treatment*: A clear coating will make the paint-remains on the rust layer more obvious. The mentioned Dinitrol 4010 is the best proposal for stability at the moment. It has an acceptable wax-like appearance on corroded iron and can be sprayed on in a thin layer (Fig. 8).

As I do, others might find the sections with detailed subsections of the decision-making model for modern art a bit too much for our purpose (subsections from 4a-d and the following). Practice should overcome this. The model structure makes the considerations more precise and though before action is taken. This model, however, seems to focus very little on the suggested treatment's ability to preserve. Also for us is the importance of an object's age and what, thereby, are acceptable features for things that old. Also not seen noted would be the difference in the choice of conservation treatment depending on an object's importance in the exhibition: as part of a whole set-up as the bicycle (Fig. 4) became, or the exhibition's main attraction.

Conclusion

Reviewing the main aspects of protection of historical iron and as here pointing out the necessary changes of surface is not merely a discussion conservators should keep to themselves. Both in obtaining results with other museum staff and when collaborating with external authorities, the practical and ethical issues involved should be presented.

When coating cleaned iron objects for changing outdoor climates, the conservator at present has to apply reliable paint systems of several layers. Surfaces looking much as the originals did can be made by means of artistic retouch in the top paint layer. In sheltered unheated locations such as the National Museum's Open Air Museum's houses the needed protection should be the same as for outdoor conditions or a drying semi-transparent oil product that has been found reasonably reliable.

The task for iron under nearly controlled climate conditions will differ from case to case. Under sheltered and climate-controlled conditions, the conservator can apply a clear or semi-transparent coating hoping it is protective enough or just leave the object untreated. Important is the possibility here of letting most of the object's original textures

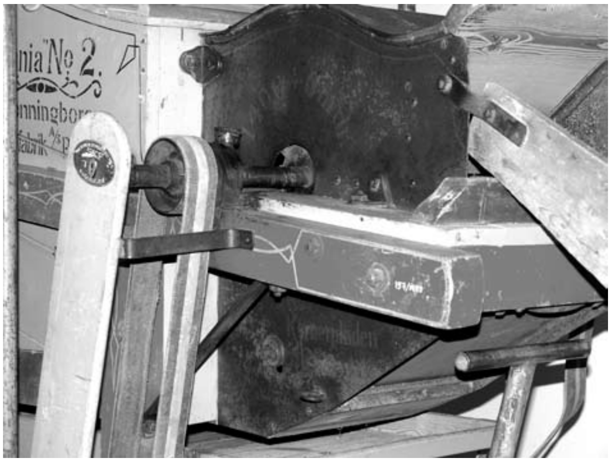


Fig. 8 Nearly visible in the picture is that the text information and line ornamentation on the machine's rusty thin panels are more easily seen now after treatment.

be unchanged or, with clear or semi-transparent coating, looking much like the authentic surface. These coatings can, however create a plastic shine that changes an object's appearance very much. The plastic look seems less obvious when the coating has a wax-like appearance (not too shiny).

Protective coatings must either be very reliable or must be regularly checked and maintained. The conservator must make reasonably realistic predictions on a treatment's protection time and, in choosing, be aware of the costs of any needed follow-up maintenance. Having the possibility of weighing options of treatment against each other by using a decision-making model can make the considerations of conservation more precise and thought-through before acting.

Acknowledgements

It is with gratitude that I received suggestions from conservation scientist, PhD Michelle Taube on several aspects in the preparation of this paper. The illustrations used are mine but have been optimised by photographer Svend Erik Andersen.

Author

Karen Stemann-Petersen
National Museum of Denmark
Department of Conservation
I.C. Modewegsvej, Brede
DK-2800 Lyngby
Denmark
Email: karen.stemann@natmus.dk

References

1) To learn more about products small comparative tests of clear coatings on iron samples prepared in different ways has been carried out by colleagues at the Conservation Department: Vivi Lyndborg Andersen in 1982, Susanne Petersen and Karen Stemann Petersen 1993 and Torben Holst and Bodil Taarnskov 1997. All are unpublished.
2) Shashoua, Y., Taube, M. and Holst, T. 2009: National Museum of Denmark, Department of Conservation: Ongoing comparison of coatings for iron and steel. *Personal communication*.
3) Götz, K. and Seipelt, B. 1996: Der Schutz von technischem Kulturgut gegen atmosphärische Korrosion. Wihr, R. (Ed.), *AdR-Schriftenreihe zur Restaurierung und Grabungtechnik*, heft 2, p. 95-100.
4) Hummelen, I-J. (Ed.) 1999: The decision-making model for conservation and restoration of modern and contemporary art. *Modern Art: Who Cares?* Foundation of the Conservation of Modern Art and the Netherlands Institute for Cultural Heritage, pp. 164-172.
5) Otieno-Alego, V., Heath, G., Hallam, D. and Creagh, D. 1998: Electrochemical evaluation of the anti-corroison performance of waxy coatings for outdoor bronze conservation. Mourey, W. and Robbiola, L. (Ed.), *Metals 98*, p. 309-319.

Products

Cortec VCI 386 from: Cortec Corporation, 4119 White Bear Parkway, St. Paul, MN 55110 USA email: info@corteccvci.com http://www.CortecVpCI.com

Dinitrol 4010 from: DINOL AB, Garnisionsvagen, Hassleholm, Sweden. Tel: +46 45 18 80 00

Grafital 350, a graphite containing alkyd-drying oil paint from: Salcolor, Sofielundsvej 52, DK-2600 Glostrup, Denmark.

Rustilo 2000 from: Castrol a/s, Hasselager Centervej 15, DK-8260 Viby, Denmark.

Rust-Oleum 1080, 7500 and a spray-paints from: *Rust-Oleum* Brands Company, 11 Hawthorn Parkway, Vernon Hills, *Illinois* 60061, USA.

Another look at painted finishes on outdoor industrial artifacts

George Prytulak

Introduction

It is difficult to overstate the importance of painted finishes on industrial artifacts in the context of museum collections. In most cases, the finish is the largest component of an artifact that the visitor sees. If one were to take away the painted surfaces, all that would remain would be rubber, glass, some plated metal trim and a few brass or bronze fittings – sometimes as little as ten percent of the artifact in one's field of view. [1] The museum experience of industrial artifacts being predominantly visual, one could argue that a major part of what a visitor actually experiences is painted finishes.

But a finish is more than just a visual component of an industrial artifact. The finish is usually the last thing applied by the manufacturer to the artifact.[2] As such, it functions as a direct and intimate connection with the artifact's manufacturer and in turn, with our industrial heritage.

Accepting that finishes are a dominant feature of industrial artifacts [3], one would expect museums and private owners to be obsessed with preserving and displaying original paint in almost any condition. But this is rarely the case. Finishes in anything less than perfect condition are often deemed as expendable; they continue to be removed and replaced with new materials in an effort to create "like-new" and "showroom condition" versions of the artifacts.

It is an indisputable fact that no more "original" finishes from a particular time period can be created and very few undiscovered originals will miraculously appear, like the legendary automobiles found in long-abandoned barns. The collective inventory of original industrial finishes from any given period can only decrease with the passage of time. This threat of extinction is rarely appreciated when decisions are made concerning the repainting of artifacts.

Defining 'original'

But what is actually meant by the term "original?" Strictly speaking, original means "the first, preceding all others." This is a very restrictive definition. In terms of mass-produced industrial artifacts, it can mean only one thing: the finish applied by the manufacturer at the factory. With one-of-a-kind artifacts, it can mean only the finish applied by the maker or under the maker's direction. As will be seen, such a precise meaning of "original" can be applied only to a handful of industrial artifacts in existence.

Such a narrow definition is linguistically correct and it should be upheld, but it may have serious consequences: museums and private collectors might be inclined to disregard, remove or replace everything that is not strictly original. In reality, there are many non-original finishes that are still historically valid. It is time to widen our focus – what might be called our value system – beyond finishes that are strictly "the first, preceding all others."

Broadening our value system

As a rule, the finish on industrial artifacts was rarely expected to last the lifetime of its parent artifact. Removal and reapplication of aged paint was a crucial part of an object's maintenance program. This was particularly the case with large artifacts like trains, ships, and airplanes owned and operated by corporations or governments. These corporate bodies repainted their vehicles on a regular basis to protect their investments, to ensure high safety and performance standards, and to please potential users and buyers. The exterior maintenance of a railroad passenger coach during its working life was said to equal the cost to its original construction. Much of this maintenance involved repainting. [4]

A large machine might also change ownership several times during its working life as the result of corporate mergers or other business-related measures. Each change might result in a new paint scheme. This occurred frequently in the latter half of the twentieth century with diesel locomotives and passenger airplanes and the practice continues today. The resulting coats of paint are all genuine.

Even if repainting were carried out today, just prior to donating the machine to a museum, the finish would still be considered as historically valid. What ties all of these finishes together and gives them legitimacy is the fact that they were all *applied under the supervision and direction of a corporate body in accordance with written specifications.* Specifications are the key. They are a form of written documentation that guarantees what might be called, for lack of a better term, the *lineage* or *pedigree* of a finish. [5]

Artifacts in private hands such as automobiles, motorcycles, bicycles and small boats are a different story. All were subjected to a much less rigorous maintenance schedule. In general, they were repainted on an ”as needed” basis, often by individual owners with little or no experience and substandard tools and equipment. Refinishing ads and brochures distributed by firms like Valspar, Glidden and DuPont suggest that do-it-yourself repainting of automobiles by private owners was a widespread practice in the 1920s.

Some might argue that a 1924 automobile repainted by its owner in 1927 has a historically valid finish because of its age, but this may be stretching the value system to an unacceptable level. Giving anonymous individuals the same status as corporations debases

Figure 1 1924 Valentine & Company ad. Repainting was part of a vehicle's routine maintenance. Source: The Saturday Evening Post, May 24th, 1924, page 45.

the currency of the finishes. The work of private individuals involves too many unknowns.

By contrast, an automobile that was repaired and repainted by a professional body shop has a better chance of being classed as valid. A professional paint shop would have had a greater responsibility to carry out the work in accordance with a manufacturer's specifications, and the tools, equipment and skills of the painter would have created a finish of much higher quality. It is an echo of the original, unlike the private job, which might be considered the echo of an echo.

The broadened value system for finishes described here requires a broadened vocabulary of descriptive terms. As mentioned, "original" denotes "the first, preceding all others." The term "historical" could be used to denote a finish with corporate pedigree (i.e. applied following written specifications) and a new, replacement finish might be termed "replica." The term "restored" should probably be dropped except in exceptional circumstances. It implies that the original surface has been revealed by removing obscuring layers of historically invalid material. With respect to industrial artifacts, a "restored" finish usually means that every trace of the original was removed and replaced with new material. The artifact has been "refinished" or "repainted," not "restored." [6]

Problems with refinished artifacts

The problem with new finishes is that they are modern approximations based on questionable evidence and carried out by workers trained and experienced with modern tools and materials.
We have lost the materials, tools, and the infrastructure connected to early finishes, as well as the experience and skills that utilized these resources. Consider the following:

Materials

Most of the materials from the paint-and-varnish era (ca. 1850 -1925) are no longer made, they have been banned as health hazards or they have been permanently depleted. This includes pigments, white lead, roughstuff (surface filler), and copal varnish. The same situation exists

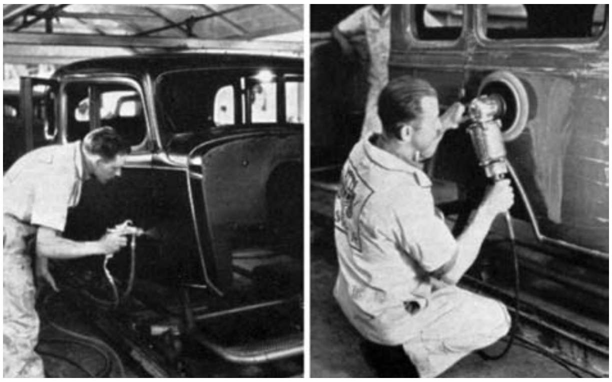


Figure 2 Finishing Chevrolet automobiles at the Chicago World's Fair, 1934. The materials, tools and skills from any given period no longer exist
Source: Building the 1934 Chevrolet, a General Motors - Fisher Body souvenir brochure from the Century of Progress International Exposition.

with nitrocellulose finishes. There is no viable commercial market for any of these products and at any rate, the manufacturing facilities that made them no longer exist.

Tools

The tools that were used to apply the materials are no longer commercially available. These include large natural-bristle brushes of all shapes and sizes and abrasives such as horse hair, rottenstone and pumice bricks.

Infrastructure

A factory finish can only be made in a factory, with specialized equipment such as dip tanks, conveyors and drying ovens, many being time and temperature regulated. The factories and their production equipment are long gone and will never return.

Skills and experience

The hard-earned skills of the factory and shop workers no longer exist. There are no apprentices and very few instructors versed in the use of historical materials. Only written descriptions have survived, missing much vital information.

One can collect unopened samples of original materials (e.g. tins of white lead, japan dryer, coach colors and finishing varnish) from online auction houses and flea markets and one can probably find unused brushes and/or spray equipment, but the painting techniques and experience will still be lacking. There is no guarantee that the results will be accurate or that the materials will have remained unchanged with the passage of time.

New finishes and false impressions

The approximations we create yield very little information about the artifact's material past. Nothing is gained by examining them at close range. They can also be misleading, in that they convey false impressions about early industrial finishes to museum visitors.

Durability

The new finishes on museum artifacts convey a false sense of durability. In the first half of the twentieth century, paint was not nearly as durable as it is now. Whereas a modern car might retain its gloss for over seven years, automobiles in the 1920s might look good for only half a year, at which time the paint might begin to fail.[7]

As mentioned earlier, the finish on many artifacts was routinely replaced, indicating that the paint lacked durability and had a very limited service life. Why then do we put so much emphasis on recreating and displaying new finishes? They represent only a short period in an artifact's working life. [8]

Uniformity

Another false impression is that of uniform appearance. If all the artifacts in an industrial museum are repainted with modern urethane acrylics, the collection conveys the impression that all finishes looked the same in the 20th century. This was not at all the case, at least in North America. In the 1920s and earlier, automobiles were painted and varnished with linseed oil-based materials like copal varnish; in the 1930s, auto makers turned to nitrocellulose paints; in the1940s baked synthetic enamels were the norm; and the 1950s ushered in the era of acrylic finishes. All of these finishes have a unique luster and depth. It is a mistake to assume that they can all be replicated with modern urethane acrylic paint.

With these points in mind, the arguments in favor of repainting an artifact become less forceful. A repainted finish does not necessarily have more interpretive value than a worn and weathered finish. And in most cases, the weathered finish is much more interesting because of its historical character.

Creating new finishes with accuracy

In some cases, creating a new finish is unavoidable. As museum professionals and custodians of material heritage, it is our responsibility to conduct thorough research and create a new finish that is as true to the original as possible. Where do we turn for information and evidence that can be used in the process?

Four sources of information for recreating finishes merit a closer look:

- human memory and written records
- photographs and film
- traces of original paint
- paint brochures

Human memory

Human memory is without question the least reliable source of information. There is only a very small "window" of what one can call living memory, and it advances every day as the population ages. Taking 80 years as the average life expectancy, living memory only stretches as far back as 1929. But memory is flawed at both ends of a person's life. Childhood memories are distorted and inaccurate, and memories at an advanced age are suspect because so much time has passed and important details may be lost or confused.

Moreover, most people are not conscious of finishes during the formative years of their lives, beyond the perception of color. The consciousness of finishes might not begin until adulthood, when a person is 30 years of age or older and trained in paint technology or museum conservation. This would narrow the reach of accurate living memory to around 1959. [9] Even the "window" of living memory is clouded with ambiguity. Only a person who has had a long, intimate association with a machine, e.g. as a crew

Figure 3 WW2 airplane with newly-painted engine cowling and propeller. New paint is conspicuous in archival photos. Source: Library of Congress, Prints and Photographs Division, Washington, D.C. Call Number: LC-USW36-393.

member or maintenance person, will have formed a reliable memory of the painted finishes. [10]

Finally, we must consider the deficiencies of language. Most people do not have a reliable or accurate vocabulary for such things as luster and depth. The best we can hope for is a memory of "shiny" or "flat." Only a paint technician or a professional painter might have a more accurate vocabulary.

For the same reasons, written records offer little information in terms of recreating finishes.

Photographs and film

Original finishes on such things as automobiles, airplanes and locomotives are best viewed in their original historical context. The best – and arguably the only – way to do this is to study them in period photographs. That is, automobiles and airplanes from the 1940s should be studied in photographs taken during the 1940s. The Kodachrome transparencies in the American Library of Congress archive are an excellent example of a photographic resource. The photographs show artifacts in use and are extremely informative. Unfortunately, Kodachrome was not introduced until 1935, so everything before that time is in black and white.

The LOC photographs vividly show that new paint was far from the norm during the 1940s. New paint stands out in the images. It often indicates that repairs or maintenance were recently carried out on a machine, and in many cases, it was only applied to part of the object. There are signs of wear, dulling and overspray in the vicinity. [11]

Most museum professionals would regard the combination of old and new as grotesque and unsuitable for display. It is usually a case of "all or nothing." But the photographic evidence supports a patchwork approach. The conservation profession discourages treatments that might have potentially deceptive or misleading results, such as artificially aged or worn finishes. New finishes are tolerated because they are obviously not original. Accordingly, the trick with artificially aged finishes is to make the process known to the public by means of the didactic display. That is, one should use photographs to explain what it being attempted in the physical display.

In the long run, internet photo archives like Flickr's *The Commons* (which hosts the Library of Congress collection and many others) may go a long way in correcting people's perceptions of finishes, and their expectations may change. The public might eventually develop an aversion for repainted objects and demand access to unrestored originals.

A complementary resource to photographs is historical film footage. It does not offer the same resolution as a static image, because the film is a sequence of short exposures, but it can capture the effect of light on an artifact in motion.

To recap, several important lessons emerge from studying archival photographs:

- paint does not have to look new
- new-looking paint is relatively rare and very conspicuous
- a patchwork of new and old paint on an artifact is completely acceptable

Traces of original paint

An original exterior finish in glossy, showroom condition, unaffected by time or any agents of deterioration, is arguably a physical impossibility. Only traces of the originals remain, and they are in varying condition.

In general, industrial finishes deteriorate proportionately with the amount of time they spend outdoors, but outdoor exposure can vary dramatically, depending on such factors as the frequency, purpose and duration of use and the severity of local climate conditions. Poor storage conditions can also cause deterioration. [12]

Many of us are familiar with the techniques used to uncover traces of original paint. During cleaning and disassembly operations, one may find protected, unweathered finishes between mating surfaces, under trim and fittings and under layers of grease and dirt. Original paint may exist under more recent coatings, but the surfaces might have been sanded beforehand and they are extremely difficult to uncover without causing further damage.

Traces of original and historical paint should be left intact. They are the last remaining vestiges of their kind. At the same time, a number of peripheral resources should be explored.

Original paint in unexpected places

One place to look for original finishes is on *indoor* industrial artifacts that probably would not have been repainted during their operational life. They might have been manufactured by firms that also made machines for outdoor use and they might have been painted using the same materials and equipment. This would include things like domestic and industrial machinery, hardware, recreational items (e.g. camping equipment) and fire extinguishers. Many companies had quite a diverse line of products. For example, the White Sewing Machine Company of Cleveland, Ohio also produced bicycles, roller skates, lathes, steam automobiles and bird cages. It would probably have been uneconomical to have separate paint facilities for every product, so there may be some crossover in terms of finishes. Creating a database of these items would be an interesting and useful project.

Another resource might be children's toys, such as tricycles and wagons, die-cast scale model cars (e.g. Matchbox and Corgi) and construction toys like Meccano. These objects demanded durable finishes and although the coatings may be relatively thin, there could be some parallels with what was used in the automotive industry at any given time.

Paint brochures

The closest we may ever get to seeing a genuine original finish may be the samples in paint brochures that have not been exposed to oxygen and light for extended periods of time. Many publications contain paint chips that are simulated with printer's ink, but the majority of samples were created separately and glued in place on the pages. They may be actual samples of paint. Very little has been published on this subject. It is a prime candidate for further research.

Displaying repainted industrial artifacts

Accepting that a recreated finish is a modern creation, made with modern materials, modern equipment and modern techniques and based on questionable evidence, we should reassess the way we display refinished artifacts.

The following guidelines are suggested for the display of "like new" artifacts.

1. Display repainted industrial artifacts outdoors

There are a number of compelling reasons for recommending this approach.

a. The finish is a replica and does not merit close scrutiny. In an outdoor setting, no one will examine the artifact at close range.
b. Shiny, "like-new" machines make a stronger impression outdoors than indoors. They come closer to recreating the original experience that the first users or operators had with the artifact, and as such, they evoke strong feelings of nostalgia.

Figure 4 An aircraft plant in 1942. Museums might consider recreating settings like this for partially refinished artifacts. Source: Library of Congress. Call Number: LC-USW36-238

c. Repainted objects shed water and are easy to clean.
d. In the event of damage or deterioration, the modern finish is easily renewed with no loss of historical materials or information.
e. The outdoor setting is authentic in terms of lighting. Artificial light is a recreation of natural light. The appearance of sunlight has not changed drastically in the past century. Showing a replica finish in natural light is at least half way to an authentic experience. It is preferable to showing an approximation of a finish in an approximation of natural light.

2. Do not display repainted and original artifacts beside each other

The two kinds of finish do not complement each other in close proximity. The repainted artifacts look overly new and artificial, while the originals look unfairly shabby and dull. They detract from each other.

3. Display repainted industrial artifacts in historically appropriate indoor displays

If a shiny, "like-new" object must be displayed indoors, it should be exhibited in an appropriate setting, such as a factory, showroom or repair shop. An automobile in "showroom condition" should be displayed in a salesroom setting. A newly painted airplane should be shown in a repair shop or factory.

4. Use historically authentic lighting in displays

Human vision is a matter of perceiving light. Therefore, the finish on an artifact should be seen in authentic lighting conditions. Shiny, "like-new" paint jobs should be seen in lighting that approximates the settings listed above: sodium or mercury lighting for a factory setting, and a combination of incandescent and natural light for a showroom or repair shop. Modern museum track lights or color-balanced fluorescent lighting may be inappropriate.

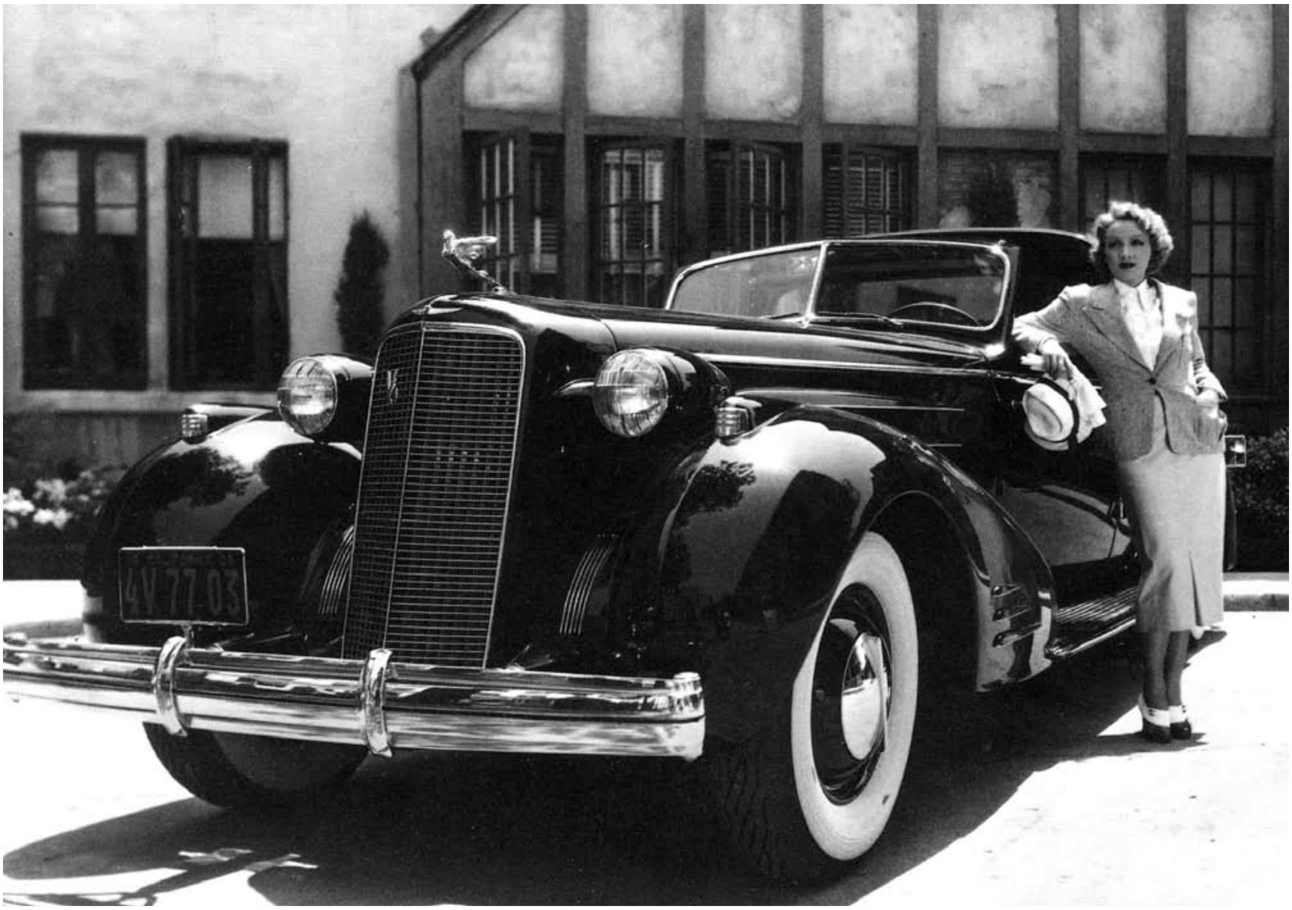


Figure 5 Marlene Dietrich and her 1935 Cadillac. Both the actress and the finish can only be experienced through film. Neither can be recreated.

5. Include reference photographs in displays

As discussed above, only photographs can really convey such qualities as original luster and gloss, and they could be used to explain the patchwork paint jobs in an exhibit.

6. Consider partial restorations

Instead of completely repainting an artifact, consider leaving it partly finished. For example, an aircraft could be half-primed and half-unpainted within a factory setting. It would look authentic and it would offer visitors a glimpse of the manufacturing process as well as the materials underneath the paint.

Conclusion

Original and historical finishes on outdoor industrial artifacts are both rare and ephemeral. They are direct links with our industrial past and as such, they should be valued and protected. They may yield information to future generations in ways that we can scarcely imagine. In most cases, a finish is never truly “finished.”

Author

George Prytulak
Conservator of Industrial Artifacts
Canadian Conservation Institute
1030 Innes Road
Ottawa, Ontario, Canada K1A 0M5
George.Prytulak@pch.gc.ca

Notes:

1. There are a few notable exceptions: the polished aluminum aircraft of the 1950s and the stainless steel streamliners and railway coaches made by the Budd Manufacturing Company from the 1930s to the 1950s. Also, a number of brass or bronze parts on industrial artifacts are left unpainted as a matter of tradition, such as the bells on ships and locomotives. Metallic finishes will be discussed in a future article.
2. In fact, the very word "finish" carries with it a sense of finality.
3. The importance of surface coatings was recognized long before conservation existed as a profession. One could argue that painting was an early form of conservation.
4. For example, in the 1930s, Canadian Pacific Railway steam locomotives were estimated to have a service life of thirty-five to forty years. Freight locomotives were sandblasted and repainted in the railroad shops on average every 130,000 kilometers (80,000 miles). It was not uncommon for a freight locomotive to accumulate approximately 1.6 million km (1 million miles) during its working life, during which time it might have been repainted 12 times or more. Every one of these finishes would be considered as historically valid, regardless of its date, because of its association with the railroad shops. "Reconditioning of Locomotives," in *Canadian Pacific Facts and Figures*. (Montreal: Canadian Pacific Railway, 1937), p.140.
5. In the realm of fine arts, there is a parallel between the value placed on works by a recognized master, such as Rembrandt, and those created by his students.
6. In the future, we might consider creating a vocabulary similar to the one used by numismatists, ranging from "Brilliant Uncirculated" all the way down to "Counterfeit." Numismatists also have a certification system, whereby a coin is authenticated and graded by a professional service. A similar certification process for finishes could be carried out by conservators and curators.
7. See Valentine & Company ad (*Saturday Evening Post*, Sept. 27, 1924, p.36) "...there are cars...that need re-finishing before they are six months old." The owner in this ad is amazed that his refinished car, "...looks as though it had just come out of the paint shop, yet it has been used continuously many months in all kinds of weather."
8. Attempting to make an artifact look shiny and new is misguided in another sense, in that it appears never to have been used. An unused artifact is in reality an anomaly. The object did not fulfill its intended purpose, suggesting that it was a failure. Why didn't someone buy it or use it? Was the design defective? Were more desirable items available from competitors? Did some tragedy intervene with its intended use? Unused artifacts – or artifacts made to look unused – should make museum visitors uncomfortable because there is no association with the human experience.
9. Consider the situation with volunteers restoring airplanes from WW2. The war ended in 1945. Anyone old enough to have served during the final year would now be 82 years old. Most would be older.
10. A person may also have memories only of incorrectly restored vehicles. For example, automobile tires before 1925 were predominantly grey or white. By 1935, they were predominantly black. White tires were no longer produced after the mid-1930s, so "antique" cars that followed were invariably outfitted with new black tires. This went of for a period of over forty years. As a result, entire generations saw vintage cars only with incorrect black tires. If the collective memory of something as obvious as tires could be completely reversed from white to black, the memories of more subtle things like finishes have little chance of being accurate.

11. The American Library of Congress dramatically increased access to its digital archive through a cooperative venture with the image-hosting web site Flickr in January 2008. The archival project is called The Commons [http://www.flickr.com/commons/]. As of March 2009, twenty-two institutions were participating. The Commons, to some degree, inspired the writing of this paper.
12. Attempts to predict or quantify the probability of a finish surviving, based solely on outdoor exposure and frequency, will be unreliable because many variables might have had a significant impact. The results are surprisingly similar for all kinds of artifacts in all kinds of conditions. For example, a ceremonial carriage might have been used only once every five years, but it might have spent much of its time in poor storage conditions, and it might have been refinished prior to every use. Similarly, an emergency vehicle might have been used only on rare occasions, but the usage might have involved extremely rough handling and exposure to damaging conditions.
    Many large vehicles also traveled great distances through varying climates and topography. For example, a train might have run between Chicago and New Orleans, and an airplane might have flown regularly between New York and Copenhagen. These artifacts would have been exposed to different climates on a daily basis, and in the case of airplanes, to varying altitudes and all this entails.

Industrially produced paint and the perspective of its reconstruction.

Nynne Raunsgaard Sethia

Many museums operate with different aspects of authenticity. Exhibitions of a historic environment often need both material and visual authenticity to complete the display. In this article material authenticity is defined as giving the original material of the object highest priority, and visual authenticity is defined as giving the original appearance of the object highest priority. In cases where visual authenticity is of importance, reconstruction of surfaces is an option. This applies to objects with severely deteriorated or altered surfaces on interiors, exteriors and occasionally on objects. An example could be the display of industrial machinery or objects related to the production of food. A reconstruction of the surface may also be advisable as a protective measure, when the object is to be located in a harsh environment.

Den Gamle By is an open-air museum in Aarhus, the second largest city in Denmark. The museum's focus is urban history and appears as a town from the middle of the nineteenth century. On first sight, many visitors have the impression that the museum is in fact an old part of the city of Aarhus, but the houses have all been dismantled from Danish towns and erected on this site. Den Gamle By employs a team of brick layers, carpenters and painters who specialize in rebuilding and restoring old houses. They use the original materials and tools as often as possible, but still adhering to modern health and safety measures. Using original materials and tools is important because the museum's core focus is to give a quality "historic experience", taking the spectator on a visual and thus emotional travel in time.

Most objects in Den Gamle By are preserved and restored with focus on material authenticity. However, there is another category of objects, where the priorities are the visual authenticity as well as the authentic functionality of the items. An example could be the signboards hanging outside shops. They have to be maintained according to the standard, the shopkeeper would have kept them. Reconstruction of original surfaces is also used for this category of objects.

In 2008, Den Gamle By began recreating a modern city adjacent to the existing museum. As with the rest of Den Gamle By, the area will consist of dismantled houses from all over Denmark. The purpose is to present everyday life in the twentieth century, but has two major focus years: 1927 and 1974. This challenges the way the craftsmen work. For example, our painters must now take into account, that it is historically correct to use industrially manufactured paints, and this raises questions. Which types of paint were used for which purposes during the twentieth century? Is it possible to reconstruct these materials and their methods of application?

The object of this paper is to discuss the possibilities of reconstructing industrially manufactured paint. It includes an outline of when the different types of paint came into use in Denmark during the twentieth century and which purposes they served. The paper will focus on the Danish paint industry, because it is and has been the major supplier for the Danish professional painters since the First World War. Before that period English, German and Dutch paints were very popular [1,2,3]. During the 1920s, the Danish paint manufacturing industry grew rapidly and was eventually able to saturate the Danish demand and also export large quantities all over the world [4,5,6].

What is industrially manufactured paint?

During the twentieth century, the paint industry as well as their suppliers in the chemical industry continuously developed products to meet the demands of customers and to survive in the market. Those who survived did it by constantly reformulating their products to improve

Figure 1. The content of solid binder, in this jar of styrene-butadiene paint from the 1950s, is shown next to the jar. It is obvious why the binder determines most of the paint's characteristics.

durability, appearance, the ease of applying, lowering costs, avoiding health hazards etc.

In the beginning of the twentieth century, industrially made paint would typically consist of one pigment, one or two binders and usually a diluent. By the end of the twentieth century this list could compromise: binder, binder surfactant, binder coalescing agent, one or more pigments, pigment dispersant, pigment wetting agent, filler (extender), matting agent, solvent (or carrier fluid), pH buffer, anti-foam agent, freeze-thaw agent, biocide, UV-absorber and possibly more additives.

This development confronts us with a difficult situation. Is it realistic to reconstruct paints with such complicated formulas? What is our objective in reconstructing these paints?

To the first question, the answer is "probably not". The second question is subjective in that every professional may have his or her own opinion. One answer could be, "we want a reconstruction to show the appearance of the original". Appearance in this case means gloss, colour, evenness or signs of application mode, thickness and deterioration patterns. All these characteristics influence our impression of a surface. Thus, the combination of these parameters must be taken into account when working with visual authenticity as mentioned above.

The general assumption is that apart from the pigment, the binding media has the greatest influence on the appearance of a paint film. The binding media is not just the dominant ingredient, but also determines most of the characteristics of the paint. In fact, just the binder and carrier fluid (which will evaporate) constitute between 35 and 75% of modern paint. And with the pigment and extender we are up to between 72 and 96% by mass [7,8].

Figure 1 shows the content of binder in a styrene-butadiene paint called Spred Satin. Produced under license from The Glidden Co., it was the first latex (emulsion) paint to be introduced on the Danish market. On this photo the producer, Sadolin & Holmblad, wanted to show the customer that in spite of the very low viscosity of the paint, the product had a high content of binder. At that time, this seemed a contradiction, and was a sensational feature of the plastic emulsion paint.

A realistic reconstruction of paint, with an appearance close to the original, may thus be one in which the binder, solvent or carrier fluid, pigment and extender are historically correct. To be able to assess the possibilities of producing such a reconstruction, information about the most important materials is required.

The most important paint binders in Denmark during the twentieth century

Table 1 shows an overview of some of the most important binders as they occur in Denmark. Below is Figure 2, in which the binders are arranged in a time line.

Pigments during the twentieth century

Organic pigments

Development of synthetic organic pigments commenced in the second half of the nineteenth century, and by the turn of the century they were widely used. They became popular because of the bright hue and relatively good light-fastness compared to the natural organic pigments. Yet especially the red ones were known by painters to bleed when over-painted, a problem which was vigorously discussed in the first half of the twentieth century. In the same period, the red and yellow organic pigments were unpopular for outdoor purposes, as they had poorer weather resistance than inorganic pigments [9]. Almost all the different classes of synthetic organic pigments were developed before 1970 [10]. In 1927, which is a focus year of Den Gamle By, the synthetic organic pigments existing were a wide variety of red, orange and yellow colours [11] as well as a single blue and green pigment [12].

Inorganic pigments

Although the number of inorganic pigments in use has declined during the twentieth century due to the development of many synthetic organic pigments, titanium dioxide white, carbon black, iron oxides etc. are used in huge amounts. Before health and safety became an issue many harmful inorganic pigments were widely employed. In 1927, this included zinc green and yellow (containing chrome), chrome orange and yellow (containing lead) and of course the important red lead and lead white. Unlike other countries, such as Sweden, Denmark did not legislate in accordance with the Geneva Convention of 1921, which strongly limited the use of lead in paints and varnishes. The only limitation of the Danish law of 1925 was a ban against grinding and polishing dry lead paints. Due to the availability of other white pigments, lead white was not widely used by house painters at the time, but the use of other lead containing pigments was still extensive [13]. Until 2001, it was still legal to sell lead containing paints in Denmark, and in fact, due to an exception in the law, it is still legal to use red lead on historic objects [14]. In the second half of the twentieth century, zinc chromates gradually took over the important role of red lead for metal primers. Though toxic itself, it is not banned.

The pigment titanium dioxide white has truly become a giant in the paint industry. It entered the Danish market in 1920, but the Danish painters were suspicious and therefore reluctant to use it in the beginning [15]. By the mid 1920s, the painters eventually acknowledged the qualities of the pigment and it became popular for high quality work. Bear in mind that the pigment was a mixture of titanium dioxide (>18%), zinc white and blanc fixe [16]. For less important work the white pigment lithopone was used. The first titanium dioxide was an anatase crystaline modification. Around 1950, the rutile modification was introduced to the market, providing better resistance to weathering. Later, coated titanium dioxides of various kinds were developed [17].

In the 1920s iron oxides were sold, but had not yet substituted the natural earth colours of yellow, red and brown [16]. In the second half of the century, these natural earth colours no longer had any extensive use.

Extenders

Most extenders of paint have been in use during the entire twentieth century. They are not toxic, and therefore not problematic in reconstructions. Important extenders are chalk, china clay, talc, blanc fixe (especially in the first half of the century) and mica [7,17,18].

Methods of application

By the beginning of the twentieth century, all application was done by brush. Around 1910 the air brush was introduced to the Danish market, but this method was still relatively rare by the end of the 1920s [16,19,20]. Later, air brushing became a standard method of application, and different types of equipment were invented. It is possibly the most important industrial mode of application today. By the 1940s, the methods of application included dipping (high viscosity and thick layers) and covering objects in paint in a spinning drum (low viscosity and thin layers) and other less important processes [21]. The roller for house painters was introduced quite late in Denmark, many years after the introduction in other Northern European countries [22]. Stelling began producing and selling rollers in 1953 or 1954. In the book “Malerens bog” from 1954, an entire chapter is devoted to the instruction in the use of the new roller [23,24]. This seems superfluous today, when everybody employs rollers without any instruction!

Table 1. An overview of the most important types of paint binders and their use, components, combinations and names in Denmark. The product names are not exhaustive and should only be regarded as examples. Please refer to the "References" and "Other references" lists for sources.

Type	Principal use	Comments on the components	Combinations	Product names
Whitening / lime wash	Exterior of brick houses, kitchens, less important rooms, cellars etc.	Slaked lime, occasionally added pigments	Not common	Læsket kalk, kulekalk
Distemper	Interiors, especially behind wood burners and on upper walls of e.g. stairwells.	Traditionally a product of animal origin, from the early 20th cent. cellulose based.	In the 1950s stabilized with up to 10% plastic emulsion.	Sold in boxes of coloured powder: Calsolit, Exolose.
Blood albumin	Outdoor wood	Traditionally whisked blood, later industrially separated blood albumin	Unknown	Maxima
Linseed oil	All-round, especially on wood and metal. Semi-gloss and matt variations. Applied in multiple thin layers of different composition.	Sometimes diluents. Linseed oil itself has different characteristics according to the way it is processed, such as boiled, blown or transformed to stand oil.	Other oils and resins (as described below). From 1940-1948 bans and restrictions led to combinations with fish oil, mustard seed oil, tall oil and casein.	Semi-gloss: Danox. Dyrups Oliemaling, Linol. Matt: Temporin, Flatolin, Saniton, Flatox.
Resinous lacquers	As top coats on oil paint in the early 20th cent., for floors and wooden items.	Soft resins in cheap products. Hard resins, called copals, in high quality products. Synthetic resins, principally resin-phenol-formaldehyde and later pure phenol-formaldehyde.	At first mainly dissolved, later usually in combination with linseed oil and from the 1920s principally with wood (tung) oil.	Popular floor lacquers: Sahocol, 4-timers lak 555.
Oleo-resinous paint	All-round. Very popular as top coats on oil paint to increase the gloss and durability.	Principally melted copals, added different oils, e.g. linseed, wood (tung), oiticia, perilla, ricinus and diluents. In 19th cent. /early 20th cent. foreign products were popular. By the 1920s the Danish industry took over the market.	Combined with alkyd to so-called half synthetic enamels.	Japan emaille, kulørt olielak, lakfarve, kulørt emaillelak, olieemaille, Sadolin emaille.
Nitro-cellulose	As lacquers for furniture and floors. As paint mainly industrially applied, such as automobile finishes and small mass-produced items. In the 1930s also sold for brushing, see Figure 4. If a thick layer was needed, applied on an oil primer or nitrocellulotic sanding.	Sadolin & Holmblad one of the first European producers in 1925. Cellulosenitrate. Plasticizer added to ensure adhesion and reduce brittleness: In early formulations e.g. camphor, later e.g. tricresyl phosphate or phthalates. Resin added to improve gloss and resistance: dammar, ester gum, later non-drying alkyds.	Combined with alkyd, yet still called nitrocellulose.	Sado, Herkules, Du-Flex, Zaponlak.
Chlorinated rubber (klorkautsjuk)	Industrial use, e.g. outdoor steel structures, machines.	A plasticizer, usually parafine wax, added.	Unknown.	Acidur Emaille 249. Alka emaille.
Alkyd	Truly an all-round binder, but especially popular for wood and metal finishes. From high gloss to matt.	Dyrup and Sadolin & Holmblad introduced alkyd in 1932 or 1933. Initially known as the synthetic copal glyptal, a combination of phtalic anhydride, glycerol and drying oils. Later semi- or non-drying oils were used. The oil content determines the characteristics as e.g. a drying or non-drying alkyd, the latter used in stoving coating. Pentaerythritol substituted glycerol in the 1950's. Though the most popular products were solvent based, emulsions have been made since the 1930s. These have only recently become popular.	Alkyds treated with styrol came around 1950 for air brushing. Combined with oil. Used as additive to many other types of paint, as can be seen in this table.	Syntal, Sadoloid, Sadolux, Dypp 2502, Durosan,Tempo, Colomatt, Stellux, Exolux, Flat, Betona, Pinotex With styrol: Styrox, Dyrosol.

table 1. cont.

Styrene-butadiene or synthetic latex	For interior walls.	The first plastic emulsion paint to enter the Danish market in early 1952. The only plastic binder which use has diminished, probably because it yellows, is more expensive than PVA and because Spred Satin could not be applied by roller.	unknown	Spred Satin (under licence from Glidden)
Acrylic	All-round.	Entered the Danish market in 1952. More popular for household paints than generally assumed. A co-polymerization of acrylics. Different variations developed. Most popular as emulsion, but also used in solution for industrial purposes. In 1957 Dyrup introduced the first plastic emulsion multi-colour paint in the world, called Multi-Plast. It consisted of both a water and white spirit phase.	Styrene-acrylics used for matt paints, floor lacquers etc. Alkyd could be added to improve adhesion.	Dyrotex, Dyroton, Flutex, Catuplex, Multi-Plast, Dækso-Plast, Mill, Fluganyl gulvmaling.
PVA	All-round, considered less durable than acrylics.	Polyvinylacetate. Required a plasticizer in the early days. In the 1960s this was solved by co-polymerization with a binder of lower Tg, e.g. vinyl chloride or acrylic esters. The co-polymers showed improved adhesion.	Allegedly, in some cases alkyd was added to improve adhesion.	Sadosan, PV-A plastmaling, acidur emaille 247
Urea- and melamine-form-aldehyde / acid curing lacquers.	Acid curing lacquers especially for furniture and floors. Urea- and melamine-formaldehyde are widely used in high quality, all round, industrial stoving finishes for metal. The former often as primer, the latter often as top coat.	To form a film at room temperature acids are added to the urea- and melamine-formaldehyde, hence the name acid curing lacquer.	Combined with alkyd in acid curing lacquers. Very important are industrial stoving coatings combining urea- and melamine-formaldehyde with acrylics, alkyds or polyester.	Securit acid curing lacquer, Dyrolit emaille, plasticolor emaille.
Epoxy	Industrial and professional use where excellent durability is needed, e.g. highly trafficked floors, bathrooms, domestic appliances in contact with chemicals.	Ajour, a system of different products for the industry, introduced in 1955 by Dyrup. Epoxy can be used with other binders or cross-linked by e.g. dicyandiamide, anhydrides or polyamines.	Different types are available such as Epoxy-ester resins, epoxy-alkyd, epoxy-phenol, epoxy-urea-formaldehyde or with acrylic co-polymers	Epoxid emaille, Sadopox emaille, Flott gulvlak, Gå-Klar gulvlak
Poly-urethanes / iso-cyanates	Almost as epoxy but even better for outdoor purposes.	Polymer of different isocyanates. Cross-linking can be catalyzed by adding e.g. tertiary amines.	Urethane oil (e.g. castor oil) and urethane alkyd can be found.	DD-emaille, DUR emaille, Exodur emaille.

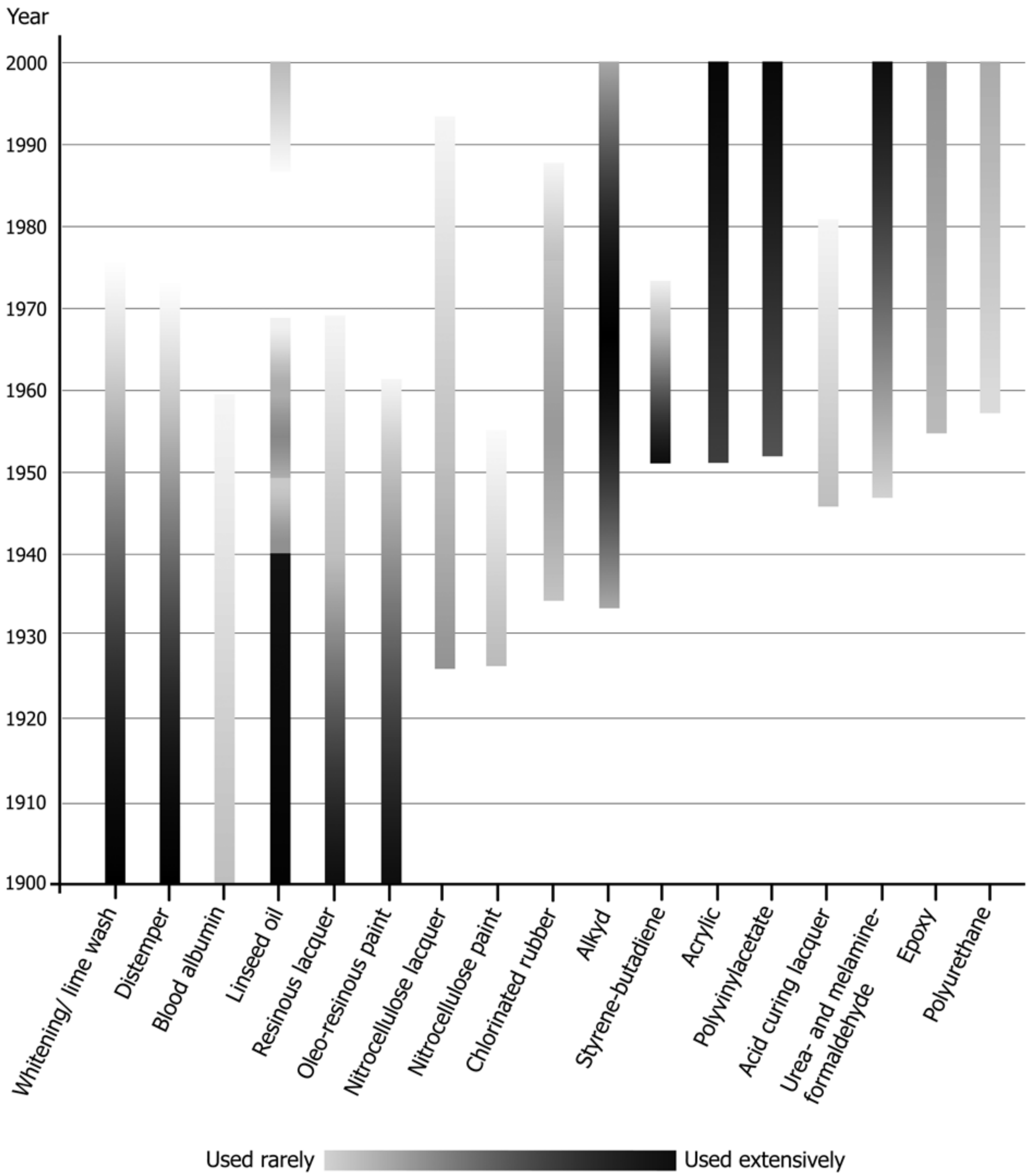


Figure 2. A time line shows the use of the different paint binders in the twentieth century in Denmark. The uses of the binders are not based on statistical material and are merely indicative. Notice that many of the dates are approximate.

Figure 3. "A useful play!" is the title of this advertisement from the 1930s. Letting a child paint with nitrocellulose enamel would certainly not be considered responsible today!

Is reconstruction possible?

An exact reconstruction of an industrially produced paint, which is more than a few decades old, is probably never possible. However, if a reconstruction through using correct binding media, pigment and extender is considered acceptable, there is a chance of succeeding.

As shown above, most binders and pigments were invented in the first half of the century. Interestingly, most of the binders mentioned were common during the 1950s and 1960s. Those were the years when the use of old materials gradually declined and new products gained popularity on the market. With regards to reconstructing a painted surface from the last three to four decades of the twentieth century, it is thus possible to use many of the available paints being produced today.

But which type of paint from the first half of the twentieth century is most important for Den Gamle By? Especially the oleo-resinous oil enamel paint is of high interest for reconstructions, because it was widely used in 1927. See Figure 4. However, it is not as easily prepared at the workshop as ordinary linseed oil paint. This is due to the high temperatures involved in melting the copals. Furthermore, an industrial production results in a more uniform product. The Danish paint producing factory, Boesens Fabrikker ApS, has specialized in making small batches, tailored to the customer's need. They have indicated that reconstruction of paint from the first half of the twentieth century is indeed possible, as long as a proper paint formulation is at hand. This poses a serious problem, because most of the remaining paint factories from that time have not saved their old formulations. Usually, explanations such as "we moved location" or "we merged with another company" are used to justify why the archives have been discarded. Some have deliberately shredded old formulations as soon as they were out of use, probably to protect their secrets from leaking to rivals. The Danish National Business Archives unfortunately only received very little material, and nothing regarding paint formulations. Only one company, the important Dyrups, has indeed kept the old paint formulations, but they are temporarily packed away, and while working on this presentation it has not been possible to see that archive. If indeed Dyrups keeps a formulation, which is suitable for use, there can be no way of ensuring its representativity, due to the limited availability of formulations. Yet the aim must be "better one than none".

Broadening the search for old paint formulations has lead to an interesting "recept-bok", from Sweden, written by hand in the 1890s [25]. Some of the paint recipes of that book have been printed by Johansson, including four recipes for oil enamel. As an example, the oil enamel paint of zinc green could either be of: 25% pigment, 4% boiled linseed oil, 0.25% drier and 70.75% copal or of 25% pigment, 25% copal and 50% dammar-lacquer. This dammar-lacquer should contain a maximum of 20% dammar resin in white spirit. The first recipe, with 70.75% copal, must have been very thick and should probably be diluted before application.

The potential process of reconstructing the oil enamel paint will start in the research lab of Boesens Fabrikker. The engineers will attempt to reconstruct the Swedish formulation on a small scale. First of all, the binder itself is going to be tested, because the museum needs large quantities of binder. Different pigments, grinded with a binder or solvent to a thick paste, are to be provided separately, so the museum painters may mix the pigments and binder when needed. Which pigments are still to be decided, but non-toxic pigments are obvious choices. The museum keeps and occasionally uses some of the old and toxic pigments for small samples to be matched visually with non-toxic pigments, which are used for the actual work [26].

In some cases it could be interesting to use nitrocellulose enamel in Den Gamle By. For instance, nitrocellulose layers can be polished to give an extremely high gloss, a surface which we may want to reconstruct in the future. Boesens Fabrikker still produces nitrocellulose lacquers, and possibly these can be used as binders for nitrocellulose enamel. In Denmark it is not illegal for a museum to use nitrocellulose paint as long as safety measures are taken. It may interest some people to know that nitrocellulose paint is still used in some places. For example the Duco automobile paint of India is still on nitrocellulose base. Thus, broadening the search for specific paint types to other countries may also be a way to find the right products for reconstructing surfaces. [27]

Acknowledgments

For valuable support, the author wishes to thank Karen Woer, Johnny Møller Jensen, Thomas Block Ravn and Karen Marcmann from Den Gamle By. The author is grateful that Kari Berg had the patience to look through hundreds of painters' newsletters. A very special thank you goes to Jørgen H. Olsen and Knud Nielsen from AkzoNobel, former Sadolin & Holmblad, who devoted hours in sharing information. Others from the paint industry, who were helpful, included Bjarne Willum Thomsen, Ulf Schnack from Flügger A/S, Ester Hougaard Sørensen from Dyrup A/S and Gert K Thomsen. Thank you very much, Nina Seirup and Bodil Klarskov Larsen for valuable suggestions.

The Heritage Agency of Denmark (Kulturarvs-styrelsen) has supported the research financially.

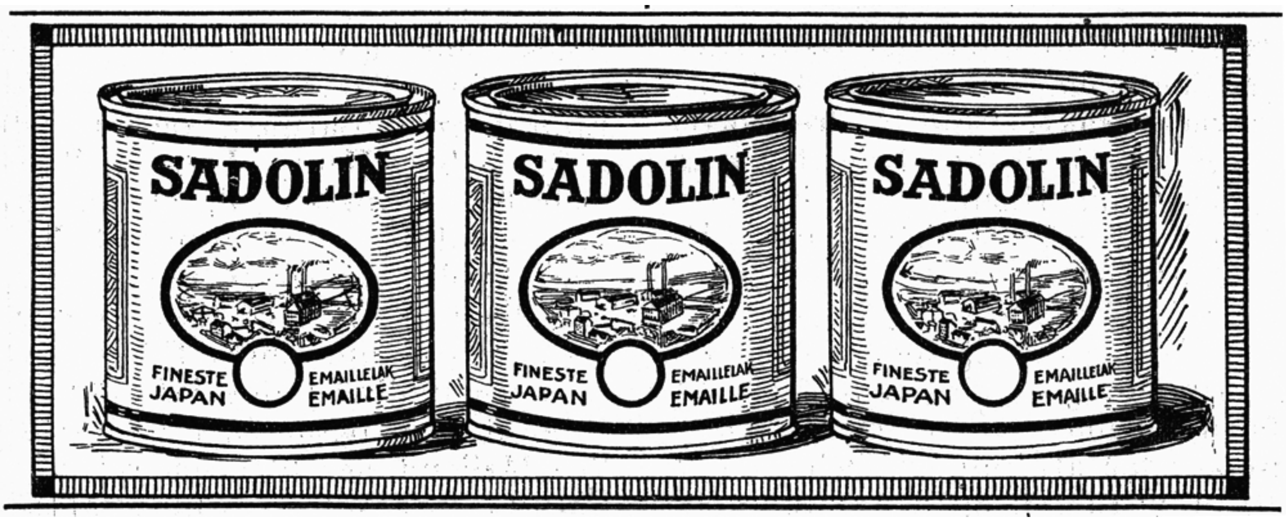


Figure 4. This is a simple and beautiful advertisement from the early 1920s of an oil enamel paint, which Den Gamle By aims to reconstruct.

Author

Nynne Raunsgaard Sethia
Den Gamle By
Viborgvej 2
8000 Aarhus C
Denmark
nrs@dengamleby.dk

References

1 Pedersen, Thomas: Farve i Praksis. In Farve og Lak 29 p. 42-45, Dyrup 1953

2 Larsen, Sven: Malerfagets teknik og materialer. In Malertidende no. 2 and 3. 1951.

3 Eikers, E.: Kært Barn har mange Navne eller om Navne paa Farver og Lakker. In Farver og Lak 19 p. 14-17. Dyrup 1944

4 Anon.: I Krisens Tegn. In Farve & Lak no. 1, Dyrup 1932.

5 Randløv, A.: Sadolins Farver. Sadolin & Holmblad Fra Farverivning til kemisk Industri. Egmont. Copenhagen 1932.

6 Lichtenberg, Niels: Fra farveplanter til stor-industri. In Sadolins Nyt 35 p. 15-22. Sadolin & Holmblad. 1953

7 Olsen, Stig Irving: Baggrundsdokument for Miljøvejledning for maling og maleydelser. Miljoevejledninger.dk 2005.

8 Bentley J. and Turner, G.P.A.: Introduction to Paint Chemistry. Fouth Edition, Chapman & Hall, London 1998.

9 Personal communication, Bjarne Willum Thomsen, 10.01.2009.

10 Only one class, the Diketopyrrolo-pyrrole was introduced later, according to Lomax and Learner p. 110. Lomax, Suzanne Quillen and Learner, Tom: A review of the classes, structures and methods of analysis of synthetic organic pigments. Journal of the American Institute for Conservation. 45:2. 2006. p. 107-125

11 For example acetoacetarylide, Naphtol and Beta-Naphtol. Kalsbeek, Nicoline: Identification of Synthetic Organic Pigments by Characteristic Colour Reactions. Studies in Conservation 50. 2005. p 205-229.

12 De Keijzer, Matthijs: The history of modern synthetic inorganic and organic artists' pigment. In Contributions to conservation research from the ICN. London, 2002. p 42-54. For details about the different classes and pigments please read Lomax and Learner [10] or check The Colour Index International online on http://www.colour-index.org/

13 For the whole discussion about the Geneva Konvention and the Danish law, see Malertidende 1922-1925 and Medlemsblad for Københavns Malerlaug 1922-1925.

14 It is not used in Den Gamle By.

15 For a discussion about the use and properties of Titanium dioxide white see Malertidende 1920-1925 and Medlemsblad for Københavns Malerlaug 1920-1925.

16 The Danish Standard presented in Aabye, J.S.: Malerborgen. Teknologisk Instituts forlag, Copenhagen 1931.

17 Morgans, W.M.: Outlines of Paint Technology. Vol. I: Materials. Charles Griffin & Company LTD London 1982.

18 Feller, Robert. L.: Barium Sulfate – Natural and Synthetic. In Artist's Pigments. Oxford University Press. 1986. p. 47-64

19 Anon: Sprøjtemaleri. In Medlemsblad for Københavns Malerlaug 1921, no. 29.

20 Arentzen, Asb.: Sprøjtemalingsmaskinernes Indvirkning paa Malerfaget i De forenede Stater. In Medlemsblad for Købnehavns Malerlaug 1927, no. 28.

21 Anon.: Oversigt over forskellige Paaføringsmetoder med særlig Henblik paa Dyppe- og Tromlelakering. Sadolin Nyt 29. Sadolin & Holmblad 1949.

22 Johansson, Alf: Massproduktion och välfärd. Sveriges Färgfabrikanters Förening. Tierp, 2001.

23 Larsen, Johs.: Malerens bog. Forlaget Fremad. Copenhagen 1954

24 In "Malerbogen" from 1953 the roller is not mentioned even though every type of brush is described in detail. Aabye, J.S.: Malerbogen. Teknologisk Instituts Forlag. Copenhagen 1953.

25 Alf Johansson stumbled upon this book from the 1890's while writing "Med Pigment Och Kopaler" about the history of the Swedish paint producers. Sveriges Färgfabrikanters Förening. Tierp, 2001. p.100-104.

26 The conservation workshop has a permission to do so.

27 Please note that an extended version of this article, in which the binders are described individually in the text, is published on the website of Den Gamle By: http://www.dengamleby.dk/art.htm

Other references

Andersen, Sv.: Nye malermaterialer og deres anvendelse. Københavns Malerlaugs Medlemsblad 1953.

Andersen, Svend: Nye materialer i malerhåndværket. Københavns Malerlaugs Medlemsblad. 1951 p. 42-51

Anon: Den ny oliefri Grundingsteknik. Medlemsblad for Københavns Malerlaug. 1923 no.39. p.338.

Anon: Temporin. Mat oliefarve. Medlemsblad for Københavns Malerlaug 1924 p. 100.

Anon: "Emalin" Lakfarve. In Farve & Lak no. 16. Dyrup 1943.

Anon: To nye Plastic-malinger. In Farve & Lak no. 28. Dyrup 1958. p 10-13.

Anon: Træolie. In Farve & Lak no. 8. Dyrup 1936. p.14-16.

Anon: Ajour. Farve & Lak no. 31. Dyrup 1955

Anon: Lidt om plastikmaling på forhen kalkede eller emulsionsmalede facader. Københavns Malerlaugs Medlemsblad 1956 p. 127

Anon: Universal 1989. Sadolins Nyt 34. Sadolin & Holmblad 1951. p. 18.

Braagaard: Malerfagets Materialer. Københavns Malerlaugs Medlemsblad. 1953. no. 4 & 6.

Croll, Stuart: Overview of the Developments in the Paint Industry since 1930. In Modern Paints Uncovered. The Getty Conservation Institute, Los Angeles. 2007. p 17-29

Eistrup, K.:Infrarød tørring og ovntørrende emaille. In Farve & Lak no. 26. Dyrup 1950. p.12-14

Foreningen for Danmarks Lak- og Farveindustri: Handelsvarer på malevarer. 3. Ed. 1970.

Khandekar, N. Nagy, E. Miller, J. Gottshaller, P. Mancusi-Ungaro, C.: The re-restoration of Donald Judd's Untitled, 1965. In Modern Paints Uncovered. The Getty Conservation Institute, Los Angeles. 2007. p 157-164.

Learner, Tom: A review of Synthetic Binding Media in Twentieth-century paints. The Conservator no. 24, 2000, p.96-103.

Learner, Thomas: Moderne Paints:Uncovering the Choices. In Modern Paints Uncovered. The Getty Conservation Institute, Los Angeles. 2007. p 3-16.

Meineke Nielsen, L.: Farveteknik i løse Blade V. Lakerearbejders Holdbarhed. Sadolin & Holmblad 1927.

Møller, Per: Overfladeteknologi. Teknisk Forlag A/S, Copenhagen 1998.

Nagy, Eleonora and Adamson, Karlis: Saving Judd's Untitled 1964: A revival of a galvanized steel single stack sculpture with red nitrocellulose paint. Journal of the American Institute of Conservation 46 (2007) p 245-261

Nielsen, Mogens: Ingeniør Sigurd Dyrup. Farve & Lak 25, p.1-3. Dyrup 1949.

Otte, N.C.: Syntal Produkterne. In Farver & Lak no 25. Dyrup 1949. p. 4-5.

Otte, N.C.: Den tekniske udvikling gennem de sidste 25 år. In Farve og Lak no. 29. Dyrup 1953

Otte, N.C: Tallolie. In Farve & Lak no. 19. Dyrup 1944.

Standeven, Harriet: The Development of Decorative Gloss Paints in Britain and the United States c. 1910-1960. Journal of the American Institute of Conservation 45 (2006):51-65.

Standeven, Harriet: "Cover the Earth": A history of the Manufacture of Household Gloss Paint in Britain and the United States from 1920s to 1950s. In Modern Paints Uncovered. The Getty Conservation Institute, Los Angeles. 2007. p 75-82

Protection of iron and steel in industrial heritage objects

Yvonne Shashoua, Michelle Taube and Torben Holst

Introduction

In 2007, the National Museum initiated a 3-year, multidisciplinary research project into the conservation of industrial objects, the first in this new specialism in Denmark.

The first 18 months of the project focuses on the protection of industrial objects containing iron or steel. Such objects are usually large and include machinery, transport vehicles and military equipment (figure 1). Because of their size and immobility, industrial objects are either found outdoors or in uncontrolled indoor climates such as aircraft hangars. Untreated, the surfaces of iron and steel corrode and are deteriorated by exposure to oxygen, water, salts and pollutants.

The coatings industry has developed effective surface protection systems including barrier coatings and corrosion inhibitors for exterior structures such as ships and bridges which could be applied to industrial heritage objects. However, they usually require reapplication every 3-5 years which is expensive, rarely preserve the colour or significance of the object and cannot always be removed to reveal the original surfaces which is one of the ethical requirements of conservation practices.

Figure 1: Haubitzer cannons form part of Copenhagen's defence system. The untreated cannons are highly corroded by their environment close to the sea.

After discussion with professionals concerned with the study and care of industrial heritage objects in various organizations including English Heritage, German Mining Museum and Danish Technical Museum, a list of specifications for protection systems was compiled.

1. Longevity-they should last for a minimum of 3 years in outdoor or uncontrolled environments without requiring further maintenance.
2. Appearance-they should preserve the original appearance of the industrial object.
3. Function-they should allow retention of the original function or significance of objects so that their cultural, historical and technological interpretations remain unaltered.
4. Reversibility-treatments should be removable or allow retreatment.
5. Stability-they should not accelerate corrosion of metals or contribute to deterioration of any composite materials present.
6. Health and safety-treatments should be harmless to both operator and the environment.

Research strategy

An extensive investigation of peer-reviewed conservation literature and commercial sources of protection systems for outdoor steel including coatings, oils, waxes and corrosion inhibitors published since 2000 formed the starting point for the project. Availability and formulations of commercial products used before 2000 are likely to have changed. A considerable body of work was found concerning protection systems and approximately 100 publications were deemed relevant to the present project. Those materials that performed best in each study were selected resulting in a total of around 40. Protection systems were categorized by the major mechanism they used to protect metal against corrosion. The categories were those containing corrosion inhibitors, those that protected metals mainly by forming a barrier against water, those that protected metals mainly by forming a barrier against oxygen and atmospheric pollutants and those which chemically changed iron or steel. The techniques used to apply and evaluate protection systems in studies since 2000 were also selected from literature. The purpose was to use similar techniques in the present study so that findings would be readily comparable.

It was concluded that the three factors which prevented inter-research comparison were variation in dry film thickness, use of non-standard evaluation techniques and selection of appropriate reference coatings.

Most of the studies evaluated a number of coatings 'as normally applied' or 'according to manufacturer's instructions' which meant that the performance of a material applied as 5 layers (35 microns thick) was compared directly with another applied as 2 layers (10 microns thick) [1]. Although such an approach was logical because it represented actual use, it did not allow equal comparison of the coatings' properties [2]. In addition, the method of applying coatings strongly influences their corrosion resistance. The performance of protection systems applied by dipping or spray cannot be directly compared with their performance when applied by brush.

Techniques for evaluating surface treatments varied in type and effectiveness between published studies. Few methods were described to evaluate oily, non-drying films. Comparison of results from evaluation of protection systems proved a more complex procedure than expected. The literature indicated that performance of protection systems is rarely evaluated using standard procedures but those preferred by the individual manufacturer or research group. For example, procedures to induce or accelerate corrosion on coated metal panels included exposure to salt spray at 30°C and 50% relative humidity (RH) for 7 days [2], dipping panels in sodium chloride solutions prior to exposure at 40°C and 100% RH for 16 hour cycles [1] and exposure to 24 hour cycles of fluctuating RH at 30°C [3].

Researchers were not agreed on a single reference material with which to compare the performances of protection systems. They were often compared with Paraloid B72 (poly (ethyl methyl methacrylate)) [4]. While Paraloid B72 is accepted as a standard for conservation adhesives and consolidants for objects in store or on display in museums, it is not widely recognized as an effective exterior coating. Wax coatings such as BeSq195 and TWA 2095 were also cited as reference materials [2].

An experimental research strategy was developed based on the findings of the literature study. It was decided to select those protection systems which both performed best in each study and which also met the project's specifications of longevity, appearance, function, reversibility, stability and safety. They were applied so that they achieved the same dry film thickness on model bare steel substrates. Materials were screened using identical, standardized test conditions to compare performance. Development of application procedures and results of screening are described in the present publication. In the next stage of this project, all surface treatments will undergo accelerated salt spray and real time ageing to determine longevity. Those that perform best will be applied to real industrial objects such as cannons and weaving machines for in-situ evaluation.

Selection of protection systems for evaluation

The properties of the 40 materials identified as performing best from the literature study were compared with the list of specifications developed for the project. Those which did not meet the longevity and health and safety requirements according to literature were discarded. Information about longevity was not available for all protection systems. Technical data provided by the manufacturer of VP CI-386, acrylic primer/topcoat suggested that it protected surfaces for 5-10 years [5] while Ship-2-Shore Industrial, a liquid barrier coating, was claimed to protect surfaces for 5-20 years [6]. By contrast, Rustilo DWX 22 was claimed to last only 1-2 months outdoors [7]. Where information provided by the manufacturers indicated that it was not intended to be used for longer than one year, the product was not investigated further.

Because one of the aims of the project was to contribute to the conservation of industrial objects in Europe, any protection systems which were not widely available were not investigated further. A corrosion inhibitor, FPTS (3-phenyl-1,2,4-triazole-5-thione) was claimed to reduce the oxygen and chloride content of iron surfaces and showed promising results. However, because FPTS had been specially synthesized in the researchers' laboratory and was not commercially available, it was not included in the screening [8]. Excellent wetting of metals is essential if they are to be protected against corrosion for prolonged periods. Protection systems based on non-drying oils which did not make good contact with steel during trial application were not investigated further.

18 materials met the specifications and were evaluated in the laboratory screening (table 1 and table 2).

Application of protection systems

Q panels type R (low carbon, cold-rolled steel panels with a dull finish and a thickness of 0.8 mm) are the standard substrates used to evaluate industrial coatings for vehicles. In addition, they have been used in earlier research projects at the National Museum of Denmark so were selected as the test substrate in the present project. Q panels were used as supplied immediately after degreasing with acetone.

Because many of the published references stated that protection systems had been applied according to manufacturer's instructions, a trial was made to determine the variation in film thicknesses achieved using such an approach. Conservators at the National Museum of Denmark prefer to apply treatments by brush to large objects that are situated outside and cannot be dismantled. Brushing is a slow process but the applied film thickness can be readily controlled and the health protection equipment required for brushing is generally less than that required for spraying where the area may have to be enclosed to also protect the public. Where there was a choice between application of the protection systems under investigation by brush, roller or spray, brush was selected unless the coating was supplied in an aerosol can, in which case it was sprayed. Each surface treatment protection system was applied at the concentration or dilution specified by the manufacturer using a 1 inch (2.5cm) flat bristle brush to three, freshly cleaned, pre-weighed Q panels. They were allowed to dry horizontally for 7 days at 18-20°C and 35-40% RH.

The dry film thickness of each treatment was determined using a Fischer Dualscope MP4C probe. The instrument uses eddy currents to nondestructively measure the thickness of nonconductive coatings on ferrous metal substrates. A coil of fine wire conducting a high-frequency alternating current (above 1 MHz) is used to set up an alternating magnetic field at the surface of the instrument's probe. When the probe is brought near a conductive surface, the alternating magnetic field will set up eddy currents on the surface. The substrate characteristics and the distance of the probe from the substrate (the coating thickness) affect the magnitude of the eddy currents. The probe was placed in 5 places on each panel, at least 1cm from edges to minimize the influence of edge thickening. The mean value given in microns was calculated (table 1).

The thicknesses varied from less than 1 micron to 50 microns. To compare them equally, it was decided to apply all surface treatments so that they attained the same dry film thickness by adjusting the number of applications or concentration of material applied.

Evaluation of protection systems

The standard techniques used to evaluate industrial coatings were applied in this project. They include appearance, dry film thickness, adhesion, hardness and resistance of surfaces to corrosion. The electrochemical measurements include electrochemical impedance spectroscopy (EIS) in which small perturbations in the electrical potential on a sample give an indication of how resistant the surface is to corrosion. EIS is a well established technique for examining the effectiveness of coatings and has been used by other researchers in

Table 1: Selected protection systems which meet the requirements of longevity, stability and health and safety according to literature sources.

protection system	**description**	**mean dry film thickness (microns)**	**literature source**
Corroheat 4010	heat resistant, corrosion prevention giving a hard film	25.0	[2]
Tectyl 506 rust preventative	anticorrosive coating	23.2	[2]
Ship-2-shore Industrial	colourless liquid barrier coating-removable with water	non-drying	[6]
SP400	long term indoor/outdoor corrosion inhibitor	24.1	[2]
Rustilo 2000	dark brown solvent-based coating with corrosion inhibitor	22.4	regularly used at National Museum of Denmark
Rustilo 3000	anticorrosive coating containing bitumen	25.0	regularly used at National Museum of Denmark
VpCI-386 acrylic primer/ topcoat	fast-drying, water-based acrylic primer/topcoat with corrosion inhibitors-non-toxic	9.8	[5]
Tectyl Glashelder/Klar spray	acrylic-based anticorrosive coating	22.6	www.eurodeal.dk
Renaissance wax	mixture of 100g Cosmoloid H80, 25g polyethylene wax heated and thinned in 300mL hydrocarbon solvent	4.0	[13]
Cosmoloid H80	blend of microcrystalline waxes	5.5	[13]
Tromm III	WaxTeCerowax 30201 and TeCerowax 30401 (1:1)	20.0	[1]
Paraloid B72	acrylic consolidant in solid form	7.0	[2]
Perfluorodecyl iodide	wetting additive-perfluoro compound (aliphatic)	6.8 (in Paraloid B72)	[14]
Dinitrol Car/4941	thixotropic corrosion preventive-forms tough, elastic, black, waxy protective film on drying	49.9	regularly used at National Museum of Denmark
LPS3	soft, self-healing waxy film	23.1	www.itw-scan.com
Poligen ES91009	wax (ethylene emulsion 24% in water) dries to film in 24 hours	6.8	[13]
Frigilene	cellulose nitrate lacquer dissolved in acetone	6.7	regularly used at National Museum of Denmark for silver
Incralac	acrylic blend with benzatriazole and ultraviolet stabilizer	20.4	regularly used at National Museum of Denmark for silver

the conservation profession [2,9]. To date only the protection systems applied to bare Q panels have been evaluated. Evaluation of protection systems after application to pre-corroded panels will follow.

Dry film thickness

The dry film thickness of each coating was determined using a Fischer Dualscope MP4C probe as described previously. All surface treatments were applied so that they attained 20-25 microns by adjusting the number of applications or concentration of material applied (table 3). Coatings of less than 25 microns are known to offer poor protection to car bodies exposed to water, oxygen, salt and abrasion during their lifetimes [10]. However, because a single application of the waxes produced dry films thinner than one micron, it was impractical and time consuming to apply them thicker than 20 microns.

Appearance

Surface treatments were either colourless and transparent, gold and transparent or black and opaque (table 3, figure 2 and figure 3). All the gold-coloured coatings contained corrosion inhibitors which often impart a brown colouration. Treatments based on waxes did not form cohesive films and brushstrokes and crazing were visible with the naked eye (figure 4). The wetting agent, perfluorodecyl iodide, imparted a milkiness to Paraloid B72 on drying which indicated that they were poorly compatible. Vp CI-386 acrylic primer/topcoat, Tectyl Glashelder and Poligen ES91009 produced

Table 2: Suppliers for selected protection systems

protection system	supplier
Corroheat 4010	EFTEC Aftermarket GmbH, Pyrmonter Str. 76, D-32676 Lugde Germany tel: +49 5281/98298-0
Tectyl 506 rust preventative	Eurodeal Autoparts A/S Stamholmen 111 DK-2650 Hvidovre, Denmark www.eurodeal.dk tel: +45 70 13 11 13
Ship-2-shore Industrial	Ship-2-Shore Box 48205 Victoria BC Canada V8Z 7H6 www.ship-2-shore.com
SP400	EFTEC Aftermarket GmbH (details as for Corroheat 4010)
Rustilo 2000	Kemi Service A/S Bugtattivej 15 DK-7100 Vejle, Denmark tel: +45 75 85 99 11
Rustilo 3000	Kemi Service A/S (details as for Rustilo 2000)
VpCI-386 acrylic primer/topcoat	HITEK Electronics Materials Ltd. 15, Wentworth Road South Park Industrial Estate Scunthorpe North Lincolnshire DN17 2AX United Kingdom www.hitek-ltd.co.uk tel: +44 01724 851678
Tectyl Glashelder/ Klar spray	Eurodeal Autoparts A/S (details as for Tectyl 506 rust preventative)
Renaissance wax	Kremer Pigments GmbH & Co KG Haupstrasse 41-47 D-88317 Aichstetten Germany tel: +49 7564-91120
Cosmoloid H80	Kremer Pigments GmbH & Co KG (details as for renaissance wax)
Tromm III	Th.C. Tromm GmbH D-50694 Cologne P.O.B. 620168 Germany tel: + 49 221 745448
Paraloid B72	Conservation By Design Ltd. Timecare Works 5 Singer Way Woburn Rd Ind. Estate Kempston Bedford MK42 7AW United Kingdom www.conservation-by-design.co.uk tel: +44 01234 853555
Perfluorodecyl iodide	Alfa Aesar GmbH & Co KG Zeppelinstrasse 7 76185 Karlsruhe Germany tel: +49 721 84007-0
Dinitrol Car/4941	EFTEC Aftermarket GmbH (details as for Corroheat 4010)
LPS3	ITW Chemical Products Scandinavia Priorsvej 36 DK-8600 Silkeborg Denmark www.itw-scan.com tel: +45 86 82 64 44
Poligen ES91009	BASF Aktiengesellschaft Carl-Bosch-Str.38 67056 Ludwigschafen Germany http://btc-nordic.com
Frigilene	Conservation By Design Ltd. (details as for Paraloid B72)
Incralac	Conservation By Design Ltd. (details as for Paraloid B72)

highly glossy, colourless, transparent surfaces which would suit, from a cosmetic perspective, the surface appearance of polished, uncorroded steel. Rustillo 3000 and Dinitrol Car/4941 formed black coatings which were likely to be more resistant to degradation caused by ultraviolet radiation than transparent films. Ship-2-shore Industrial produced a non-drying, tacky surface which was readily marked and dust adhered readily to it.

Hardness

The hardness of dry surface treatments gives an indication of how readily they can be marked or abraded by airborne particles or during handling. Thumbnail hardness is a very practical and rapid procedure for comparing hardness of painted components [11]. Poligen ES91009, Frigilene and Incralac produced the hardest films while Ship-2-Shore Industrial, LPS3 and Rustilo 3000 were readily marked and would not withstand handling (table 3). When applying these results to real use, it should be considered that some of the coatings would be applied as thicker films and others as thinner than 20-25 microns when following manufacturers' guidelines.

Adhesion of protection systems to Q panels

Excellent adhesion of surface treatments to substrates is essential if optimal protection from the surrounding atmosphere is to be achieved. A rigorous and simple test used to compare and quantify adhesion is used by the coatings industry and was applied here. The crosshatch adhesion test is described in ASTM D3359 - 08 Standard Test Methods for Measuring Adhesion by Tape Test and involved cutting a grid of 100 squares into the coated

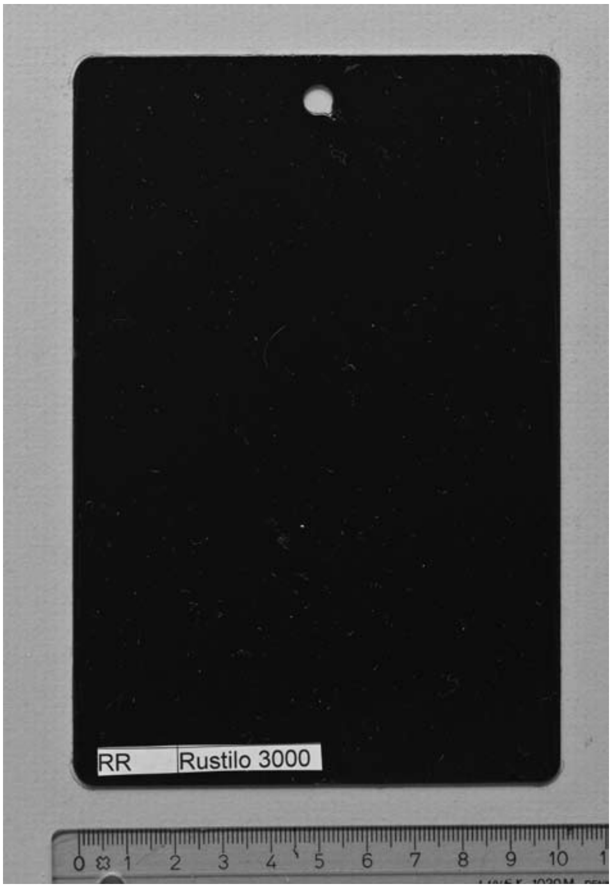


Figure 2: Rustilo 3000 is an anticorrosive coating which formed a black, opaque film on drying

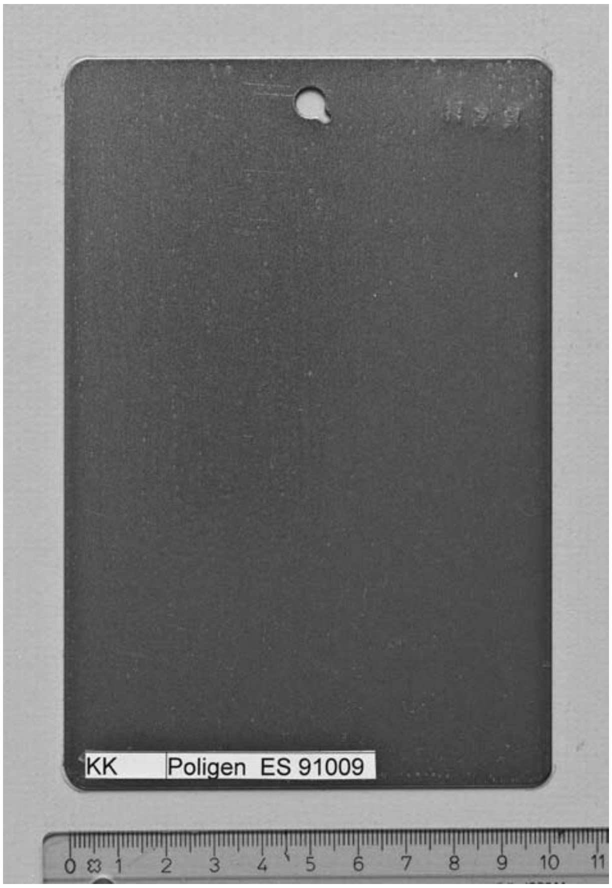


Figure 3: Poligen ES91009 is a polyethylene wax emulsion which dries to a highly gloss, transparent film

Table 3: Application, appearance and hardness of selected protection systems

protection system	preparation	number of applications to achieve 20-25 microns	appearance	marked with thumbnail?
Corroheat 4010	as supplied (spray can)	1	colourless, transparent, matte	yes
Tectyl 506 rust preventative	as supplied (spray can)	1	gold, transparent, matte	yes
Ship-2-shore Industrial	as supplied	1	colourless, transparent, high gloss, tacky	yes
SP400	as supplied	1	gold, transparent, matte	yes
Rustilo 2000	as supplied	1	gold, transparent, matte	yes
Rustilo 3000	as supplied	1	black, opaque, high gloss	yes
VpCI-386 acrylic primer/ topcoat	as supplied	2	colourless, transparent, high gloss	no
Tectyl Glashelder/Klar spray	as supplied (spray can)	1	colourless, transparent, high gloss	yes
Renaissance wax	66.7% by weight mineral turpentine	5	colourless, transparent, crazed surface	yes
Cosmoloid H80	30 % by weight mineral turpentine	3	colourless, transparent, matte, brush strokes visible	no
Tromm III	paste made with 1% by weight mineral turpentine	1	colourless, slightly opaque, brush strokes visible	no
Paraloid B72	30% by weight in acetone/ ethanol 50:50	3	colourless, transparent, high gloss	no
Paraloid B72 with 1% perfluorodecyl iodide (PI)	1% PI added to above solution of Paraloid B72	3	colourless, transparent but crystals visible, high gloss	no
Dinitrol Car/4941	10% dilution of supplied material in mineral turpentine	1	black, opaque, matte	yes
LPS3	as supplied (spray can)	1	gold, transparent, matte	yes
Poligen ES91009	as supplied	3	colourless, transparent, high gloss	no
Frigilene	as supplied	3	colourless, transparent, medium gloss	no
Incralac	as supplied	1	colourless, transparent, medium gloss	no

panels. A pressure sensitive tape (3M) was applied over the grid, and immediately peeled away. The number of whole squares remaining on the panel gave a percentage value of adhesion (table 4).

Most of the surface treatments adhered firmly to bare Q panels. However, less than half of the original soft, waxy film produced by LPS3 (40%) remained after applying tape. Cosmoloid H80 wax and Paraloid B72 did not adhere as well as many of the other treatments (85 and 86% respectively), although adhesion of Paraloid B72 was improved to 95% by adding 1% perfluorodecyl iodide.

Electrochemical impedance spectroscopy (EIS)

EIS was performed with a Radiometer Analytical VoltaLab 40 (PGZ301) potentiostat. The procedure used was based on the Rapid Electrochemical Assessment of Paint (REAP) [12]. EIS data were recorded when the panel was first exposed to solution (following 200 s to allow the potential to stabilize and 10 minutes equilibration) and again 24 hours after the first measurement was completed. The panel remained in the 0.5 M aqueous NaCl solution the entire time. A flat panel electrochemical cell, the CFC-34 supplied by Scribner Associates, was used to keep the exposed surface area constant (at about 32 cm^2). The frequency range of the initial measurement was 100 kHz to 1 Hz, while

Figure 4: Tromm III wax crazed and cracked on drying revealing the metal substrate

the final range was 100 kHz to 30mHz. The data was collected at the open circuit potential both times with 10 points/decade and 10 mV amplitude. A Pt/Nb counter electrode and a saturated calomel reference electrode were used.

EIS data collection had not been carried out for all protection systems at the time of writing. Panels coated with Poligen ES91009 and LPS3 were tested first because results from the crosshatch test suggested that they were among those that adhered best and worst, respectively and that adhesion could relate to corrosion protection properties. The EIS spectra taken after 24 hours in solution for the two coatings are shown in Bode format in figure 5. The spectra for two uncoated panels are also included in the figure. Inspection of the impedance at low frequency gives an indication of the corrosion resistance of the coating. The highest impedance value at 1 Hz was for the panel coated in LPS3 (panel TTG). The two panels coated with Poligen ES91009 (KKG, KKH) had better corrosion resistance than uncoated steel. Panel KKG appeared corroded and the coating had lifted off after 24 hours (figure 6). It can be seen that the EIS spectrum for this panel is similar to that of uncoated steel.

The entire shape of the spectrum is relevant to the coating behaviour. The spectrum of an intact, new coating should be linear. This can be seen in the data for panel TTG at frequencies above approximately 10 Hz. The flatter shape of that curve at lower frequencies indicates some reduction in corrosion protection. By contrast the curves for panel KKG and uncoated panels are linear only at the highest frequencies and flatten quickly.

Table 4: Adhesion of surface treatments to Q-panel

surface treatment	protection mechanism	percentage adhesion to Q-panel (%)
Corroheat 4010	corrosion inhibitor	97
Tectyl 506 rust preventative	corrosion inhibitor	100
Ship-2-shore Industrial	corrosion inhibitor	no film formed-not measured
SP400	corrosion inhibitor	95
Rustilo 2000	corrosion inhibitor	100
Rustilo 3000	corrosion inhibitor	100
VpCI-386 acrylicprimer/ topcoat	corrosion inhibitor	100
Tectyl Glashelder/ Klar spray	barrier to water	100
Renaissance wax	barrier to water	98
Cosmoloid H80	barrier to water	85
Tromm III	barrier to water	99
Paraloid B72	barrier to water	86
Paraloid B72 with 1% perfluorodecyl iodide	barrier to water	95
Dinitrol Car/4941	barrier to water	100
LPS3	barrier to water	40
Poligen ES91009	barrier to oxygen	100
Frigilene	barrier to oxygen	100
Incralac	barrier to oxygen	90

Conclusion

It is clear from the number of literature references found in the planning stage of this project that protection of iron and steel surfaces is a highly active area of research both in the conservation and commercial fields. However, selection of a suitable product from literature sources alone is a minefield. The three key factors which prevent inter-research comparison are variation in dry film thickness, use of non-standard evaluation techniques and selection of appropriate reference coatings. The experimental design of this project aimed to reduce the number of

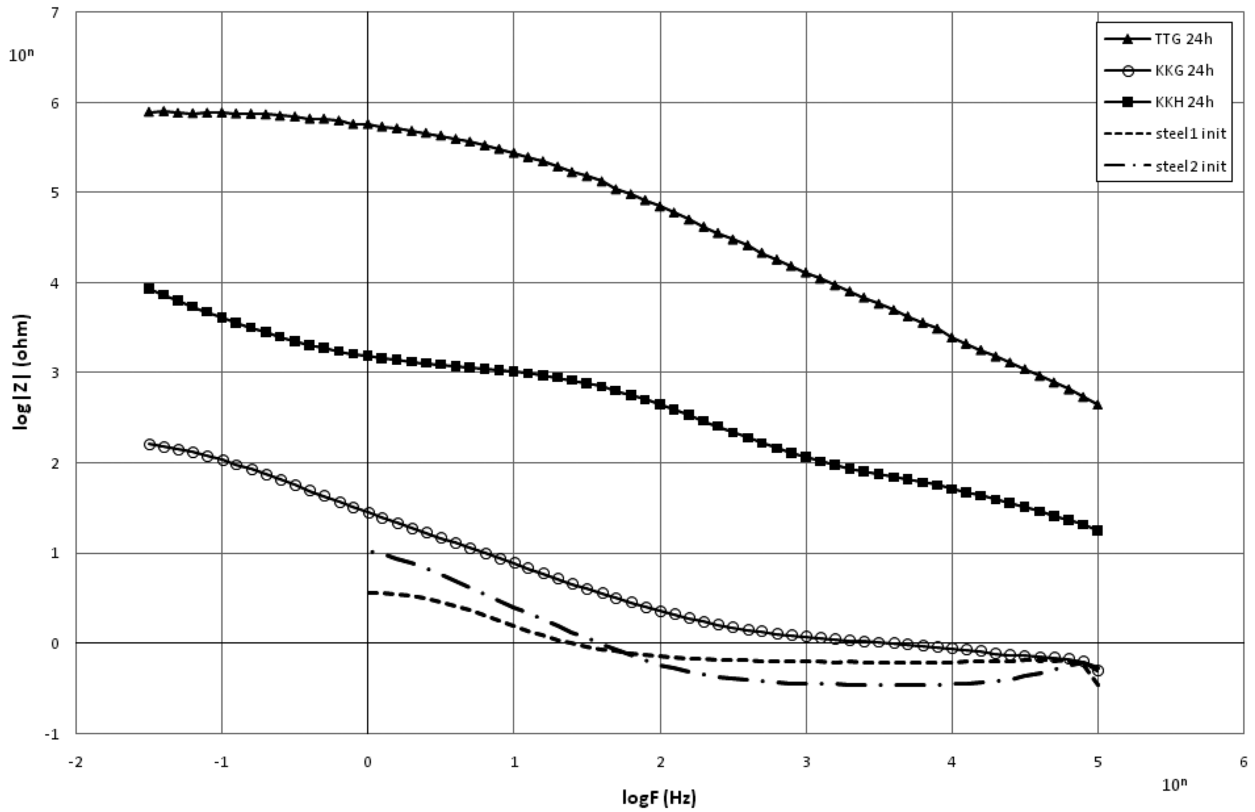


Figure 5: Impedance versus frequency plot for panel coated with LPS3 (TTG), two panels coated with Poligen ES91009 (KKG, KKH) and two bare Q panels

variables so that materials which showed potential as protection systems for use in conservation could be compared on an equal basis and using standard techniques.

When applied as recommended by the suppliers or as used in conservation practice, the thicknesses of protection systems selected from literature varied from less than 1 micron to 50 microns. Such variation in dry film thickness has great influence on the physical properties of the materials and does not permit equal comparison of test results. In the present research, all materials were applied so that they attained 20-25 microns by adjusting the number of applications or concentration of material applied. In addition, standard tests developed and used by the surface coatings industry are used to evaluate and compare all materials equally.

Evaluation of the 18 protection systems which, based on literature, are most likely to meet the current project's specifications of longevity, appearance, function, reversibility, stability and safety is not complete. The crosshatch adhesion test indicated that waxes showed poorer adhesion to Q panels and formed less cohesive films than corrosion inhibitors or solvent-based coatings. EIS suggested that poor adhesion of films over time could reduce the resistance to corrosion of treated panels until it resembled that of bare steel. The EIS results also suggested that coatings which are slightly mechanically damaged can still offer steel protection against corrosion as shown by LPS3. A simple test to compare hardness suggested that solvent based barrier coatings and waxes were resistant to abrasion from airborne particles and impact from handling while coatings containing corrosion inhibitors showed little resistance.

The next stage of the project is to apply all the coatings to pre-corroded Q panels. Most industrial objects require conservation because they are corroded. Removing corrosion layers completely is

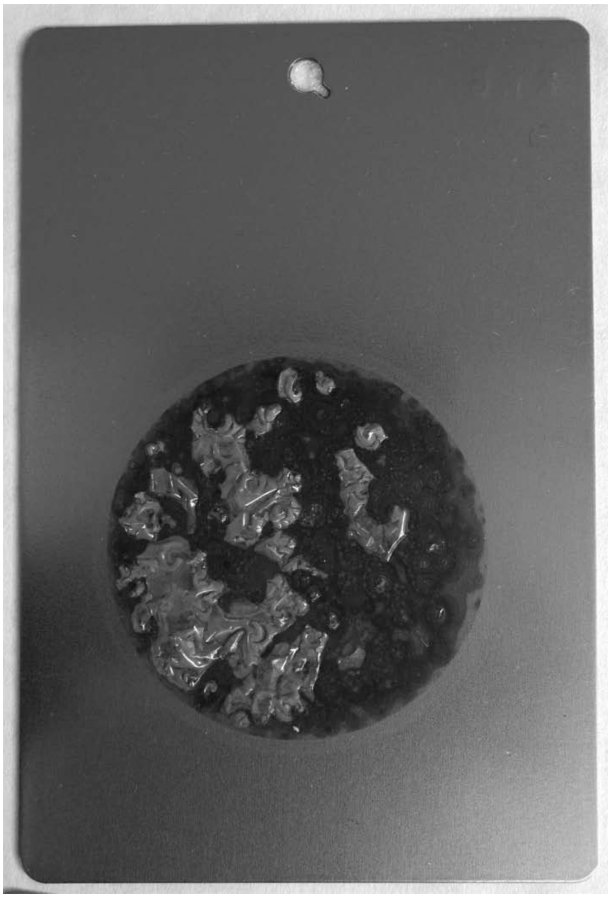


Figure 6: Panel coated with Poligen ES91009 after 24 hours in contact with 0.5M sodium chloride solution. The circle shows the area exposed to solution while in the electrochemical cell. Bare metal is visible where the panel has lifted

time-consuming and expensive, if it is even possible. The performance of the selected protection systems on pre-corroded surfaces will be evaluated using the same procedures as those on treated bare panels.

To examine longevity, treated bare and pre-corroded panels will be subject to both accelerated corrosion tests and exposure in real time to the Danish climate for at least 12 months. After the initial screening, the protection systems that perform best on the model panels with respect to the specifications outlined earlier will be applied to three industrial objects to examine their effectiveness in-situ.

Acknowledgements

The authors wish to thank Michel Malfilâtre, private conservator, for applying all coatings and Henning Matthiesen, senior researcher in the Department of Conservation for inspiration during the planning of this project. Thanks are also due to Ship-2-Shore, Eurodeal Autoparts A/S and Th.C. Tromm GmbH for providing samples of their products.

Authors

Yvonne Shashoua*, Michelle Taube and
Torben Holst
Department of Conservation
National Museum of Denmark
I.C. Modewegsvej, Brede
Kongens Lyngby
Denmark
email: yvonne.shashoua@natmus.dk
* author for correspondence

References

1. Seipelt, B., Pilz, M. and Kiesenberg, J., ‘Transparent coatings-a suitable corrosion protection for industrial heritage made of iron?’, in *Metal 98: Proceedings of the International Conference on Metals Conservation, Draguignan, France, 27-29 May 1998*, ed. W. Mourey and L. Robbiola, James and James (Science Publishers) Ltd, London (1998) 291-296.
2. Hallam D., Thurrowgood, D., Otieno-Alego, V., Creagh, D., Viduka, A., and Heath, G., ‘Studies of commercial protective petrochemical coatings on ferrous surfaces of historical and museum objects’, in *Metal 2001: Proceedings of the ICOM Committee for Conservation Metals Working Group, Santiago, Chile, 2-6 April 2001*, ed. I. MacLeod, J. Theile, and C. Degrigny, Western Australian Museum, Perth (2004) 297-303.

3. Hollner, S., Mirambet, F., Rocca, E. and Steinmetz, J., 'Environmentally-friendly treatments for the protection of iron artefacts of the cultural heritage against atmospheric corrosion', in *Metal 07: Interim meeting of the ICOM-CC Metal Working Group, Amsterdam, 17-21 September 2007*, ed. C. Degrigny et al., Rijksmuseum, Amsterdam (2007) Vol. 5. Protection of metal artefacts 64-70.
4. Hammouch H., Dermaj, A., Hajjaji, N., Degrigny, C., and Srhiri, A., 'Inhibition of the atmospheric corrosion of steel coupons simulating historic and archaeological iron based artefacts by cactus seeds extract', in *Metal 07: Interim meeting of the ICOM-CC Metal Working Group, Amsterdam, 17-21 September 2007*, ed. C. Degrigny et al., Rijksmuseum, Amsterdam (2007) Vol. 5. Protection of metal artefacts 56-63.
5. Cortec Corporation, 4119 White Bear Parkway, St. Paul, MN 55110 USA email: info@corteccvci.com http://www.CortecVpCI.com
6. Ship-2-Shore Liquid Corrosion Control Systems http://www.ship-2-shore.com
7. Castrol Lubricants (S) Pte Ltd., 24 Jurong Port Road, #01-01 Office Block, CWT Distripark, Singapore 619097. Tel: +65 262 5561
8. Dermaj, A., Chebabe, D., Hammouch, H., Goursa, M., Hajjaji, N., and Srhiri, A., 'Atmospheric corrosion inhibition of historical steel by FPTS formulation based of triazole-thione', in *Strategies for Saving our Cultural Heritage: Papers presented at the International Conference on Conservation Strategies for Saving Indoor Metallic Collections, Cairo, 25 February-1 March 2007,* ed. V. Argyropoulos, A. Hein and M. Harith, TEI of Athens (2007) 143-148.
9. Letardi, P., and Luciano, G., 'Survey of EIS measurements on copper and bronze patinas', in *Metal 07: Interim meeting of the ICOM-CC Metal Working Group, Amsterdam, 17-21 September 2007*, ed. C. Degrigny et al., Rijksmuseum, Amsterdam (2007) Vol. 3. Use of electrochemical techniques in metal conservation 44-50.
10. http://www.hightempenginepaint.com
11. DELPHI DX900165 THUMBNAIL HARDNESS TEST FOR PAINTED PARTS, http://auto.ihs.com/document/abstract/YDBRIAAAAAAAAAAA
12. Kendig, M., Jeanjaquet, S., Brown R., and Thomas, F., 'Rapid electrochemical assessment of paint', *Journal of Coatings Technology* **68** (1996) 39-47.
13. Argyropoulos, V., Charalambous, D., Poilkreti and Kaminari, A.,´ Testing new coating systems for the protection of metal collections exposed in uncontrolled museum environment in *Strategies for saving our cultural heritage, 25 February – 1 March 2007,* eds. Vasilike Argyropoulos, Anno Hein and Mohamed Abdel Harith, CairoTEI of Athens. 115-120.
14. Musa, M and Misran, M., Improving coating systems for metallic objects using an aliphatic perfluoro compound:A special focus on collections in the Islamic Arts Museum Malaysia in *15th Triennial Conference,ICOM-CC Triennial Meeting, New Delhi, 22-26 September 2008*, ed J. Bridgland, Allied Publishers PvT.Ltd. 441-446

Proposal for the conservation of weathered steel objects at the National Trust Estate of West Penwith, Cornwall and at the West Harbor in Berlin

Ulrich Stahn

With the decreasing significance of heavy industry and mining, increasing numbers of industrial facilities are being classified in some European countries as historical monuments. Some, like the copper and tin mines in West Penwith, Cornwall, have even achieved the status of World Heritage Sites. Industrial buildings from the 19th and 20th centuries were not designed for a long life, unlike the castles and palaces of earlier centuries. Their preservation brings new and interesting challenges. Examples of some possible restoration and conservation practices for weathered steel objects are being carried out on various constructions in Germany and England. Until now, there has been only limited practical work in this area, and therefore only a few written treatises and reports exist on the subject.

In each case, it is important that the object to be preserved be documented carefully in connection with its surroundings before any further work is done. A precise examination of the situation and contributing factors is also an important step on the way to a sensible preservation concept that maintains the authenticity of the object and applies modern conservation techniques.

In the case of weathered steel objects, technical problems, such as the choice of the best-suited anticorrosive, often stand in the foreground. It is sometimes overlooked that the longest-lasting and lowest-maintenance protection for modern steel products is not always the best for an historical object. Some weathered steel objects were uncoated when they were in use. Others have gradually been altered in appearance by environmental influences after being taken out of service, so that their complete overhaul would change the visual impression they created over many years. Here, the best corrosion protection would be the one that changes the original surface as little as possible or not at all. In special cases this means that the omission of any protection can be a sensible choice. A change in environmental conditions can also be a solution. A simple protective roof or a foundation that prevents direct contact with the ground can often be sufficient to slow deterioration.

A well thought-out care concept applied in the long term can be less expensive than a single intervention targeted to quickly bring the object into so-called “presentable condition“. One point at which continual care differs from the “one-time complete overhaul“ is the length of time over which an investment must be made. The advantage of regular, smaller-scale protective measures is in the associated monitoring. Endangered sites are recognized early, and cost-intensive damage can be avoided by timely intervention. In addition, a long-term care concept offers the advantage of allowing the conservation of the largest possible amount of original material. Often, large surfaces can be found on the object on which the historical corrosion-protection system is still intact and would be sacrificed in the case of a complete overhaul.

In certain cases a complete rust removal and re-coating is the end result of the decision process. Within this choice lies a great deal of leeway. Coating systems at our disposal include those based on analysis of the object, like traditional oil-bound systems, and novel methods like Polyurethane or Epoxy resin-based paints that simply imitate the color of the object.

The choice of coating system depends, again, on many factors. One factor of decisive significance is that the material which is removed and that which is added be thoroughly documented.

A completely different criterion relates to the target audience. This group of people can include residents as well as tourists. It can be determined through surveys and observation what visitors associate with the site. If one disconnects the object from this association through well-intentioned measures, the overall success of the project can be put at risk.

For the objects we discuss in Cornwall and Berlin, a variety of concepts was originated that reflect the range of possibilities.

Case Study 1: Egg Boiler

The following approach was suggested for a so-called "Egg Boiler", which may originate from Richard Trevithick's [1] workshop and is now displayed on the site of the East Pool and Agar Mine. According to anecdotal evidence the boiler was largely used to melt tar for road building. The presence of a thick layer of tar inside the boiler would support this theory. The reason the boiler was cut into pieces is not clear. By shape and construction the remaining part of the boiler still indicates a very early type. The object stands in a wind-protected corner of a ruined building. The steel surface is only slightly corroded, despite long open-air storage. This is high-grade, probably low-sulfur steel, which has come through centuries of industrial and maritime environments in good condition. A pigmented anticorrosive would completely strip away this history. Furthermore, a boiler never could have been coated when it was in use. The application of a temporary, transparent oil- or wax-based protective coat such as Anticorit BW366 [2] and Owatrol [3] could be considered. However, the appearance of the surface would be darkened and it would gain an unnatural brightness [4].

Figure 1. Cornish boiler in the East Pool and Agar Mine (Paul Bonington)

Another realistic proposal, due to the good condition of the steel, is a constructional weather protection and a foundation, which together would be sufficient to drastically reduce the rate of corrosion. As the boiler is no longer presented in its original context but displayed in a museum, a slight change of surroundings would be acceptable. With this approach, the visual appearance of the surface would not be affected, but the significance of the boiler for the viewer would be enhanced. The financial expenditure for the execution of this concept would be minimal, and the protective effect comparatively large.

From a conservation point of view, transport of the object to a dry, climate-controlled location could also be considered. For the conservation of the steel this would be a very good solution. But there is not enough space to display the boiler in the small museum on site. The only possibility would be to transport the boiler to another museum, probably miles away. The loss of such an important exhibit would not be acceptable for the East Pool and Agar Mine.

Case Study 2: Semi-gantry Crane Nr. 16

Another approach is demonstrated in the restoration concept for semi-gantry crane No. 14 in Berlin's West Harbor. The concept was developed by students in the Restoration of Technical Cultural Assets program at HTW-Berlin (University of Applied Sciences Berlin) in cooperation with the local historical protection agency and the owner of the site (Berlin Harbor and Warehouse Society, BEHALA).

The crane lost its direct significance in port operation at the end of the 20^{th} century. Bulk handling gave way to container traffic. Today, bulk goods are transported with high-performance

Figure 2. Dockside crane No.16 in front of a warehouse at West Hafen Berlin (08.08.Stahn)

conveying equipment. This crane, along with three others, stands as physical evidence of the quotidian and industrial culture of the first half of the 20th century, and as such retains an indirect significance for the entire harbor construction, for its owners (BEHALA), for Berlin's historical landscape and for technical research.

In this concept for preservation and partial restoration we aim to consider the interests of all concerned to the extent possible without moving away from our own goal, an appropriate, state-of-the-art restoration of the object. At the time of completion, all the institutions involved should have gained something from the project. We aspire to a solution in which the age of the crane is made tangible, the work it has performed is valued, and its elegant, and, in comparison with modern appearances, calm forms and surfaces fit into the scenery of the elongated, symmetrically ordered harbor.

Since the decommissioning of the equipment was planned well in advance, maintenance was already reduced to the minimum necessary during the crane's last 10 years of service. The last overhaul was 20 years ago. Nonetheless, the historical coatings from up to four phases have been preserved over large areas, and form a stable layer. Some of the labels applied at time of the last protective coating (1989) also remain legible. Here, a partial, situation-oriented surface restoration is suggested. It is preferred to the still commonly practiced complete resurfacing. A decisive advantage is the minimization of expense through the reduction of both labor costs and hazardous wastes produced. Through this approach, long-lasting protection from continuative corrosive assault and the static safety of the system are ensured.

A special challenge in the development of the restoration concept was presented by the intersections and joint areas of the riveted steel skeleton. In the 1980s, a polyurethane and zinc chromate-based injectable material was developed for similar applications. It was first used to protect ropes and cables from corrosion in bridge building. The polyurethane permeates tiny capillaries and cavities in the structure. Once inside, it reacts and becomes an elastic or elastomeric synthetic material. The grid is thus hardened and sealed, and the progression of the oxidation process is impeded. Open cracks are subsequently sealed with polyurethane/zinc-chromate foam. This method was used in the renovation of the Heinrichenburg ship

Figure 3. Abrasive blasting with dry ice pellets (09.08 Beck)

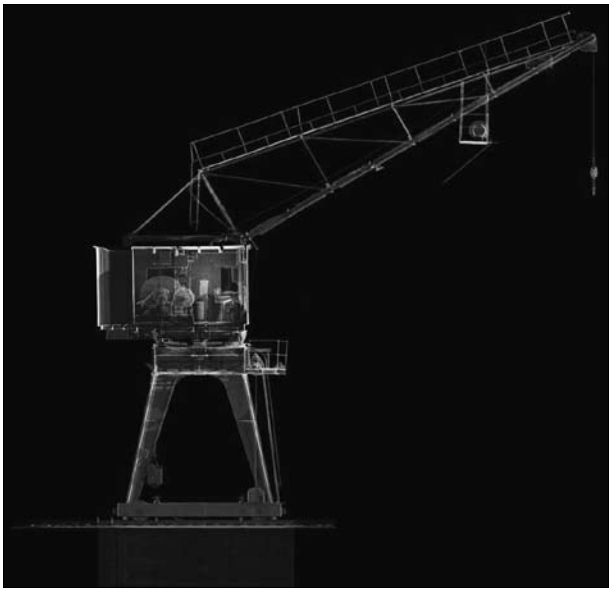


Figure 4. Dockside crane No.16 Orthofoto 06.08 Laserscan Berlin

lift [5]. Shierk's report on the subject [5] was written twelve years later and describes an unchanged corrosion preventive effect for a period of at least ten years. A pigmented corrosion protection system was chosen for the surface areas for its homogenous appearance and longer durability. The color is matched to the remaining protective coating. A special polyurethane system especially developed for such purposes is used. The special feature of this system is the single-component, moisture-hardening polyurethane primer for application over original coatings and steel surfaces with residual rust. [6] This base coat adheres particularly well to slightly rusty surfaces, and removes the residual moisture important for the corrosive process. The corrosive process is thus interrupted. The complete composition of the coating is described in the following table. (For application instructions see below.)

Table 1. Coating system from Dr. A. Conrad's Enamel Inc. (Dr. A. Conrads Lacke GmbH & Co. KG).

Composition	Color	Article Number
EK PUR Base (thin fluid)	Colorless	PE 000090
EK PUR Zinc base	Zinc grey	PE 917709
EK PUR Intermediate basecoat	Yellowish silver	PE 133309
EK PUR Enamel for the first topcoat	Grayish silver	PD 070229
EK PUR Enamel for the second topcoat	RAL or DB shades	PA „ NCS 7020 G10Y " 88
or PA „ NCS 7020 G10Y " 63		
Solvent for EK PUR System		ZP 215152

For the application of this system, a hand-derusted surface is sufficient. (The cleanliness factor should equal DIN EN ISO 12944 P MA or DIN EN ISO 12944 P St 3.) Loose sections of the old coating must be removed. For a pre-treatment meeting such requirements, abrasive blasting with dry ice pellets was tested with good results. A decisive advantage is the sublimation of the pellets after their successful application. The substance to be protected is only slightly affected.

For the exact mapping of the corrected surfaces, the crane was three-dimensionally laser scanned and drawn with millimeter-exactitude with a CAD program. All the surfaces to be re-coated are noted on the drawing. The above described and a similarly composed enamel system were successfully tested on the steel frame of the Wuppertal Suspension Railway and the furnace of Heinrichshütte in Hattingen, among other objects.

Case Study 3: Water Pump, Kenidjack Valley

In a valley to the north of Lands End and only a few yards from the sea stand the remains of a diesel-powered water pump. Originally, the pump was used to supply the surrounding area with fresh water from the tunnels of underwater mines.

Because of direct proximity to the sea, salt damage to the steel was considerable. In this case an industrial corrosion protectant was the most economically feasible solution for the object to survive in the long term. Extensive rust removal is a necessary precondition for this strategy as is the thorough removal of salt. Conscientious fulfillment of these tasks is made especially difficult by proximity to the sea, if costs are to be kept low. The use of an active anticorrosive could also be interesting because of its

Figure 5. Diesel-powered water pump in Kenidjack Valley (Paul Bonnington)

durability. Oil-bonded orange lead pigment is amply proven in a maritime climate and can be applied to lightly rusty and salty surfaces. The application of the very poisonous lead pigment is permitted under certain circumstances, but is environmentally questionable. Alternatively, the above-described polyurethane system can also be applied here. For aesthetic reasons, an understated color should be chosen as a topcoat. Despite the pigmented coating system, the need to preserve the appearance of the site as it has gradually developed remains.

Currently, topcoats are being tested that corrode on the surface without compromising the layers beneath. The appearance of corroded surfaces on an object can thus be preserved.

The decay of the equipment is already quite advanced due to vandalism and proximity to the sea. The technical coherence and meaning of the pump are no longer comprehensible to the inhabitants of the region without explanation. For the uninitiated visitor, the pump is a landmark and an indefinite relict of industrial Cornwall. An approach could be considered that would allow the continuing decay of the pump and would highlight its testimony to the disappearance of mining from the region. Necessary conditions in this case would be the exact documentation of the current state of the object and ongoing monitoring.

In all three case studies presented, a substantial one-time investment at the beginning of the intervention, reducing subsequent work to a manageable amount, makes sense. A component of this investment is in every case the documentation and examination of the object. First passive or preventative corrosion protection measures or an active intervention in the decay process may also potentially be carried out. For the preservation of the cultural value of the object, subsequent and continuous monitoring is indispensable.

The possibilities for dealing with weathered objects are numerous. Each object brings different requirements with it. A separate inspection and planning is advisable in many cases. The final costs can also, contrary to frequently expressed misgivings, be reduced through this approach.

Author

Ulrich Stahn
Am Treptower Park 18, 12435 Berlin, Germany
ulistah@yahoo.de

Literature

[1] Trevithick was the first to make high-pressure steam work, in 1799; he also built a full-size steam road locomotive in 1801

[2] FUCHS EUROPE SCHMIERSTOFFE GMBH, Friesenheimer Straße 15, 68169 Mannheim

[3] Vosschemie GmbH, Eisinger Steinweg 50, D-25436 Uetersen Vosschemie GmbH, Eisinger Steinweg 50, D-25436 Uetersen

[4] Brüggerhoff 2002: Stefan Brüggerhoff, Korrosionsschutz für umweltgeschädigte Industriedenkmäler aus Eisen und Stahl, Bochum 2002 http://www.museen-in-bayern.de/landesstelle/pdf/download/EndberichtDBUProjekt.pdf

[5] SCHIERK 1927: Schierk, H.-F.: Korrosionsschutz an Stahlkonstruktionen. In: Das Bauzentrum 44 Heft 7 o.A. 1996 S.122-127

[6] CONRADS M. 1997: Conrads M., Die Wuppertaler Schwebebahn – Korrosionsschutzmaßnahmen am Traggerüst, in: Metalla, Forschungsberichte des Deutschen Bergbau- Museums, Nr. 4.2, Bochum 1997, S. 85-89.

Recovering the Icon ?
The restoration of the *Zollern II/IV* Colliery Engine House in Dortmund

Norbert Tempel

Something New in the West

"Incredible Industry!" At the turn of the 20th century (1898-1905) a new, representative coal mine was erected in the *Ruhr* mining area, situated in a no-man's land between Dortmund, Bochum and Castrop-Rauxel. The name of the colliery, "*Zollern*", was an abbreviation of the name of the "*Hohenzollern*" imperial dynasty and its owner, the *Gelsenkirchener Bergwerks-Aktien-Gesellschaft* (GBAG), was the biggest mining company in the *Ruhr* at the time.

Two shafts were sunk and surface buildings erected in a structured layout. Head gears No. II and No. IV were erected as steel framework constructions (the "Deutsches Strebengerüst" type). The engine house and the adjoining boiler house, which made up the colliery's power plant, also housed all the major electrically-driven engines, air compressors and winding engines, including the world's first large-scale DC electric winding engine on a main shaft.

Most of the buildings were designed in an historistic style - massive Gothic red brick design - by the architect Paul Knobbe [1], the head of the company's construction department. The elaborate layout of the plant followed the basic layout prescribed by the technical foreman, Wenzel Köller, which included many expansive details like onion domes, gables and pinnacles, coloured wooden ceilings, a number of stained glass windows etc, all of which can be attributed to his influence [2].

The overall aim of the design was to make it clear to the outside world that this colliery was a model of technical innovation [3]. A garden-city type housing settlement was built for managers, craftsmen and miners directly in front of the colliery.

A revolution in building design

But there was a sudden reversal of attitudes during the construction period after Emil Kirdorf [4], the managing director of the GBAG returned from a visit to the Düsseldorf Trade Exhibition in 1902,

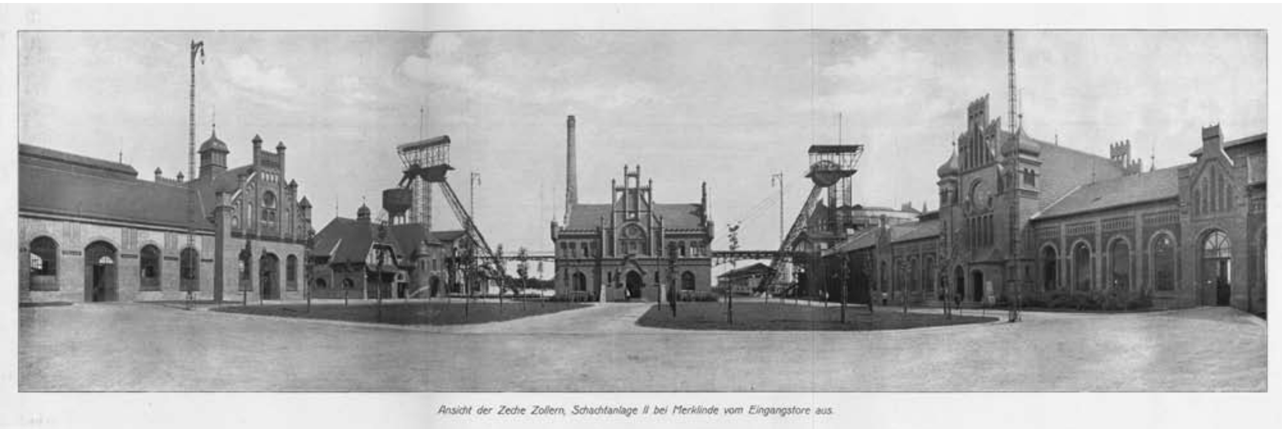


Fig. 1: This general view of the Zollern II/IV coal mine in Dortmund, seen from the entrance, has been published in 1905. The yard is surrounded by historistic architecture, the modern engine house is not visible from this point of view. (Collection LWL-Industriemuseum, Dortmund)

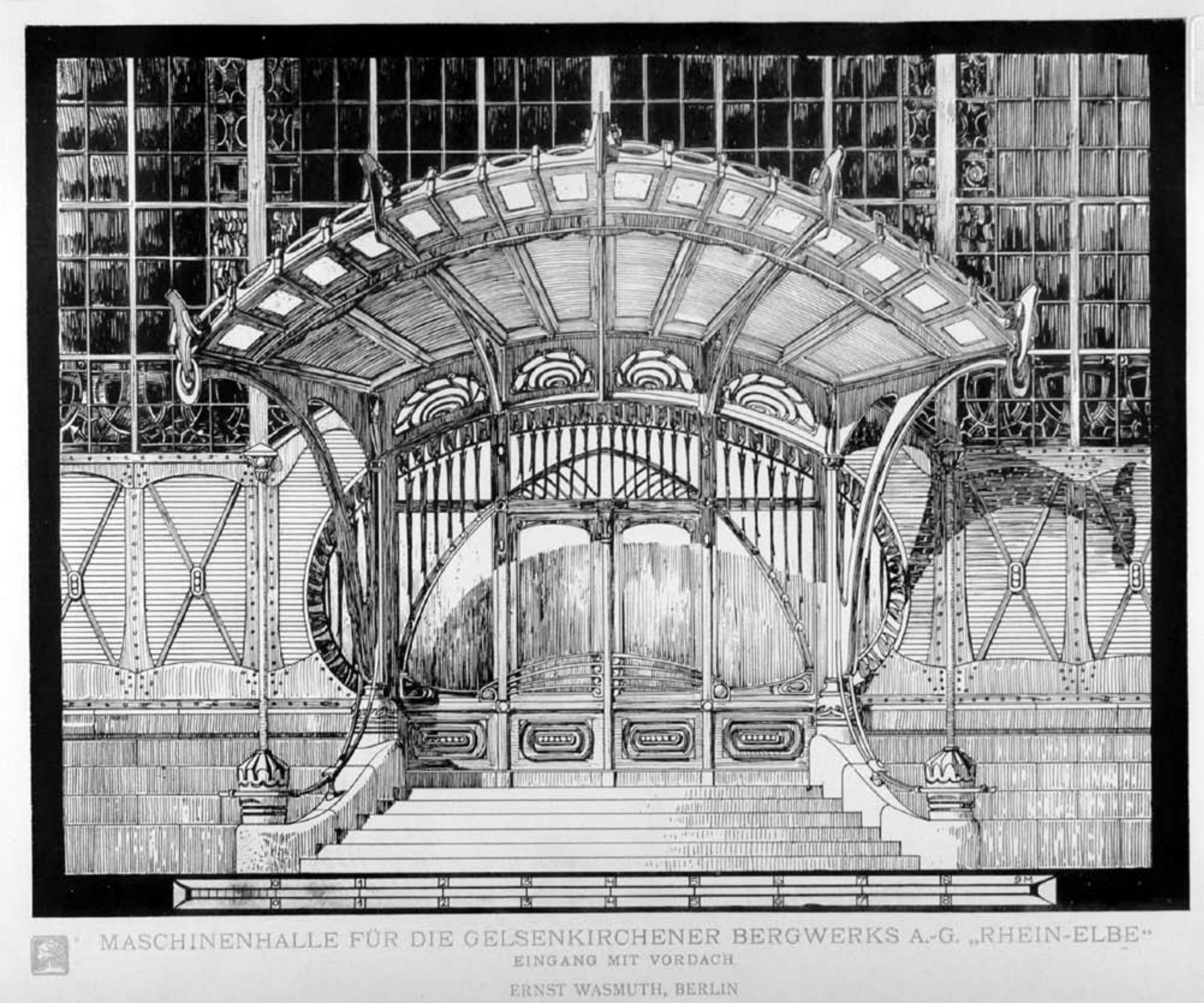


Fig. 2: Design study for the main entrance by Bruno Moehring (published in: Bruno MOEHRING [1903-1909]: Stein und Eisen)

where he had seen a modern pavilion intended for the *Gutehoffnungshütte* (GHH). He now decided to abandon the traditional architectural approach and have the engine house at the Zollern colliery – the power house of the colliery and hence a building of key importance on the site – constructed as a contemporary steel skeleton framework, the panes filled with bricks. This sober, purely functional method of construction had been in existence for around two decades and, till then, was mainly used for less important buildings like coal wash plants, boiler houses etc. Hence it tended to be disdained as nothing more than an "engine shell". There has been much speculation as to the reasons for this sudden change of attitude [5]. The most likely seems to have been the time factor: the building needed to be put up quickly because output quotas in the Ruhr mining area were soon to be redistributed.

The building retained the style of an exhibition pavilion and was further upgraded by generous areas of stained-glass windows and additional design elements and contemporary decorations. For this, the company hired the well-known Berlin "Jugendstil" architect, Bruno Möhring [6]. He was the man who had designed the GHH exhibition pavilion in Düsseldorf along with the chief constructor at GHH in Oberhausen, Reinhold Krohn [7].

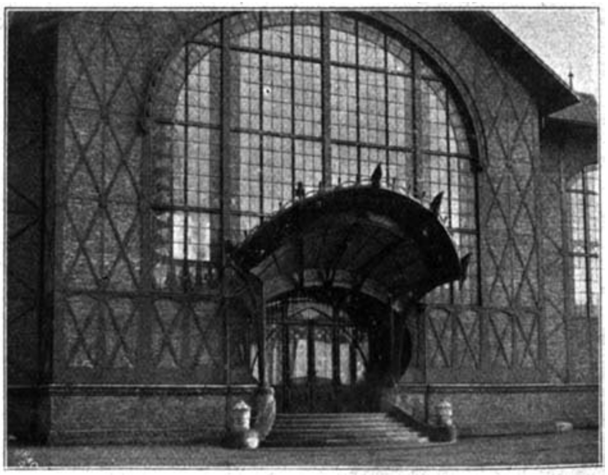


Fig 3: Early 20th century photograph of the main entrance of the engine house with canopy (Collection LWL-Industriemuseum, Dortmund)

Möhring decorated the main entrance to the engine house in a "Jugendstil" manner with an oval doorway and a windshield with stained glass decorations portraying vine leaves and grapes (!), and a canopy which is said to have been influenced by the metro entrances in Paris.

Möhring considered himself an artist and, as a result, this led to conflicts not only with Paul Knobbe [8], who had originally drawn up the historistic design for the engine house, but also with the GHH because Möhring kept changing his plans and missing his deadlines. The GHH, in turn, put the main responsibility for the considerable delays in construction on the GBAG because they were responsible for hiring Möhring in the first place. All these conflicts resulted in considerable delays in construction. "Incredible Industry!"

A revolution in monument care

65 years later, this sudden change of attitude can be seen as a happy accident for monument preservers. True, the original splendour of the engine house has faded over the years. Nonetheless the remaining Jugendstil elements have always been regarded with considerable admiration in expert circles. Their opinion was shared by contemporary authorities who made a surprisingly quick decision to preserve the building from demolition after the colliery was closed in 1966. This in turn marked a paradigm change in attitudes because the decision to list the engine house at the *Zollern II/IV* colliery signalled the start of a new movement to preserve industrial buildings in Western Germany.

The crucial factor in deciding to preserve the building was the unusually splendid design, rather than the state of the building which had been heavily affected by its industrial use. There were many ideas for redeveloping the site. These included turning it into a railway museum or an art exhibition hall, and even foresaw the removal of the historic driving engines. The unspoken core idea was to "recover the icon", and it went without saying that this would include the restoration of the stained-glass windows and the Jugendstil canopy over the entrance.

Now, 40 years later, the engine house is finally due to undergo comprehensive conservation and restoration. Over the years there have been considerable changes in approaches to monument preservation. The building substance has degraded and the removal of damage and the need for a

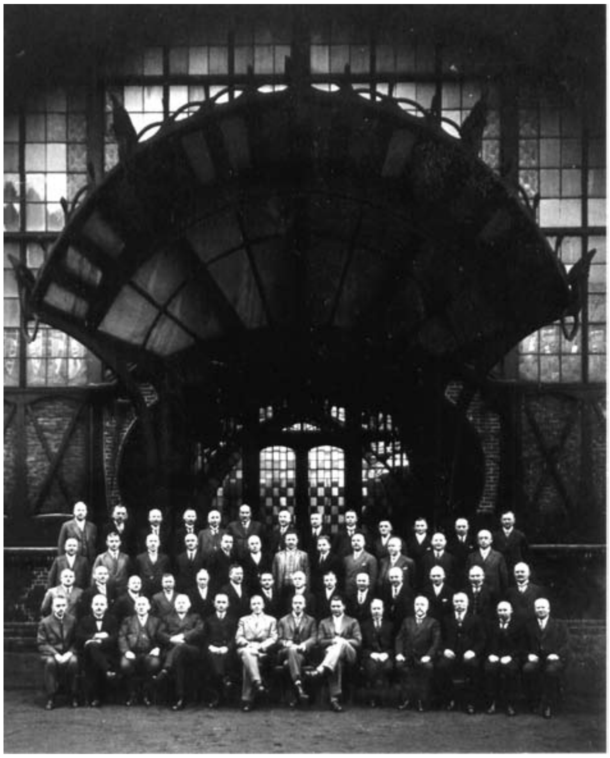


Fig 4: Office staff of the Zollern II/IV colliery posing for a photograph in front of the main entrance in the 1930s. (Collection LWL-Industriemuseum, Dortmund)

Fig 5: South façade of the engine house. An elevated monorail connects the coal washery and the boiler house, early 20th century (Bergbau-Archiv, Bochum)

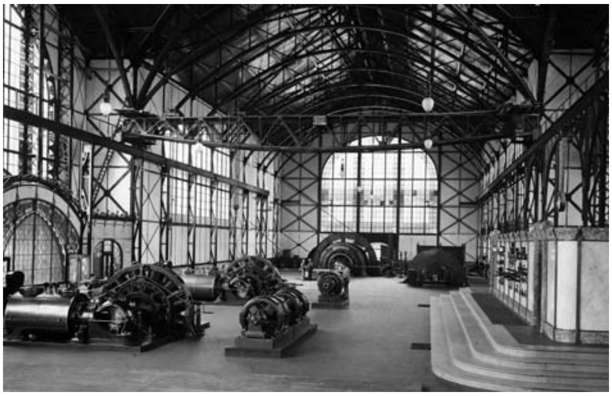


Fig 6: Interior space of the engine house with air compressors and winding machines, early 20th century (Siemens Archives, Munic)

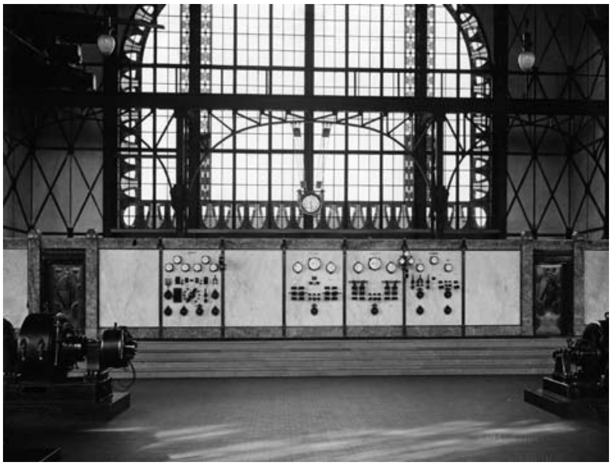


Fig 7: Marble Switchboard, early 20th century (Siemens Archives, Munic)

sustainable approach to reconstruction demands that it must be comprehensively replaced. This has not made it easier for us to answer current questions regarding the best methods of conservation. Other questions facing us include: "How do we make museum use compatible with monument preservation?"; and "What are our priorities? To conserve the material and the colouring handed down to us or to highlight the original idea behind the building as an impressive showplace for the outside world? How much reconstruction does there have to be, and how much is permissible?"

From decline to a living museum – a short survey:

1935: Plans are drawn up for a new central shaft in the adjacent *Zollern* and *Germania* coalfields. Hence all further investment in the old technical equipment is stopped. Due to the lack of building materials work on the erection of the central shaft ceases between 1939 and the 1950s, with the exception of two more powerful compressors and electrical equipment which are installed in the *Zollern* engine house in 1940.

1955: Coal ceases to be brought to the surface at the *Zollern* colliery and this operation is transferred to the new *Germania* central pit a few kilometres away. Shaft No. II is henceforth only used to transport men and material underground. The Jugendstil canopy above the entrance of the engine house is dismantled and much of the damage to the brickwork is stabilised in a basic manner.

1966: *Zollern* colliery finally closes and the buildings on the site are let out to different companies.

1969: Plans to demolish the engine house are met with a grass-roots campaign of heavy protest. At the end of the year the engine house is recognised as an icon of modern industrial design and put under a preservation order. This signals the start of a new movement to preserve industrial buildings in Western Germany.
The photographers Bernd and Hilla Becher, who were very little known at the time, start their unique documentation work of industrial buildings [9] by

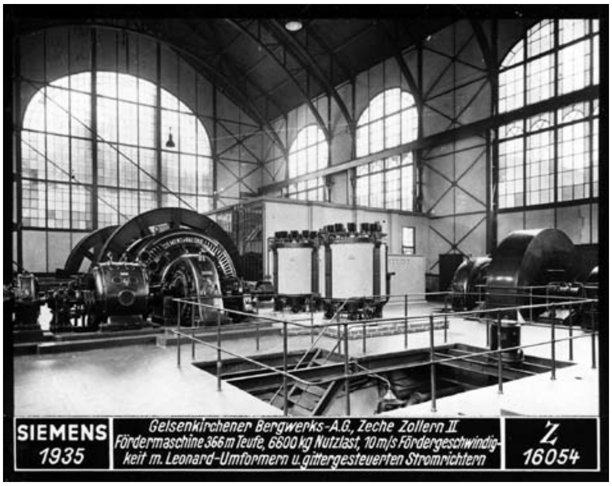


Fig 8: New mercury-vapor rectifiers and the winding engines, 1935 (Bergbau-Archiv, Bochum)

taking photos of the colliery buildings soon after the site was closed.

1973 -1980: First attempts to stabilise the structures of the engine house. Contemporary restoration approaches result in some indispensable repair work and comprehensive repainting distorting the interior appearance.

Since 1981: The *Westphalian Industrial Museum* [10] takes over the remainder of the colliery. Start of restoration activities on the site. The headquarters of the museum and the central restoration workshops are officially opened. Two similar head gears replace the ones which had been lost in the 1930s (shaft 4) and after the closure (shaft 2). The museum opens to the general public in 2001.

2008: The engine house closes to the general public in late 2007. Restoration work commenced in 2008 with an estimated budget of 6.900.000 €. We hope to finish the work by late 2010.

Some thoughts on approaches to restoration

Many problems arise when considering how best to safeguard this monument after more than a hundred years' existence. We now know that the steel skeleton design used for the engine house is not as durable as the massive brick building method. During our intensive examination of the building we have learnt a lot about aspects of statics, the physics of building materials, the original coating and decoration, hazardous materials etc. Treating a huge industrial

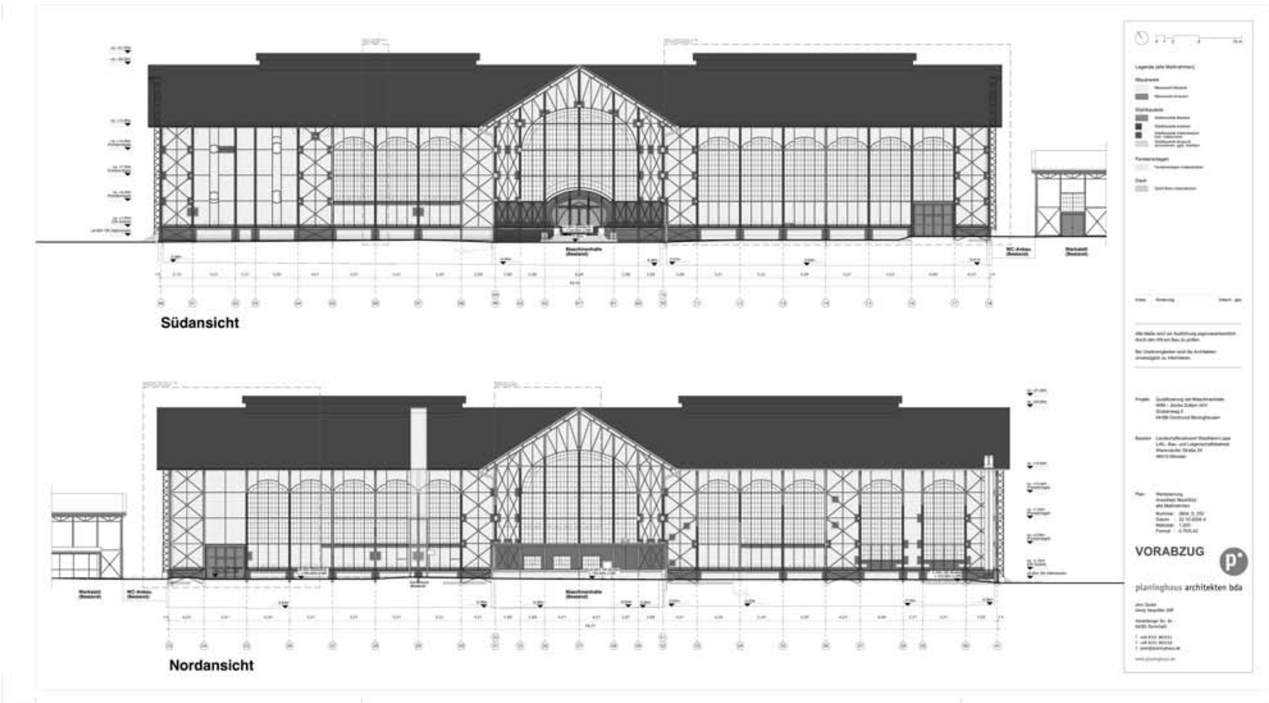


Fig 9: Documentation of the engine house, 2007 (Büro Planinghaus Architekten & Büro für Industriearchäologie, Darmstadt)

Fig 10: 1:1 mockup as a trial for recreating the stained glass windows (N. Tempel, LWL-Industriemuseum, Dortmund, 2008)

monument of this kind means that we have to find a balance between safeguarding the authenticity of the monument, redeveloping it for new usages and deciding on the best way to conserve the building on a long-term basis. The building is in a vulnerable state and we have to develop effective, constant and durable methods of care and maintenance in order to ensure its long-term preservation.

The scope and complexity of the challenge

The engine house spans an area of around 2000 m² (Length 96.47 m, width 22.14 m, height of the eaves 14 m, top of the roof 20.3 m). Unfortunately the cellars, where the engine foundations are laid out, are very damp. This is a typical Jugendstil building not only because of the dialogue between different building materials such as steel, brick and glass; but also because the façade may be considered as a semi-permeable membrane. Unfortunately the building structure itself has turned out to be semi-permeable in the negative sense of the word: the specific Jugendstil building design is responsible for the poor quality of construction.

As late as the 1970s damage to the building had reached such an extent that it was necessary to conduct a comprehensive corrective maintenance. This included repainting the interior according to the taste of the time, despite the fact that it was on the whole even then possible to recognize and deduce what the original appearance had been. The changes were – as most of them before that – in no way documented systematically [11].

Before we began the current process of comprehensive restoration, we submitted the building to a thoroughgoing programme of examination with regard to its constructional history, the building construction and static, hazardous substances in the building and its technical equipment [12], and how it had been painted over the years.

As a result we established that the following major interventions were inevitable:

- Checking and partly renewing all the column bases, the major load-bearing elements and the sheet plates of the steel trelliswork.
- Roof repairs (the membrane and parts of the wooden rafters, rain gutters and down pipes)
- Repairs to all window constructions
- Dampproof insulation work on the exterior wall of the cellar, the installation of a drainage system and the lowering of the groundwater table.

This work involved:

- opening up the exterior walls in the substructure area and cladding the interior substructure which consisted of the remains of the original marble panels, plastering and other substitute materials
- Opening up the wall in the area where the steel trelliswork had to be repaired, in order to create the necessary working space. This also involved the loss of the great majority of the plasterwork on the interior wall, most of which was damaged anyway [13].

New usages for the museum and their effects

Before the engine house was closed for restoration work it was open to the general public for a long time (1985-2007) for occasional major exhibitions during the summer months, and other special events some of which used their own heating arrangements. During this period we were able to gather a lot of knowledge and experience. It is clear that the climatic conditions in the engine house have been exceedingly problematic since the colliery closed down because of the loss of warmth emitted by the operation of the engines. At the same time it was quickly clear from a closer examination that the installation of a heating and insulation system would involve an intolerable intervention in the original architecture. But to dispense with this would negatively affect the comfort of visitors and strongly reduce the chances of using the engine house during the winter months.

In future we foresee using the engine house in the following appropriate ways:

- Making it freely accessible to the general public (ground floor and cellar), also for disabled persons.
- Setting up a permanent exhibition in a part of the cellar (only using climate-insensitive exhibits, or copies).
- Regular demonstrations of some of the restored working engines (a hauling machine dating back to 1902, a converter and a compressor).
- Presenting special events during the summer months, like concerts with a maximum capacity of up to 800 visitors – all special exhibitions will have movable partitions and walls).

This very restricted usage concept has meant that the following interventions are indispensable:

- Additional emergency exit stairs from the cellar (outside the building) and one extra escape door in the east gable. The existing ridge turret must be strengthened for ventilation purposes. After much agonising we have decided to do without a fire sprinkling system and a coat of fire-proofing paint on the steel construction.
- The construction of an adequate public toilet in an empty part of the cellar. For this, however, the cellar level must be connected to the ground floor by an additional staircase and lift in the south east corner of the building.

Fig 11: 1902 air compressor, "retro-fitted" by museum restorers and retired craftsmen, during a demonstration run for visitors (N. Tempel, LWL-Industriemuseum, Dortmund, 2007)

Ethical basic rules for the restoration process

The necessary interventions to restore the building substance and make it usable for the museum necessarily entail a certain loss of the old building substance. In connection with these steel construction works and corrosion protection measures and other repair work, a large part of the surface must be re-walled, re-plastered and repainted. The resultant strictures – you might also call them design margins – demand a set of ethical ground rules for dealing with the engine house.

Our main restoration target has to be the long-term conservation of the engine house. The original material should be retained as far as possible. The premises for cleaning the building up and putting it to new uses are as follows: monument protection has the highest priority. Preserving the character of the monument is more important than its extensive use. As far as changes are concerned, as a rule the changes which happened during the time the colliery was in operation have precedence over those which happened during the interim period (ca. 1969-2006). All the new building works and reconstruction work must as clearly as possible be recognisable for what they are. That said, these basic rules have their limits in the detail. We want to prevent the creation of a "patchwork" which would run counter to a cohesive all-round aesthetic.

The work has to comply with the requirements of monument authorities. In addition the Museum has set up an expert monument-care advisory board, all of whose members are experienced in industrial archaeology.

The ethics and aesthetics of reconstructions – two case studies

As described above, restoration work on the roof and the interior facade require a new coat of paint, and we cannot avoid making a decision on the exact colour. At the moment the ceiling is painted white, but it used to be dark. The chamfers of the girders by contrast, are in a garish red, the wall areas – field by field – are painted in stripes to mirror the steel construction, and the substructure is clad with two different types of marble. The great majority of the engines were once black but in the 1970s they were irreversibly coated with red lead and painted over in light grey. Apart from the marble control panel and the stained glass on the windscreen near the door, little remains of the original decoration. Despite all our efforts to the contrary we have only been able to retain the idea behind the building rather than the original material.

Our restoration plan throws up a crucial question of how to make the engine house a vivid and comprehensible experience for our visitors as a total work of art. After intense discussions we decided on presenting the original character of the place by repainting and re-glazing it in an appropriate manner. But what do we mean by appropriate?
We are not trying to create the fiction of an exact "reconstruction" but a recreation which makes no claim to being the original.

Each attempt at a recreation throws up methodical problems. First, we need a secure database. How reliable is our knowledge of building components and of layers of paint which are no longer available? Monument conservators would like to be 100% certain. At the same time, however, visitors must be able to recognize a reconstruction at second sight and differentiate it from the original on which it is modelled.

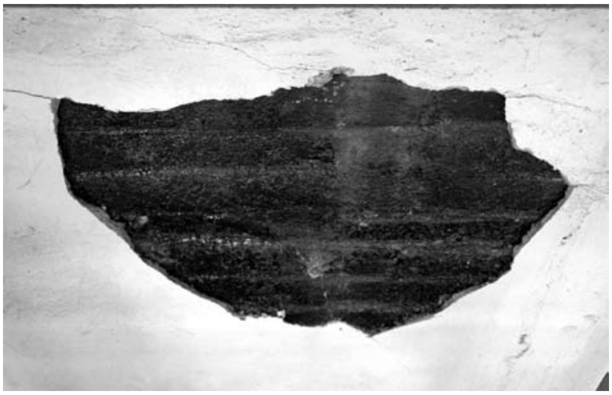


Fig 12: Challenge for the conservation work: Tar has been used as insulation coating on the brick façade, visible through the damaged plaster (N. Tempel, LWL-Industriemuseum, Dortmund, 2007)

Despite all our rational attempts at being "faithful to the work", it seems to me – as an engineer and admirer of this unique building - legitimate to interpret the recreation of the original building idea as being true to the spirit of the place. Just as every new performance of a classical piece of music is of, necessity, a reinterpretation, we wish to reinterpret our monument in a consciously responsible manner.

This process comes up against its limits when the existing substance is destroyed at the expense of recreation. It goes without saying that we also have to discuss the scope and positioning of the recreation in the context of the building itself.

Two basic decorative elements in Bruno Möhring's building will serve as practical examples here: the stained glass in the large windows in the façade, and the Jugendstil canopy over the entrance door to the engine house.

The surviving windows on the outer façade all have clear transparent glass. There are many signs that the steel window frames were partially repaired, changed or even renewed in the 1950s, and at this point of course they would have received new panes of glass. When we look at the sources and the old black and white photographs it is possible to clearly establish that the windows were originally lavishly endowed with stained glass. Both the large windows in the central projection contained lead glazing motifs. But what colour were they and what was the quality of the glass? A good indication of what it might have been like is provided by the interior windscreen near the door, where 98% of the glazing still exists [14], although it is clear that the motifs were entirely different from that of the main windows on the façade. Intensive searches made in obscure corners of the interior of the building and in the ground outside threw up a few very small coloured glass splinters. That said, it is still difficult to reconstruct an exact quantitative arrangement of the motifs in the windows. There now exist new methods of making a comparison by using black-and-white photos and "reference glass fragments", and these have enabled us to make a plausible reconstruction of the original stained glass. But we have still not solved the problem of how to establish the exact properties and surface structure of the glass. And even if we do, today's coloured glazing, including so-called cathedral glass, differs considerably from the original glazing in its method of manufacture and the materials used.

Such differences would not really matter if we simply used the replica of a complete stained-glass window without comparing it with the original. What is to stop us from making a conscious new interpretation and presentation of the original? Many recent publications have described the engine house as a "cathedral of labour" – and it must have made a similarly solemn impression over 100 years ago. For this reason I would be in favour of at least furnishing the windows on the west wing of the engine house, which still contains original engines, with new stained glass, provided there is no attempt to imitate the original state of the window but merely present it as a "surrogate" in the sense of

Fig 13: Conservation work on the façade has been tested on a small scale in order to get experience for the entire task (N. Tempel, LWL-Industriemuseum, Dortmund, 2008)

a one-to-one model. In this way the colours could be presented by means of glued transparencies or sprayed on patterns using templates. The overall aim must be to present this icon of industrial heritage in an adequate manner by creating an aesthetically pleasing, cohesive spatial harmony of colours which have as close reference as possible to the original. More detailed information on which to base further decisions will be provided by large-scale one-to-one trials.

The imposing Jugendstil canopy over the entrance disappeared from the building about 50 years ago. It not only provided an impressive demonstration of the architectural ambitions of the coal mining company, but put it on a level with those of other public buildings like railway stations, theatres and concert halls. It was very probably dismantled because it had fallen into disrepair due to poor maintenance: Whatever the case, there is no evidence to indicate that any consideration was given to the subsequent appearance.

What remains is a torso, laboriously concealed clues and rough profiles. A complete new recreation would heal this wound and provide a clear indication of the original splendour of the building. None of the original building substance has to be sacrificed in order to achieve this. The construction of the canopy could be achieved in a coherent manner and presented graphically in such a way as to banish all doubts as to its relevance. The original canopy was constructed with rivets, but the new version could substitute these with screws or welding methods. The profile could be differentiated from the surrounding colours by using zinc coating for example. Both measures would be reversible, thereby enabling people to take a different approach to the monument at any time without any detriment to the original substance. We are still discussing all the relevant issues, and no final decisions have yet been made.

The question remains: can we truly recover the Icon? The answer is no.

Given the circumstances outlined above, this is impossible. Nonetheless I would strongly plead for the recreation of the engine house in a consciously responsible manner.

Fig 14: Work started in 2008 with the insulation work on the exterior wall of the cellar, installation of a drainage system and lowering of the groundwater table.

Summary

The 1903 engine house of the *Zollern* colliery in Dortmund is generally acknowledged to be an icon of modern industrial design. The building documents the change in industrial buildings from a traditional, historistic style to a modern, economical design. The state-of-the-art nature of the technical equipment was reflected in the style of the engine house.

Rescuing this example of outstanding industrial heritage from demolition in 1969 signalled the start of a new movement to preserve industrial buildings in Western Germany.

Recovering the monument after more than a hundred years throws up a great deal of problems. As we now know, the durability of the more modern design cannot match that of the massive brick building method. During our intensive examination of the building we have learnt a lot about aspects of statics, the physical qualities of building materials, the original coating and decoration, hazardous materials etc. Treating a huge industrial monument of this type entails finding a balance between safeguarding the authenticity of the monument, putting it to new usages and finding the best way forward to ensure the long-term conservation of the building.

Author

Dipl.-Ing. Norbert Tempel,
LWL-Industriemuseum - Westphalian State Museum of Industrial Heritage,
Dortmund, Germany
norbert.tempel@lwl.org

Notes and References:

[1] Paul Knobbe * 2.1.1867 in Eastern Prussia, † 4.4.1956 in Essen; 1901-06 Head of the construction department at GBAG, Gelsenkirchen

[2] Interestingly enough, the balustrade to the open staircase in the administration building hallway illustrates the change in style from historicism to Jugendstil.

[3] A model of the colliery was presented at the world exhibition Lüttich/Liège 1905

[4] Emil Kirdorf (* 8. April 1847 in Mettmann bei Düsseldorf; † 13. Juli 1938 in Mülheim an der Ruhr)

[5] see Literature: Fischer/Horstmann [1988]

[6] Bruno Möhring * 11. December 1863 in Königsberg (Eastern Prussia), † 25. March 1929 in Berlin

[7] Dr.-Ing. Reinhold Krohn (* 25. November 1852 in Hamburg – † 29.6.1932), starting in 1904 – when the Technical Academy in Danzig was founded – he was Professor of Bridge Building and Structural Engineering. He had constructed the roof truss system with arched girders without a beam tie („Tragsystem mit Bogenträgern ohne Zugband") especially for the GHH exhibition pavilion. This was also retained in the Zollern engine house.

[8] Both men seem to have been hard-headed Eastern Prussians, and both studied at the TH Charlottenburg in Berlin. Möhring, by the way, never completed his course.

[9] Bernd und Hilla BECHER [1977]: Zeche Zollern 2. München

[10] The *Westphalian Industrial Museum* (*WIM, recently named "LWL-Industriemuseum"*) was established under the aegis of the regional authority, the *Landschaftsverband Westfalen-Lippe (LWL)*. The museum consists of eight industrial monuments in Westphalia, all of which document important aspects of industrial history in the region. The *Westphalian Industrial Museum* (like its partner the *Rhineland Industrial Museum*) was set up by its regional authority to preserve industrial sites as monuments, present them as valuable evidence of a bygone age, and find contemporary usages for them. *WIM'*s specific job is to present and research the culture of the industrial era and its development in Westphalia. It aims to shed light on the technical, economic, political, legal and social developments in the industry and show how they affected the lives of working people and their families (cited from KIFT, 2000, p. 36). See also the publication "Schätze der Arbeit – 25 Jahre Westfälisches Industriemuseum" (*Treasures of work – 25 years Westphalian Industrial Museum*), Westfälisches Industriemuseum Schriften Band 23; Dortmund, 2004; and the museum homepage in the internet: www.industriemuseum.de.

[11] Our knowledge of the revised version has recently been enlarged by coloured slides by the artist Friedrich Gräsel, made as working outlines for an art project in the engine house.

[12] The following experts and offices were involved in the examination so far: LWL-Bau- und Liegenschaftsbetrieb, Münster; Büro für Industriearchäologie, Darmstadt; Deutsches Bergbau-Museum, Bochum; HEG-Ingenieure, Dortmund; Moll Steinrestaurierung, Viersen; Planinghaus Architekten, Darmstadt; Engineering and Restoration Workshops Department of the LWL-Industriemuseum, Dortmund; Wessling Beratende Ingenieure GmbH, Altenberge.
[Publications on hazards in industrial monuments with case studies from the Zollern engine house include: Norbert Tempel: Beiträge zur Restaurierung von industriellem Kulturgut, Folge 1: Verborgene Schätze. Zum Umgang mit Schmutz und Gefahrstoffen im

Industriedenkmal - Erkennen, stabilisieren, entfernen, In: IndustrieKultur 3/2007, S. 22–25; Norbert Tempel: Hidden Treasures. Investigation and Treatment of Hazardous Substances in Industrial Monuments; In: Benjamin Fragner (ed.): Průmyslové dědictví – Industrial Heritage. Conference Proceedings from the international Biennial “Vestiges of Industry” (Prague 2007). Published by the Research Centre for Industrial Heritage of the Czech Technical University in Prague, in cooperation with the Technical Monuments Committee of the Czech Chamber of certified Engineers and Technicians and the Czech Union of Civil Engineers. Prag 2008, pp. 116-124 (Czech) and pp. 295-298 (English)

[13] The quantification of interventions according to the latest state of knowledge is: steel construction ca. 20 %; brickwork: brickstones ca. 25 %, mortar joints ca. 50 %; plastering ca. 30 %; the interior panelling ca. 60 %.

[14] Some of the pieces of glass, which do not “fit” the windscreen allow us to pinpoint several earlier stages of repairs even though it is impossible to put a date on them.

Literature:

Bruno MÖHRING [1903-1909]: Stein und Eisen. Lieferungen 1-7. Berlin

Paul RANDEBROCK [1905]: Die Schachtanlage Zollern 2 der Gelsenkirchener Bergwerks-Aktien-Gesellschaft. In: Glückauf, Nr. 25, Jg. 41, 24.6.1905, pp. 781-797, (Paul Randebrock (* 23.10.1856 in Recklinghausen, † 25.7.1912 in Gelsenkirchen) has been director of the GBAG at the time when the Zollern colliery was erected.)

VEREINIGTE STAHLWERKE (Ed.) [1931]: Die Steinkohlenbergwerke der Vereinigten Stahlwerke AG. Die Schachtanlagen Zollern-Germania in Dortmund, Band I (Text) and II (Tafeln). Essen

Bernd und Hilla BECHER, Hans-Guenther CONRAD und Eberhard G. NEUMANN [1977]: Zeche Zollern 2. Aufbruch zur modernen Industriearchitektur und Technik. Entstehung und Bedeutung einer Musteranlage in Dortmund um die Jahrhundertwende. München

Manfred FISCHER und Theo HORSTMANN [1988]: Demonstratives Statussymbol oder ökonomisch fundierter Nützlichkeitsbau. Ein Diskussionsbeitrag zur Funktion und Baugeschichte der Maschinenhalle auf Zeche Zollern II in Dortmund. In: Technikgeschichte, Bd. 55 H.4, pp. 263-300. Düsseldorf

Ingrid TELSEMEYER und Norbert TEMPEL [1988]: Die Schachtfördereinrichtungen der Zeche Zollern II/IV. In Dies. (Hg.): Die Fördergerüste der Zeche Zollern II/IV, pp. 13-34. Dortmund

Michael PETERS [1990]: Bau und Inbetriebnahme einer Zeche: Zollern II. Master thesis Ruhr-Universität Bochum

Dagmar KIFT [2000]: The Zollern II/IV >model< colliery. The museum of social and cultural history of coal mining in the Ruhr area. Essen

Ulrike GÄRTNER und Dagmar KIFT [2001]: Die Zeche Zollern II/IV. Denkmal der Industriekultur. DKV Kunstführer, München

Rudolf KÄPPLEIN und Andrea WIEGOSCH-FREY, [2001]: Historische Eisen- und Stahlkonstruktionen. Untersuchen, Berechnen, Instandsetzen. Karlsruhe

Katrin HOLTHAUS [2004]: Architekturführer Zeche Zollern II/IV. Essen (esp. pp. 41-72)

Norbert TEMPEL [2005]: Die Fördermaschine von Zollern II dreht sich wieder. In: IndustrieKultur vol. 1/2005, p. 35

Baldo BRENNER, Jens DAUBE, Franz-Peter FLACH und Rolf HOEHMANN [2006]: Konzeptstudie zur denkmalgerechten Instandsetzung der Maschinenhalle der Zeche Zollern II/IV in Dortmund-Bövinghausen.

Norbert TEMPEL [2007]: Vintage Civil Engineering Structures - A Challenge for Restoration and Maintenance. In: The restoration of large scale civil engineering structures, pp. 83–103. Tokyo, The National Institute for the Restoration of Cultural Properties

The conservation of a Victorian ship and a Victorian bridge

Robert Turner and Shane Casey

Introduction

Iron is a wonderfully useful material, lending itself to incorporation into a fantastic range of materials, structures and objects. This flexibility was not lost on the Victorians, who often treated it as their material-of-choice for prestige projects as well as for mass-produced objects.
However, iron is also very prone to corrosion when used outdoors.

This paper will compare two case studies: the conservation/restoration of a Victorian iron bridge from Fort Brockhurst and the conservation of a Victorian iron ship, the ss Great Britain. Both had suffered significant corrosion and both required equally extensive conservation intervention. However, the projects differed in a number of major respects, factors which determined the direction and nature of the conservation task.

The first factor was that the rationale for intervention differed: a major reason for conserving the bridge was that it should continue to fulfil its original function, providing vehicular access into the fort, and be capable of bearing the weight of a fully-laden fire engine. The ship, on the other hand, was to be preserved as a significant object in its own right, and was also to serve as the heart of a major independent museum.

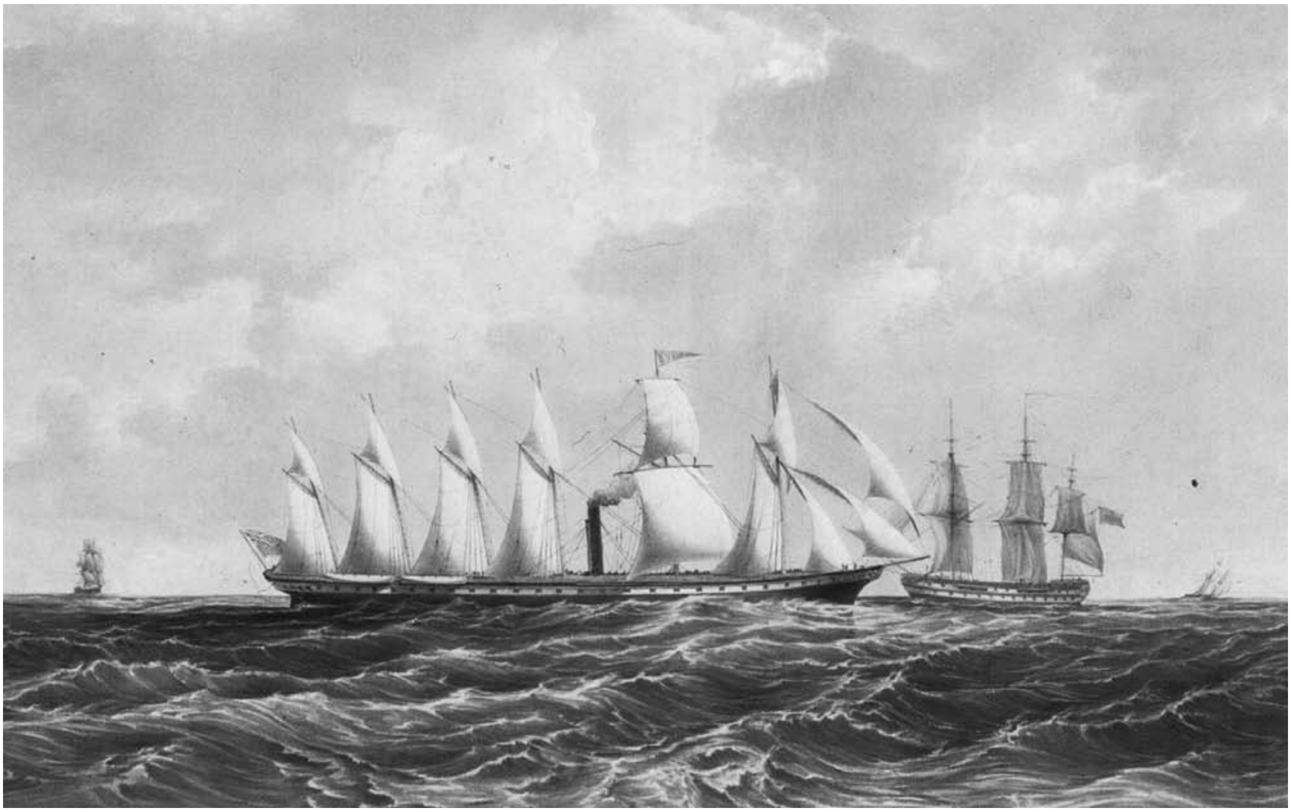


Figure 1. The ss Great Britain shortly after launching

Figure 2. Fort Brockhurst Bridge before conservation

Second, while the ship was an internationally significant and unique artefact, and thus given high cultural significance, the bridge was one of a number of similar structures, and seen as of lesser importance than the fort it served. Combined with its more solid construction and thicker materials, a more robust approach could be taken to its restoration.

Third, there was a huge disparity in the funds and timescale available for conservation: about six million euros was made available over 4 years for the conservation of the iron in the ship, whereas the conservation/restoration of the iron of the bridge cost about four hundred thousand euros, and was completed within six months. .

This paper will illustrate the compromises necessary when treating large-scale outdoor objects and contemplate the differences between a project where the funding was relatively generous, and every effort was made to treat the object as a museum artefact; and one where "cost-effectiveness" was essential, and significant dismantling, fabrication & rebuilding was required.

Background

Purpose-built under the supervision of the great Victorian engineer Isambard Kingdom Brunel, the ss Great Britain was the largest and most powerful ship in the world at the time of her launch in 1843, measuring 96 metres long, and weighing over 2000 tonnes. She was the first propeller-driven ship to cross the Atlantic Ocean and went on to have a long and eventful working life. Part of that eventful life involved becoming damaged while trying to sail round Cape Horn in 1886. The nearest safe port was Port Stanley in the Falkland Islands. It was too expensive to repair her in Port Stanley so she was sold to the Falkland Islanders and remained as a floating storehouse. This was extremely fortunate because she would almost certainly have been sold for scrap if she had been too expensive to repair in the Northern hemisphere.

In 1937 the harbour master became concerned about her condition. He ordered that she should be removed from the harbour and scuttled in a nearby cove (see Figure 11). There she stayed until, in 1970, she was salvaged and returned to the Great Western Dockyard in Bristol, the dockyard that Brunel had built for her construction. Owned by a trust, operating as an independent museum, she was partially restored between 1970 and the mid 1990s. At this point the trustees decided that she should in future be treated as a museum object, and that the traditional shipyard approaches used in her restoration should be replaced with conservation methods.

Fort Brockhurst Bridge, by contrast, was built by the army from a kit of parts in 1862. Several similar examples, dating from the period, are located nearby. The bridge provides access over a moat to Fort Brockhurst, one of a number of forts built in the 1860s to protect Portsmouth and its strategically important harbour. The fort remains physically largely unaltered, although it currently serves as a store for objects from English Heritage's extensive reserve collections. These include stonework, textiles, jewellery, and furniture from many periods. It was crucial that the fort retain safe vehicular access.

Condition and Treatment ~ Fort Brockhurst Bridge

The bridge had lasted for almost 150 years before receiving conservation treatment. As can be seen in Figure 2, the bridge was re-inforced on at least two occasions before receiving full conservation and restoration to its original function in 2004.

The bridge was constructed from a combination of wrought and cast iron. Generally, cast iron was used for elements such as the support columns, hand-rail stanchions, bridge-deck plates and the landing beam of the drawbridge. Riveted wrought-iron beams were

Figure 3. Corrosion of the wrought iron

used where tensile strength was required. The owners of the bridge, English Heritage, had specified the design life of the treatment should be as long as was reasonably practicable. For this reason, it was decided to dismantle everything except the cast iron columns and treat the bridge in the conservation workshops.

The main conservation issues to be addressed were corrosion of the wrought iron and some fracturing of the cast-iron elements.
The main structural elements of the bridge were composite riveted wrought iron I-beams. These were constructed from plates and angles.

The horizontal plates, particularly the upper ones, were heavily corroded. It was decided to de-rivet the beam and to cut down plate No. 2 to become a new plate No. 1. A new plate No. 2 was made from mild steel because wrought iron is in very short supply in the UK and it can be next to impossible to obtain high-quality replacement material in the large sizes.

The engineers had determined that if more than 60% of the thickness of a material remained then it could be left un-repaired. Minor areas that were below this threshold (small holes for example) were repaired by welding in small patches or the application of weld metal to build up the required thickness.
Cast-iron elements were visually inspected and dye penetration tests were conducted if fractures were suspected. Fractured cast-iron elements were metal-stitched together.

All iron elements were cleaned to SA3 and zinc metal-sprayed.

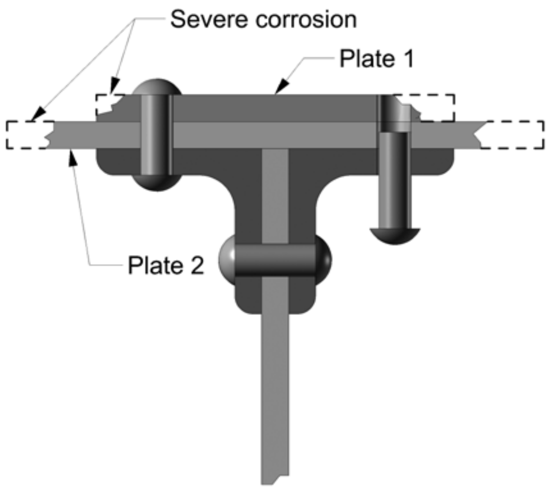


Figure 4. Sketch of the design of the upper part of an I-beam

All the plates and angles that made up the I-beams had slightly changed shape during the life of the bridge so that once they had been dismantled they no longer fitted perfectly together. When a rivet is fitted the shank is squeezed so that it completely fills the hole it is in. This is an important part of the strength of the system and it is more easily achieved when all holes line up properly. Therefore, the I-beams were initially reconstructed using bolts in each alternate hole.

Once this had been done the empty holes could be reamed to ensure a perfect fit for the new rivets. Once these holes had been re-riveted the bolts were removed to allow reaming and re-riveting of the remaining holes.

Figure 5. Metal stitching castings

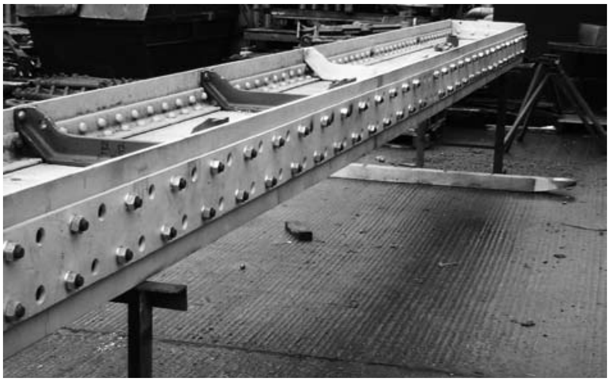


Figure 6. I-beam re-constructed using bolts in alternate holes

The metal-sprayed surface was over coated with two-pack epoxy paint with a top coat of two-pack urethane paint.

The cast-iron columns that support the bridge deck were hydro-blasted to HB2½ and given the same paint system as the metal-sprayed elements that had been treated in the workshop. Temporary dams

Figure 7. Re-riveting an I-beam

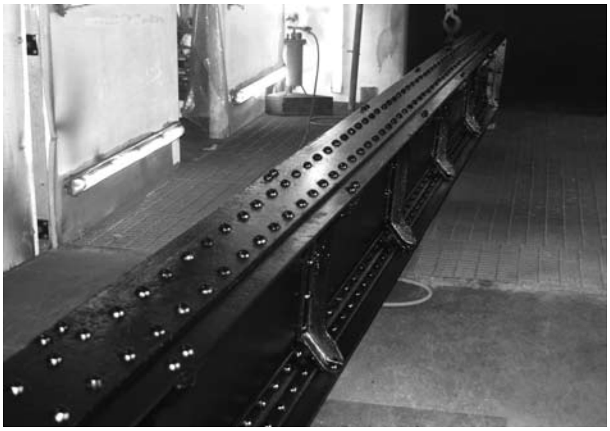


Figure 8. A fully conserved I-beam

Figure 9. Fort Brockhurst Bridge – fully conserved and rebuilt

were built around the columns in order to pump out the water to be able to treat the parts that would normally be submerged.

Condition and Treatment ~ ss Great Britain

The ship had undergone several major refits during her working life so by 1970 she was very different in appearance to the ship that had been originally launched. The individuals who brought the ship back to England were fortunate however, in that the ship had been photographed immediately after her launch in 1843 by Fox Talbot, a pioneer of modern photography.

The original Trustees relied on Talbot's photograph to make the ship look as she had in 1843. Consequently a considerable amount of material was removed from the ship, including masts, decks, timber cladding to the upper hull and a propeller lifting mechanism fitted in 1857. She was given replica masts, rigging, decks, funnel, rudder, propeller and a significant amount of internal interpretation. Several large corroded areas of the hull were cut away and replaced with mild steel.

By the late 1990s it became clear that the ship was unstable. Conditions within the lower hull were extremely corrosive and movement between the keel and the keel blocks indicated that the hull, the dock or both were moving. The Trustees decided with the support of the Heritage Lottery Fund, to undertake a review of the significance and condition of the ship and this resulted in the publication of a full Conservation Plan and condition report for the Dockyard and the ship. [1] [2] This allowed the Trustees to resolve that in future the ship would be treated as a museum object and that all actions relating to the ship and surrounding dockyard would be conservation-led.

The conservation plan also considered the advantages and disadvantages of a large number of options for preserving the ship's metal. Analysis

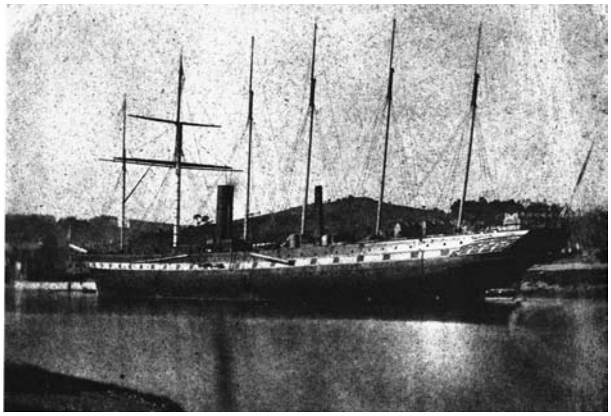


Figure 10 Fox Talbot's 1843 photograph

Figure 12. The ss Great Britain mid 1990s

of the options showed that control of the relative humidity (RH) around the original iron was likely to be the most effective way of conserving the maximum amount of original material. What was less clear was the level of RH required and the optimum physical arrangements for providing the controlled environment.

Eventually, after considering all possible options it was decided to recommend the installation of a glass plate at the level of the ship's waterline. The glass plate would seal between the hull and the walls of the dry dock, allowing environmental control of the iron below the waterline. Iron surfaces within the ship were environmentally controlled by sealing corrosion holes, installing air locks on doors, and sealing a new mild-steel deck to the bulwarks of the ship. This left only the topsides (the external area of the hull above the waterline) to be treated. It was decided that these areas should be treated conventionally. There were several factors that lead to this decision. It was hard to envisage any form of encapsulation other than a complete building that would be more aesthetically pleasing than the waterline plate. Although tests had shown the presence of large quantities of chlorides in the iron, they were significantly fewer in the iron of the topsides, perhaps because the iron had been washed with Bristol rain for 30 years. Furthermore, significant areas of the topsides had been replaced with mild steel or glass re-inforced plastics in the 1970s and 1980s. So although the majority of the ship had not responded well to a cleaning and re-painting regime since 1970 it was believed that with careful use of conventional treatment, and careful maintenance, the topsides could be effectively conserved.

Figure 11 Scuttled in Sparrow Cove

A 'hierarchy of intervention' was agreed between the conservator and the curator. All material dating from before1970 was designated as' precious' and could not be cut, drilled, or welded without their agreement. All treatments were to be reversible. (In the event, only two forms of non reversible treatment proved to be necessary. One was the use of abrasive cleaning to some parts of the topsides and the other was the removal of a small part of a deck hatch to permit the fitting of a lift to ensure complete access to all parts

Figure 13 Artist's impression of the waterline plate

of the ship for disabled visitors.) Post-1970s material could be used or removed according to the needs of the pre-1970s material.
The plastic patches in the topsides were degrading to varying degrees. It was decided to remove them all.

The topsides were to be re-painted using modern two-pack epoxy and urethane paints and these required cleaning to SA 2½ or equivalent. Many of the holes were large and surrounded by extremely fragile ironwork. This lacelike ironwork was cleaned by a wet abrasive method followed by a dry abrasive method to remove the flash rusting that occurred during the necessarily slow initial cleaning. The pressures used in abrasive cleaning varied according the strength of the underlying material and hardness of the products of corrosion. However air pressure was usually limited to 70kPa. The cleaned holes were re-patched using glass reinforced plastics. Approximately 20% of the area of the topsides had been cleaned once all patches had been replaced. The remaining 80% was cleaned by hydro-blasting or ultra-high pressure washing. This uses pure water at 250MPa to remove dirt, paint and corrosion. Although the process will not abrade sound iron, it will distort weak iron and so can only be used on strong elements. The cleaned iron was inspected by conservators and we were pleased to discover previously unknown makers' stamps on several iron plates confirming that they had been made in Coalbrookdale. Before this, there was only secondary documentary evidence indicating this fact [3].

The plastic patches were designed to fulfil two functions: to keep de-humidified air inside the ship and to support the decorative paint film on the outside of the ship. Additional structural support was provided by replacing wooden dock shores with steel ones and inserting internal steel frames alongside the ship's original iron frames, where the engineers' model indicated it was required. 144 new steel members were installed in the ship, each one fastened to the hull using existing holes or other reversible methods. This resulted in some steelwork that looked unconventional but at least could not be confused with Victorian ironwork! In fact it represented a productive collaboration between engineers and conservators whereby both sets of professionals were able to argue for elements of treatment that were of fundamental importance to

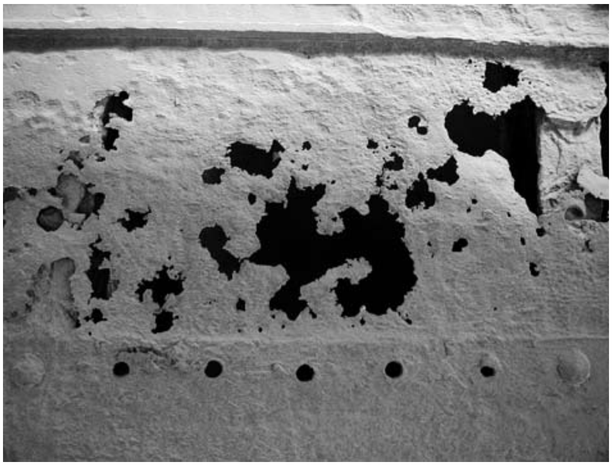


Figure 14 Holes revealed by the removal of patches

Figure 15 Makers stamp "C B DALE ~ BEST"

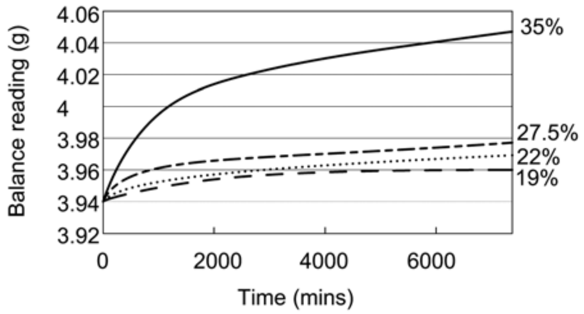


Figure 16 Ferrous chloride and iron response to relative humidity

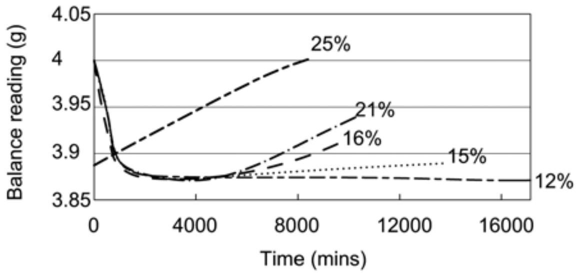


Figure 17 β-FeOOH and iron response to relative humidity

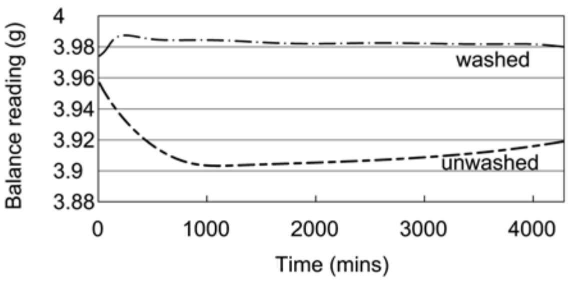


Figure 18 Response of washed and unwashed beta ferric oxy-hydroxide at 20% RH

each. This continued a style of teamwork developed in the initial investigative phase of the work. [4]

While this work was continuing, David Watkinson and Mark Lewis at Cardiff University were commissioned to establish the appropriate level of RH for the ship. Their work looked at the rate at which iron and corrosion products corrode at various levels of RH. [5]

Figure 19 The ship before treatment

Figure 20 The ship after treatment

The initial work looked at ferrous chloride and suggested that the ship would be stable at around 20% RH. However, when the role of beta ferric oxy-hydroxide (β-FeOOH) was considered it appeared that the required RH level was closer to 15%.

Obviously running costs would be significantly lower if the iron could be kept at an RH of 20% so Watkinson and Lewis [6] looked at the response of washed and unwashed β-FeOOH because, as has been previously noted, the ship had spent 30 years away from the sea being regularly washed by rain. Furthermore, it appeared that there was relatively little β-FeOOH .

It was finally decided to design the dehumidification plants to have the capacity to deliver an RH of 15% but to run them at 20% and monitor the results.

Figure 21 View from bow after the waterline plate had been fitted

Once the treatment of the topsides had been completed the glass waterline plate could be fitted. Various measures were required to stabilise the dock and to protect the caisson which had not been moved for thirty years! The dock floor was also provided with foundation pads for the support steelwork for the glass plates and the new steel shores. The external dehumidification plant was also installed in the dry dock before the glass plate was fitted. A second plant of equivalent size was manufactured in demountable elements and fitted inside the ship.

The aim of most conservation exercises is to conserve the object at the same time as minimising the intervention. Clearly in the case of the Great Britain the intervention was to be significant. Nevertheless the aim was to minimise the visual impact of the environmental changes that were needed.

Conclusion

In both cases, a number of key factors dictated the conservation treatment of both objects. The bridge had to be used for vehicular purposes. In effect, its treatment was determined by the functional needs of Fort Brockhurst as a whole and not the conservation needs of the bridge in isolation. This was continuing a trend begun when the first of the inelegant strengthening schemes was put into effect. A desire to improve the physical appearance of the bridge in relation to the fort was an understandable factor in the choice of treatment. Another was the desire to minimise the risk of intervention being required in the near future. Although metal spraying can be regarded as the most long-lived form of treatment for outdoor iron and steel (other than environmental control) it is very intrusive, particularly when applied to riveted structures. However when balanced against a desire for cost-beneficial treatment and a simple improvement, the form of treatment can be seen as both ethical and desirable.

The treatment of the ss Great Britain in the early part of the 21st century represented a complete change in how she was viewed. This was bought about in large measure by the Heritage Lottery Fund's decision to fund the appointment of a full-time professional curator and to provide a budget for a serious review of the ship. These measures not only resulted in conservation-led treatment proposal but also an increasing understanding of the importance of the whole of the ship's working life. This led to her designation as a museum object, to be conserved as such, and to her becoming the heart of a "Victorian dockyard". Paradoxically this appeared to conflict with the legal situation. For as a built structure of heritage significance the dock had been given 'listed' status whereas as a moveable object the ship was not. This meant that various legal constraints which applied to the dock did not apply to the ship. In the event however, the dock received rather more intrusive treatment than the ship. These compromises were in part due to the fact that various engineering works were required to stabilise the dock (to safeguard both ship and dock) but also due the fact that the conservation needs of the ship imposed the additional requirements for the treatment of the dock (e.g. foundations for the waterline plate steelwork and dehumidification plant and the control of flowing water in the dock). It is interesting to contemplate what other compromises might have be considered if the conservation management plan had not been able to attribute such overwhelming significance to the ship.

Author

Robert Turner and Shane Casey
Eura Conservation Ltd, Unit H 10, Halesfield 19,
Telford, Shropshire TF7 4QT UK
UK
Email: robert@eura.co.uk

References

[1] Cox, J. and Tanner, M. 1999. *Conservation Plan for the Great Western Steamship Company Dockyard and the ss Great Britain.* Volume 1. ss Great Britain Trust

[2] Turner, R, Turner R, Casey, S, and Tanner, M, 1999. *Conservation Plan for the Great Western Steamship Company Dockyard and the ss Great Britain. Volume 2 – Condition report and recommendations for the ss Great Britain.* ss Great Britain Trust. http://www.eura.co.uk/ssgb (April 2005)

[3] Transactions of the Institute of Naval Architects from April 1871 notes that the iron was made from clay band ironstone by the Coalbrookdale Iron Company in Shropshire; and an entry in Barclay Fox's journal for 14 April 1839 states that 'the Colebrookdale Iron Co…have an order for 800 tons of rolled plates for the Great Western Co…'.
[4] Watkinson D., Tanner M, Turner R. and Lewis M., 2006 *ss Great Britain: teamwork as a platform for innovative conservation.* The Conservator **29** 73-86 ISSN 0140-00960
[5] Watkinson D. and Lewis M. 2004. ss Great Britain iron hull: modelling corrosion to define storage relative humidity. In: Ashton J and Hallam D (eds.) *Metal 04 Proceedings of the International Conference on Metals Conservation.* Canberra Australia 4-8 October 2004 88-103 National Museum of Australia.
[6] Watkinson D and Lewis M., 2005, *The role of β-FeOOH in the corrosion of archaeological iron.* Materials Research Society of America Fall Meeting Boston.

KLEVFOS Forever – how long is that?

A new conservation plan for a pulp and paper mill

Vigdis Vingelsgaard

Klevfos Pulp & Paper mill (1888-1976) is a piece of industrial history from the times when wood based products was the main export business of Norway. It is located at Løten in the county of Hedmark, 120 km north of Oslo.

Klevfos Pulp & Paper mill [1] was never the biggest, most important or otherwise especially significant amongst the many similar industrial plants in the country. What eventually lead it to be singled out as THE place of its kind to be saved for prosperity is the result of a number of factors.

After the decision of a total closure of the plant in 1976, the thought of transforming this site into an industrial ”memorial” or museum started to grow in the local municipality and amongst workers at Klevfos.

When it closed in 1976 the industrial plant was nearly unchanged in respect of both machinery and production line since the 1920s, thus providing a possible long historical perspective. Many enthusiastic people locally supported the idea of turning it into a museum telling the story of working class people and industrial history.

The local authorities supported the idea and so did the Norwegian Paper Industry Union and The Norwegian Pulp and Paper Association.
As a result Klevfos became one of ten most highly prioritized industrial sites in Norway, from a list of

Figure 1. Klevfos Pulp & Paper mill in the 1960s.

38 in total, included on the Norwegian Directorate for Cultural Heritage List of Technical/Industrial Heritage [2], and is today a part of the Norwegian Forest Museum.

The museum opened to the public in 1986. The main objective of the museum was to present this Pulp and Paper Mill for the general public, as it looked the very day the last whistle blew. Interspersed at the plant was didactical interpretation/explanation in a variety of forms. The following year saw the birth of a still ongoing and most appreciated activity: a theatrical play, staged in the area itself; depicting the life at and around Klevfos, called *Working days*.
From the start the museum focused on recounting and depicting the story of the workers and their families, but lately in addition to this the museum emphasizes the technical story of papermaking as well.

The main focus of the paper for this conference is the Pulp and Paper Mill at the Heritage Site, but the Industrial Museum also includes dam and water channel as well as housing for the workers, officials and the director.

Klevfos Paper

Klevfos was built as a cellulose factory in 1888, but a paper-making machine was purchased after just a few years. Selling paper proved to be more profitable than simply selling the raw material.

Klevfos produced the cellulose needed to make Kraft paper which had no other added fibre materials. The unbleached paper had a characteristic brown colour. Other colourings could be added if ordered.
The paper produced at Klevfos ranged from cardboard to writing paper (approx. 40 g/m2), and was used for a variety of purposes; from packaging, to sacks and building felt. During the Second World War a black felt was produced to be used as blackout curtains.

Don't change! A strategy for preservation or destruction?

The main objective of the museum is to present this industrial plant as it was on the very last day the whistle sounded – as if the workers just left everything behind.
Maintaining the buildings and the related facilities is the focus and main interest of The Norwegian Directorate for Cultural Heritage, *Riksantikvaren*, who contributes a total of 1 million NOK each year and even more for special projects. Their main focus is on the preservation of the buildings. High priority is stressed on the use of the correct materials and methods for conservation. That includes mending the roof with the same materials as before, using lime mortar instead of cement if that was used at the actual time, etc.

Since 1986 a five year conservation plan for the buildings has been set up and implemented. A local architect advising company has made the current plan for 2006-2010 [3], which is a conservation plan for the building and interior focusing on safety for the visitors, drainage and the critical conditions for the buildings. These issues are of core interest for the preventive conservation of machines and equipment inside as well.

The museums in the county of Hedmark have a Regional Conservation Department at their disposal and in 2005 we visited Klevfos for the first time in this capacity, taking pictures and talking to the people working there. Their focus at that time was solely on the conservation and maintenance of the buildings.

As far as the interior of the Pulp and Paper Mill is concerned, the philosophy of the museum was that the ongoing degradation would come to and end; that the corrosion of the machinery would naturally reach a point of no further deterioration. The "main road" where tourists have access, gets the most attention and is cleaned to a certain point, focusing on personal security on staircases etc.

In our opinion the "Don't change-preservation" with time had become the foundation from which a substantial degradation had arisen.

Condition survey. Conservation of the interior

Two years later, in 2007, all museums in Hedmark were surveyed by The Norwegian Archive, Library and Museum Authority (ABM-utvikling) reporting on conservation conditions for objects and archives. Every visited museum received a report stating the finds and possible solutions and suggestions to remedy encountered problems. The Hedmark County administration received a copy of these individual reports plus a summarized conditions and suggestion report for their use only. The Regional Conservation Department considered this event a good opportunity to contact the Klevfos Museum administration anew for a meeting to discuss the conclusions in this report.

The conservation survey points to some of the weak aspects of the "Don't change"-conservation strategy of Klevfos. Deterioration does indeed not stop by itself, but one can gradually get used to it, and when this happens slowly, it is not always easy to recognise. Moreover there are some corners of the site that groups of visitors are not shown, but all the same the museum has the obligation to take care of it.

The initial intension of making an industrial plant of "yesterday" open to the public has become a difficult task to maintain. Time has passed, problems arisen, and a lot of questions now have to be answered. Time in itself has not worked in a positive way, neither for the preservation nor the interpretation of the site. It is now high time to make a new conservation strategy encompassing all aspects of the site.

Charter for the Industrial Heritage

Where can we find help and inspiration to set up this new strategy? Maybe in the Charter for Industrial Heritage?
There exists a special Charter for Industrial Heritage which also refers to the Venice Charter for Cultural Heritage: It is called The Nizhny Tagil Charter for the Industrial Heritage [4] from July 2003, and it is endorsed by the Industrial Committee for the Conservation of the Industrial Heritage (TICCIH). It provides definitions of what is meant by Industrial Heritage and gives it a value along the same lines as more traditional historic sites.

In this Charter § 5 about Maintenance and Conservation, part VI says: "Interventions should be reversible and

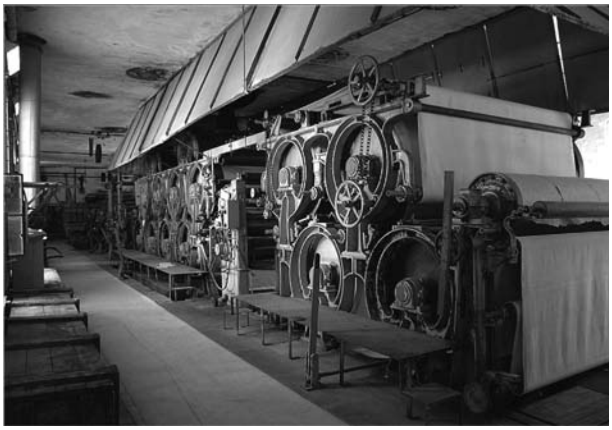


Figure 2. The Machine Hall 1995. Credit: Jan Haug/ Hedmarksmuseet photograph library.

have a minimal impact. Any unavoidable changes should be documented and significant elements that are removed should be recorded and stored safely. Many industrial processes confer a patina that is integral to the integrity and interest of the site."

We must take into account what they call *patina,* when we plan any remedial actions for Klevfos. But what is patina? Is it a state of conservation where nothing deteriorates, where no changes occur? Do painted machines made of steel get a sort of patina with time or do they get more corroded year after year due to lack of maintenance? It is possible that this charter is not concerned with the conservation in detail in an Industrial Heritage Site.

Maybe the traditional museum way of thinking offers better advice?

Good housekeeping in a Pulp and Paper Mill

Industrial museums differ from ordinary museums in many ways. The curator, who wanted to register the Pulp and Paper Mill in the traditional way, quickly gave in. How many numbers should a paper machine get, one or one thousand? Where does it start and where does it end? The museum decided to try photo documentation instead and now have to text each photo in detail to make it meaningful.

Maybe an industrial museum like Klevfos is more akin to open air museums and traditional historic houses? In England the National Trust in 2006 published a new version of their first Manual of Housekeeping, with the subtitle "The care of collections in historic houses open to the public."[5].

Let us take a closer look at this Manual of Housekeeping. Their current definition of conservation is:"... the careful management of change. It is about revealing and sharing the significance of places and ensuring that their special qualities are protected, enhanced, understood and enjoyed by present and future generations". [6]

...the careful management of change, this expression is very interesting, because there is an acceptance embedded here regarding the fact that there inevitably will be some sort of change as time goes by and that our role is to manage this change carefully.

...revealing and sharing the significance of places, at Klevfos this has been the main focus since the day the museum opened in 1986, as explained earlier.

... *ensuring that their,* (Klevfos)*, special qualities are protected, enhanced, understood and enjoyed by present and future generations.*

What meets the visitor today does indeed not relate to any "true" historical event, the time machine does not run smoothly.

To protect the qualities. The need of a new strategy for conservation

The special qualities of Klevfos - how can we protect them for future generations? [7] The museum has a high quality in their communication to visitors, to children as well as adults: theatre performances, workshops for papermaking in addition to ordinary guided tours. The memory of Klevfos is well taken care of.

But we have to admit that the protection of the qualities of the interior will not last for future generations. The machines and equipment throughout the museum are at high risk of self-destruction, so although the Museum has good intensions, the result so far is not adequate.

A constructive dialogue between conservator and museum staff about this has just recently started. For us to find better ways of defining means and needs, we now try to address the problems of conservation in a more strictly analytical form.

One way of doing this is by means of analyzing the nine agents of deterioration as mentioned in the manual of housekeeping [8], based on the work of Michalski 1994 [9] and Waller 1994 [10]: *fire, loss, water, physical, chemical, biological activity, light, wrong relative humidity* and *wrong temperature.*

When this plant was functional a natural procedure of ongoing maintenance was undertaken. Parts needed to be mended or shifted regularly; all moving parts needed constant lubrication; in times of production standstill more time-consuming maintenance was undertaken; removal of rust and concurrent painting; cleaning and improving. All this ended in 1976 when the plant was closed down for good.

To protect the inherent qualities of this site we have to understand the production process, to a certain point at least. Are the conservation problems we encounter today related to the former production process? Are they related to the museum period with none or very different activities, or is it a combination?

For almost all the agents of deterioration these questions are utterly important; and could theoretically be of some variation along the production line.

The production line

The production line of the pulp and paper production is still complete, but there has never been any intension to start even a small museum production, or make the machines run during special events.
Here follows a short description of the various stages of production at the plant:

Cellulose factory

To make Kraft Pulp also called Sulphate Pulp the chopped wood was boiled into pulp mixed with liquid caustic soda (cooking lye).

The liquid chemical - called black lye - were filtered out and was sent for recycling to *Sodahuset* (soda house). As the chemicals were expensive a quite complicated

recycling process was profitable. It included heating, steaming and mixing in natriumsulphate to compensate for lost chemicals. The natriumsulphate gave name to the Sulphate Pulp process used for paper production at Klevfos as well as the characteristic odour from the soda house chimney. This was indeed one of the intangible qualities at Klevfos which had a positive designation implying work, money and happy husbands returning from work.
The cellulose pulp was transported via a chute to *Silhuset* (filter house) for rinsing and filtering.

Hollenderiet

Then the cellulose pulp was run through a type of grinding mill called *Hollenderiet* before being processed into paper. The only paper ever produced at Klevfos was Kraft paper, and glue was added to make it strong and more resistant to moisture. Alum was also added to make the glue react with the fibres, and colours was added here, Victorian red, blue or green.

Hollenderiet was considered the pivot point of the entire paper-making process. If the grinding process was not exact, then this would course problems for the paper-making machine. Connected to this part of the plant are an office and a small laboratory.

Paper-making machine

The paper-making machine consisted of four parts: a wet part (perforated cloth), a pressure part, a drying part and a rolling part. First the pulp was sent through a rinsing process, and then sprayed out through nozzles to ensure an even distribution of fibres across the width of the paper-making machine. Excess water was removed by running the pulp through a perforated cloth. The pulp was then carefully transferred to a felt section, and the felt protected the wet paper while it was being pressed. The paper was then transferred to a drying area. Large cylinders were filled with steam, and the paper gradually dried as it was fed through the cylinders. At the end of the drying process, the paper was pressed to give it a smooth surface. Finally, the paper was rolled onto steel cylinders. The paper rolls were later re-rolled and cut according to order.

Figure 3. Melting snow, and water into the cellulose factory. Credit: Jan Haug/Hedmarksmuseet photograph library.

Sorting hall, cutting and packing

Some of the paper was cut in various sizes, rolled into separate rolls weighing from 5 kg and up. Some of the paper was cut in a special sheet cutter. Sorters then sorted, counted and packaged the sheets into bundles. The bundles were then stored on pallets and lifted up onto the floor above, where they were packed and labelled according to size, number and quality.

Deterioration agents related to Klevfos

Fire and *loss* is well taken care of at the museum with fire detection and alarm systems. For many years these areas of running a museum have been of prime interest to the national authorities, who have offered grants for the purpose of installing fire and burglar alarm systems in museums.

The third deterioration agent mentioned is *water*. This is a far more complicated agent. *Riksantikvaren*, the architect company and everybody agrees that the original procedure of leading water under the building to the Francis turbines in the turbine hall must come to an end. The initial idea of preserving this important part of the living plant: the flow of water and the sound stemming from this is a major source of deterioration. In order to preserve the iron beam underneath the floor, the exposure from the current water stream will have to be eliminated. It is very important to keep the drainage around the Paper Mill in good order. The annual snow-melting

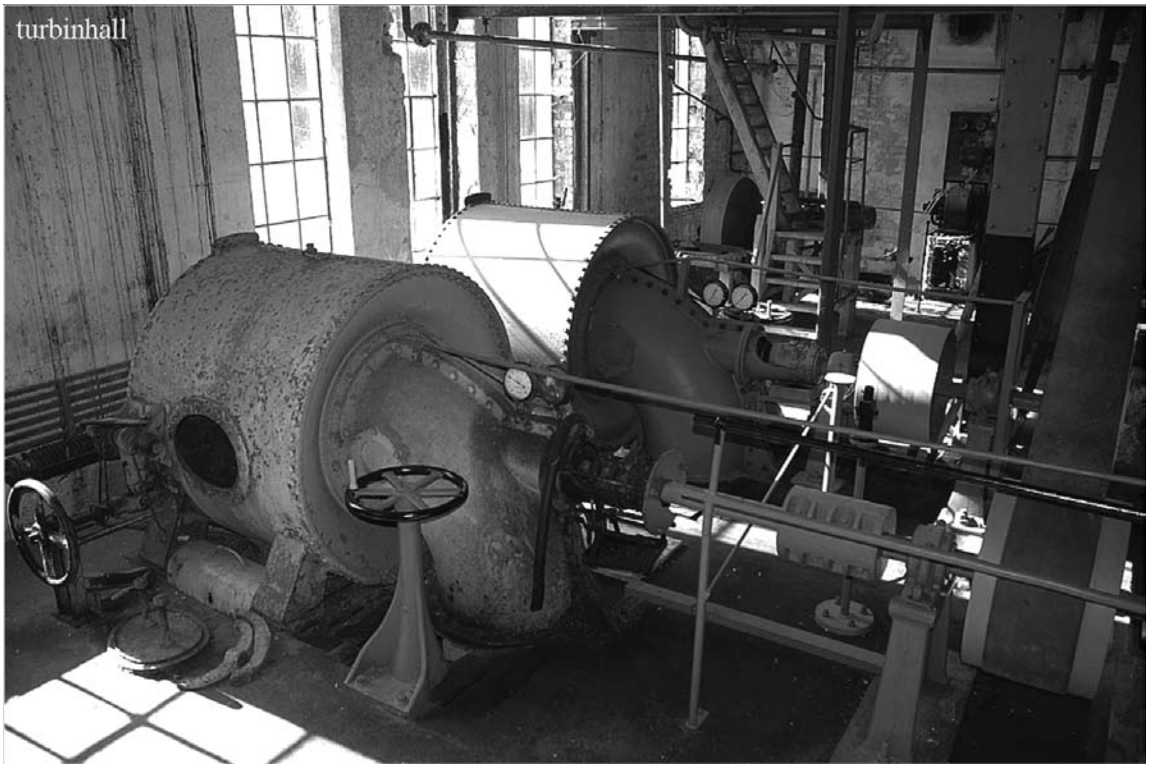


Figure 4. The turbines, one original and one repainted some years ago. Credit: Jan Haug/Hedmarksmuseet photograph library.

and water running into the machine hall every spring lead to corrosion at the base of machines exposed for water.

The forth deterioration agent to consider is what we call *physical.*

Here we talk about physical forces generated in Klevfos by staff and visitors. Some areas are used by the theatre actors, for instance the office in the *Hollenderiet.*

The *chemical agents* of deterioration are “aggressive” chemicals in the form of gases, liquids or solids, which react or interact with materials and cause e.g. corrosion. We will have to ask questions and undertake some research: What kind of dust and deposit do we actually have? Is it alkali, is it a result of acidic action, could it be salt efflourecense from the building material? If the dust is aggressive it has to be removed. If what we see is salt efflourecense it could be caused by problems with drainage of water or leaks in roofing.

It is obvious that the soda gave rise to problems for the wooden beams in the soda house which initially had to be exchanged regularly. The ovens for steaming of black lye also have problems because of the lye. Residues of caustic soda are difficult to get rid of in brick walls.

In other parts of the paper mill the paper making processes provided less hazardous chemicals.

We may look upon dust from another point of view: How much dust is “historically correct” in a paper machine hall? There were no investments in new production equipment the last 30 years at Klevfos, but that does not mean that it was all dirt and disorder. In some parts of the Pulp and Paper Mill it had to be very clean, other parts were dirtier. The laboratory was clean, and the fire room not so clean.The paper machine hall also had to be clean, especially the steel cylinders for pressing and rolling paper.

We do need to make up a routine for cleaning; having in mind the patina of the museum, the historic dirt, must be left.

What about *biological deterioration*?
In a showcase with small objects there is no dust, but a lot of mould growing. Here some silica gel would be helpful.

A major problem with swifts has arisen over recent years. An important part of the paper mill is the soda house where sodium was recycled from the production process. But after the life of the paper mill stopped and no noise, smelly vapours or people are in action anymore, the birds have taken over the soda house. Their droppings are all over the place. This biological activity leads to chemical deterioration on the painted surfaces of the iron ovens causing corrosion on the iron itself.

As long as the windows are not too clean, we feel that *light* deterioration is not a significant problem at the Pulp and Paper Mill. Sunshine makes the temperature rise in the damp halls and helps lower the RH.

Wrong relative humidity is not unusual at Klevfos nowadays. The former director told us that they did not open the doors in spring before the temperature inside was the same as outside, to avoid condensation on the machinery.

In a Pulp and Paper Mill Museum like Klevfos it is not easy if at all possible to control the climate. There is no warmth at all, no dehumidification or any airconditioning. What we can do is to eliminate and minimize the impact of excessive moisture, as mentioned above.

When the production was still running, there were different climate zones in different parts of the plant. An important part is the cellulose boilers that created a hot and dry climate. In the soda house a lot of warmth was produced in the recycling process for soda. In the paper machine hall the big drums were filled with steam to dry the paper. Therefore the corrosion of iron in most parts of Klevfos was minimal.

The workers of course tried to minimize the corrosive action on iron by cleaning and painting the machinery and equipment. All over the site we find the same light green paint, but now we have reached a critical point where we see more corrosion than paint on most surfaces.

Wrong temperature we must admit is part of the problem causing corrosion all over the plant. As mentioned above a too high RH is causing a lot of corrosion on iron, and if the production process was still going on, the temperature everywhere would be different.

Conclusion

At the Regional Conservation Department our role is to give advice and work out a new strategy in cooperation with the museum staff.
Regarding this huge and indeed complex industrial site, our proposals so far are:

1. A careful cleaning and tidying up, especially where the visitors are not allowed at all: the forgotten places: the lab, the paper package, the bathroom etc. Remember to leave historical dirt, taking care of the patina of the place, not leaving it too tidy at the wrong places.
2. Consider dehumidification, especially in the paper machine hall this might be the only possibility to preserve the delicate paper machine with all the intricate details.
3. Make a list with priority of what needs direct conservation: considering the condition of the painted surfaces, how severe the corrosion is, which part of the machines ought to have a more “polished” look, and which could be repainted. We have to decide on a surface protection for iron: wax, oil or repainting. When and which parts need lubrication?
4. Replace original instructions at different parts of the plant with copies.
5. Taking care of the bird invasion by putting up netting on top of the soda house, cleaning bird droppings from the soda ovens.

These measures will see us take a more active role in the careful management of change. It is about revealing and sharing the significance of places and ensuring that their special qualities are protected, enhanced, understood and enjoyed by present and future generations.”

And hopefully this may become the start of a longer life for Klevfos.

Author

Vigdis Vingelsgaard
Conservator
Conservation department (Bevaringsavdelingen)
Stiftelsen Domkirkeodden
Postbox 1053
2305 Hamar
Norway
e-mail: vigdis.vingelsgaard@domkirkeodden.no.

References:

1. Jervan, Magne. (1987). *Klevfos Cell- & Papirfabrik 1888-1976*. Klevfos Industrimuseum. Temahefte. Elverum Trykk A/S. Norsk Skogmuseum: www.skogmus.no/innhold/klevfos.
2. Riksantikvaren (1994). *Verneplan for teknisk industrielle kulturminne:* www.riksantikvaren.no.
   The Norwegian Directorate for Cultural Heritage list of Technical/industrial heritage.
3. Sjåtil & Fornæss (2005). *Vedlikeholdsplan 2006-2010*. Copy.
4. The industrial Committee for the Conservation of the Industrial Heritage (TICCIH). (July 2003). *The Nizhny Tagil Charter for the Industrial Heritage*. www.international.icomos.org/18thapril/2006/nizhny-tagil-charter-e.pdf
5. Oddy, Andrew edit. (2006, 2008). *The National Trust. Manual of Housekeeping.* Butterworth-Heinemann. Series in Conservation and Museology.
6. Staniforth, S. (2006, 2008). 4. Conservation: principles, practise and ethics, 2.1 Definition of conservation. *The National Trust. Manual of Housekeeping. p35.* Butterworth-Heinemann.
7. Staniforth, S. (2006, 2008). 4. Conservation: principles, practise and ethics, 2.1 Definition of conservation. *The National Trust. Manual of Housekeeping. p36.* Butterworth-Heinemann
8. Staniforth, S. (2006, 2008). 5. Agents of deterioration. *The National Trust. Manual of Housekeeping,* pp. *45-55.* Butterworth-Heinemann.
9. Michalski, S. (1994a). Sharing responsibility for conservation decisions. In *Durability and Change: the Science, Responsibility and Cost of Sustaining Cultural Heritage (W .E Krumbein, P. Brimblecombe, D.E. Cosgrove and S. Staniforth, eds) 241-258, Chichester: John Wiley and Sons*
   Michalski, S. (1994b). A systematic approach to preservation: description and integration with other museum activities. In *Preventive conservation: Practice, Theory and Research* (A. Roy and P. Smith, eds.) 8-11, London: International Institute for Conservation.
   Mikalski, S. (1994). *Framework for the Preservation of Museum Collections.* (Wall chart). Ottawa: Canadian Conservation Institute. (Available online via www.cci-icc.gc.ca)
10. Waller, R. (1994). Conservation risk assessment: a strategy for managing resources for preventive conservation. In *Preventive conservation: Practice, Theory and Research* (A. Roy and P. Smith, eds.) 12-16, London: International Institute for Conservation.

Hazards in industrial collections of the Canada Science and Technology Museum Corporation Ottawa, Canada

Sue Warren

The Canada Science and Technology Museum Corporation consists of three major collections: those of the Canada Agriculture Museum, the Canada Aviation Museum, and the Museum of Science and Technology. This paper offers a brief overview of the hazards encountered so far, in the diverse collections of these three institutions.

The nature of technological artifacts, being on the forefront of innovation and advances in material science, means that the dangers or stability problems we understand today, were not well known or anticipated at the time of invention or common use. Today, our knowledge of toxicity and exposure hazards far exceeds that of the original users of these artifacts. Conservators and museum personnel are required to interact with these objects both for storage and treatment, and to make them safe for display or research.

The following discussion will describe five major projects undertaken at the CSTMC related to hazard management, followed by an overview of other hazards identified according to three broad categories: 1. physical and mechanical hazards, 2. biological, and 3. chemical and mineral.

Large Projects at the CSTMC:

1. Polychlorinated biphenyls (PCBs)
2. Asbestos
3. Mercury
4. Explosive squibs and methyl bromide fire extinguishers
5. Radiation

1. Polychlorinated biphenyls (**PCBs)** have been used historically as coolants and insulating fluids for transformers and capacitors, stabilizing additives in flexible PVC coatings, pesticide extenders, flame retardants, hydraulic fluids, caulkings, adhesives, paints and carbonless copy paper. PCBs are a persistent bioaccumulative pollutant with low water solubility and high thermal resistance. They are classified under the Stockholm Convention of 1995, as a persistent organic pollutant. They were first identified as a risk by our Conservation Division in 1992 during treatment of an X-ray machine. The transformers of these early machines sometimes contained large volumes of coolant oil and so consequently, all of the x-ray units in the collection were assessed and the oils

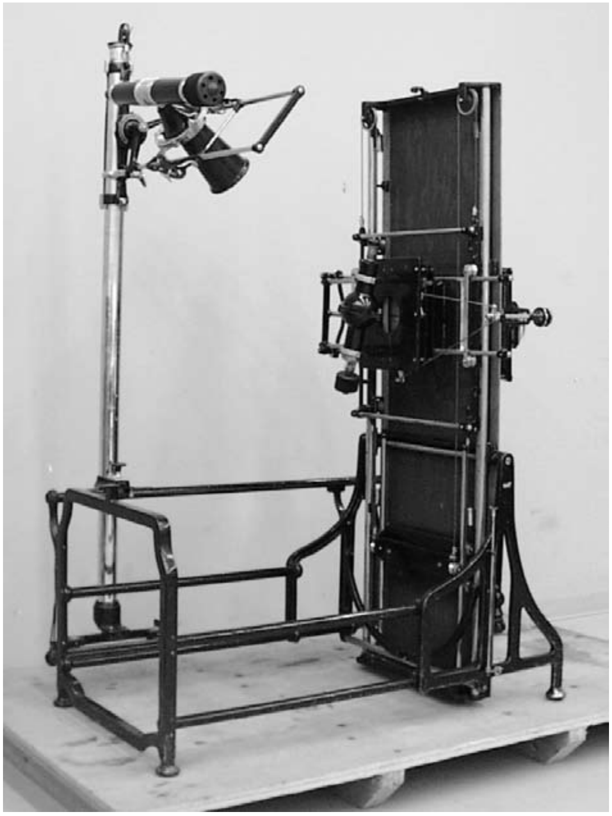


Figure 1: x-ray machine c. 1925

Figure 2: 6200 locomotive on front lawn of the Museum 1989.

tested. Of a total of 16 machines, 9 tested positive for PCBs, with only 2 having concentrations over the allowable limit.

The early computer collection was also found to be a major source of PCB contaminated oils; as the cooling systems in these machines also required large quantities of oil.

In Canada, there is a legislated allowable limit of 50 ppm, above which the material is classified as hazardous. It is illegal to transport PCBs on public roads, requiring a special hazardous materials transport license. Shipping companies contracted to move artifacts containing PCBs must be notified, as there is a high probability of leakage in historic objects.

Simple identification procedures for PCBs do exist: generally PCB fluids are viscous and dark (the higher chlorinated ones are darker); PCBs have a characteristically acrid smell; and they are more dense than water, so that a drop of the fluid will sink to the bottom of a beaker of water. These tests are qualitative, and must be followed by chemical analysis to determine the concentration of contaminants. All contaminated fluids and materials must be labeled and disposed of by a licensed disposal company.

2. **Asbestos**. Asbestos is a naturally occurring mineral with long thin fibrous crystals. It was widely used in industrial applications particularly in locomotives, ships, and other large machinery, as well as auto and rail brake pads; and flame retardants in buildings, appliances and vehicles. The friable fibres are a severe inhalation hazard and a known carcinogen. It has been a regulated substance in the United Kingdom since the 1930s; and in the U.S. since the 1940s. There are two mineral groups of asbestos: the Serpentine group which includes chrysotile (white); and the Amphibole group (blue, brown and grey). All of the minerals in the Amphibole group have been banned in the Western World since the mid 1980s. Chrysotile asbestos continues to be used in many countries, though there is currently a ban in the EU and in Australia.

Chrysotile asbestos accounts for about 95% of asbestos found in the construction industry in North America. Because the fibres are curly, it can be spun and woven into fabric, but its most common use is in asbestos sheeting for roofs, ceilings and floors. It is also the most likely type found in electrical appliances and domestic applications.

CSTMC has addressed several major asbestos concerns over the past years; mostly related to the locomotives in the collection, but also with aircraft, and on a much smaller scale various domestic appliances and pieces of scientific equipment. The first such project was in 1989, and involved the removal of asbestos insulation in the 6200 locomotive which stands on the front lawn of the Museum.

The second large-scale project involved removal and/or containment of asbestos in the locomotives on display in the Museum's Locomotive Pavilion. In 2007, asbestos abatement of the North Star Aircraft at the aviation Museum was undertaken.

In Canada, the Environmental Protection Act Procedure C-10 outlines the removal procedures at sites containing substantial quantities of Asbestos waste. Recognized consultants must be engaged, who are familiar with current regulations. Waste asbestos "must be pre-wetted and kept in an appropriately wet condition…. during all phases of the operations to eliminate visible dust emissions". Further, all asbestos waste must be properly packaged for transportation in accordance with legislation. All sites must be provided with passive and active security, and workers must use respirators and safety clothing as necessary. Ambient air at the worksite must be monitored according to Ministry procedures, and measured against the primary criteria for ambient air of 0.04 asbestos fibres of length greater than 5 µm per cubic centimetre of air. [1]

Figure 3: CSTMC lighthouse assembly 1981

Where possible, the asbestos in historic artifacts is contained rather than removed. The Museum has an Asbestos Management Program to monitor and control any risk to the visitors or staff.

3. **Mercury** is a d-block element in the periodic table, otherwise known as a transition metal. It is the only element liquid at standard temperature and pressure and is volatile at room temperature. It is a persistent, cumulative toxin with proven severe and fatal effects on neurological, respiratory and circulatory systems. It has been used extensively in the industrial world as a coolant or lubricant, in electrical applications such as rectifier bulbs, switches and vapour bulbs, in textile making, cosmetics;, paint additives, and as amalgams for mirrors or dentistry.

In the original patented design for a mercury drive system for lighthouse lenses, 100kg of mercury could support a 3000 kg. optical assembly.[2] The lighthouse at the Science and Technology Museum has such a mercury drive system designed to be extremely low-friction to support the enormous weight of the lens. Our unit consists of about 4-5 litres of mercury which supports an optical assembly of about 1000 kg. The lighthouse was dismantled at its original location at Cape North, Cape Breton in October 1980, and was reassembled and installed on the front lawn of the Museum in 1981.

In 1993, the Conservation division undertook an inspection of the mercury bath due to a leak of amalgam. The mercury was drained and the mechanism cleaned of corrosion. Both the Coast

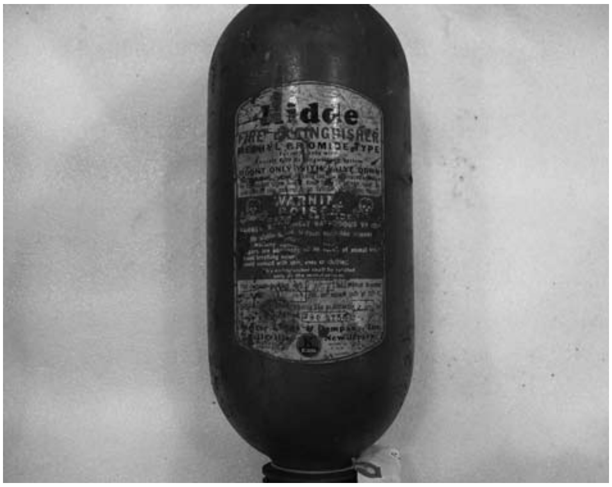


Figure 4: Methyl bromide extinguisher 2005

Guard and the Department of Labour were called in to inspect the mechanism and also to check the mercury vapour limits as defined by regulations for workplace exposure. All of the measurements were within acceptable limits, however additional precautions were taken to improve ventilation considering the fact that public tours are conducted through the lighthouse in the summer.

Mercury exists elsewhere in the collection in a variety of artifacts; many of them meteorological, some on scientific equipment as mirrored surfaces. The barometer collection was assessed in 2006, in response to a mercury spill. All barometers were inspected, and where necessary, the seals replaced or consolidated. All barometers are now stored together on a custom-pallet with drip trays, which serves as a good means of monitoring as well as a health and fire safety measure. Other artifacts containing mercury are identified on the database and are stored with drip trays or in bags to prevent leakage.

4. Explosive **squibs and methyl bromide** at the Aviation Museum. Squibs are small explosive devices, in this instance used with fire extinguishers to activate liquid or compressed gas cylinders. They are triggered by a small electrical current initiated by the pilot .The most commonly occurring type of fire extinguisher in early aircraft in the collection is methyl bromide, in use in the 1920s and 1930s. Methyl bromide has also been used historically as a pesticide and is classified as an ozone-depleting substance whose use is restricted in accordance with the Montreal Protocol on Substances that Deplete the Ozone Layer, January 1, 1989. It has short term neurological and long term respiratory effects on humans, and causes severe eye injury with exposure to liquid or vapour.

In 2005, a project to identify and neutralize the explosive squibs and extinguisher contents resulted in the destruction of 62 squibs and the emptying of 50 bottles containing methyl bromide. These assemblies are usually in confined spaces and are difficult to access and remove. An external company was engaged to remove and neutralize the mechanisms and hazardous gas, but had to work closely with the aviation technicians in order to minimize risk to the aircraft and personnel.

5. **Radiation** occurs in the collections of CSTMC primarily in the form of luminous paint, and in the case of aircraft, in depleted uranium ballast. Radiation is a known carcinogen and mutagen.

In Canada, occupationally exposed workers have an annual dose limit of 20 mSv/yr over five years (for a total of 100 mSv), or a maximum of 50 mSv in a one-year period. In contrast, the public have a dose limit of 1 mSv in any one year. We are classified as "the public" for the purposes of determining our allowable exposure.

Radiation first came to the attention of the Conservation division in 1991, during treatment of an analytical balance acquired from a nuclear facility. In point of fact, radiation has been part of the collection since its inception, though it was not monitored or identified. The Corporation has had a license to store

Figure 5: storage of radium dials

radioactive materials since 1995, and we currently have a Geiger counter and personal dosimeters for monitoring staff exposure.

The Aviation Museum has radiation in the form of radium luminous devices, as well as in depleted uranium ballasts and in tritium emergency exit signs. The dials were the subject of a major project in 2008 to re-locate all of the devices to a secure storage location. The project began with a Health Canada inspection of the Bomarc Missile currently on display at the Aviation Museum. This was in response to documentation published in 2007 about the missile, and the likely presence of radioactive ballast. Health Canada personnel completed an inspection of the display area and also undertook an assessment of the storage rooms: taking both radiation and radon gas measurements. Their findings related to radon gas were sufficiently worrying to prompt a relocation of a staff member working in the room, and a plan to relocate all of the devices to a secure storage area.

Radiation is one of the most worrying hazards in the collection, as it is not something easily identified or avoided. There can also be resistance from staff to working with radioactive materials. This, of course, is entirely valid unless precautions are taken to minimise risk and to monitor exposure at all times. The planning stage of the project at the Aviation Museum was undertaken in consultation with Health Canada and the Nuclear Safety Board of Canada; reports were generated and circulated to staff, however the information gathered was not disseminated in a way that staff was able to understand; and they therefore felt pressured to work in an environment that was harmful. It is important to remember that not everyone has the knowledge or physics background to understand the numerous terms used by radiation specialists, and some interpretation was in fact necessary to reassure staff. Personal dosimeters were acquired for all staff working with the materials, and in-house training in personal protection and safe handling of radioactive objects was also provided.

Despite the fact that locating a number of luminous devices together increases the intensity of radioactivity in that one location, it was decided that this was the best method of restricting access and therefore decreasing the risk of exposure. It also meant that radon gas could be better monitored and safely vented.

All dials were stored in compartmented corrugated polypropylene copolymer boxes, with the cracked or broken ones being placed in sealed polyethylene bags to contain any loose paint or fragments. This, in itself, presents an increased risk if further handling of the broken dials is required, since contamination can build up inside the bags and increase the harmful dose if the bags are opened.

The boxes were then placed in storage cabinets in the secure, vented room. The space is regularly monitored for radiation levels, though not currently for radon gas.

Other hazards identified

1. Physical and Mechanical:

These are the most obvious type of hazard in any technological collection, and in many ways the easiest to deal with and avoid. At times, the sheer size and weight of artifacts can pose a hazard for moving, treating and displaying. Large agricultural, mining, or forestry artifacts often have cutting or sharp edges.

Stored energy can be present in any size and in many ways: springs in clocks and music boxes, high capacity springs (e.g. aircraft propeller nuts), satellite stem antennas, and some medical implements such as scarificators, which may be inadvertently released. Stored energy is also present in examples of pressure: high pressure hydraulic systems (3000-5000 psi) in aircraft, high pressure steam in operating locomotives. Pneumatic tires of aircraft, particularly modern ones, require very high pressure. More mundane items which can pose physical threats include light bulbs and vacuum tubes.

Explosives occur in such things as safety flares, ammunition, firearms, explosive charges for fire extinguisher systems, ejector seats or canopies and jettison tanks in aircraft. Most explosive charges in aircraft are identified by warning signs or labels; however many are hidden such as in extinguishers or in wartime aircraft radios such as in the Mosquito.

2. Biological:

Obvious biological hazards such as moulds and bacteria from animal excrement are of concern in the collection of the Agriculture Museum. Many objects come to the Museum in a state of "last use", often dirty and infested; frequently neglected. Mould can be present on any artifact; paper, books, leather, wood, even metals with organic coatings.

Less obvious are the bacteria found in old fuels and lubricants, or contaminants to be found on medical implements. Depending on the age, blood products can be assumed to be harmless; but some strains of viruses and anthrax can survive in dried blood or tissue.

3. Chemical and Mineral:

These are by far the most numerous type of hazard in our collection. The list of substances that we have encountered so far is extensive; and no doubt there are things we have yet to identify. Most of these substances, if deemed toxic, must be contained or disposed of according to health and safety regulations. To this end, an agreement with a reputable disposal agency must be in place, and all waste products must be properly contained and labeled.

In this category we can include pesticides and fungicides present in agricultural technology, chemical residues in industrial processing equipment, solvents from printing or photographic developing, scientific experiments or old pharmaceuticals; fire extinguisher contents; refrigerants in domestic technology artifacts or cooling systems; aerosols; cellulose nitrate film; batteries containing acids or alkalis; PCBs; and minerals such as asbestos, cadmium, mercury and lead.

Batteries: There are hundreds of different types of batteries, and many different types of electrolytes. Older zinc-carbon batteries used a carbon paste which poses little danger to the conservator, though may be corrosive to metals. Lead acid batteries containing sulfuric acid and wet-cell batteries filled with sodium hydroxide obviously do pose a threat. Modern batteries which use heavy metals as their electrodes are beginning to enter the Museum's collection. Nickel, cadmium, lithium and mercury are extremely toxic substances, particularly if the conservator becomes involved in "neutralizing" these battery cells.

Beryllium copper is a specialized metal, found in our collection on space technology artifacts. It is a blood poison, and poses a threat if in contact with blood, for example through a cut.

Cadmium as a protective layer on metal components in communication artifacts especially can pose a problem when that layer begins to corrode and becomes powdery and friable. Usually the quantities of cadmium dust are small; but in the case of an experimental WWII military radar truck in our collection, the quantity present and the advanced stage of corrosion combined to create a hazardous working environment. Samples of the pale yellow dust on all interior surfaces, were tested at the Canadian Conservation Institute, and identified as cadmium formate salt; the product of exposure to formaldehyde or formic acid vapours present in the form of various "waterproof" polymeric materials such as flooring, insulation, and furnishings.

Fire Extinguishers were invented in the late 19^{th} Century, and initially used a combination of concentrated sulfuric acid and sodium bicarbonate solution. The carbon tetrachloride extinguisher was invented in 1912 and was popular in automobiles due to its efficacy on liquid and electrical fires. Chlorobromomethane (CBM) was invented in the 1940s in Germany for use in aircraft and was used until 1969. Methyl Bromide was discovered in the 1920s and used extensively in Europe until the 1960s. [3]

Lead is present in a collection of technological artifacts in paints, model parts, bearings, and the inside of exhausts on vehicles. Oxidized lead is friable and easily inhaled.

Pesticides and fungicides are commonly found in agricultural technology, whether as residues or in some cases as unused packages. Seeds were often treated with liquid or dry chemicals to prevent disease and decay. Residues of these chemicals are found inside seed hoppers, seed treaters, and seed storage containers. Pesticides used for the eradication of insect blight are found in historic insect sprayers and dusters. The Pest Management Regulatory Agency, a division of Health Canada, has a list of all registered and

Table 1: Pesticide timeline

1877	Kerosene in soap
1882	Bordeaux Mixture
1886	Inorganic lime sulphur & Hydrogen cyanide
1892	Lead arsenate
1901	Arsenicals: Paris Green, Copper arsenite, arsenite of Lime, London Purple, lead Arsenate, Scheele's green
1913	Organic mercury compounds (fungicides)
1920	Calcium arsenate
1928	Ethylene oxide
1932	Methyl bromide
1940	Introduction of DDT
1944	Phenoxy acetic acids (2,4-D)
1945	Organic phosphate insecticides
1946	Synthetic organic insecticides
1950s	Also included formaldehyde, Mercury and lead

historic pesticides and fertilizers. In some instances, the equipment lists a code number of pesticide or fertilizer and this can be researched at the PMRA to give a trade name and chemical composition.

Prior to World War II, insecticides were limited to several arsenicals, petroleum oils, nicotine, pyrethrum, rotenone, sulfur, hydrogen cyanide gas, and cryolite. Pyrethrum is a natural pesticide made from the dried flower heads of members of the chrysanthemum family. It has been used for centuries as an insecticide and continues to be used today. World War II opened the era of chemical control, with the introduction of synthetic organic insecticides the first of which was DDT [4]. Table 1 offers a brief timeline to help identify possible chemicals present in artifacts of a determined age.

The Stockholm Convention agreement of 2001 on "Persistent Organic Pollutants" was tasked with identifying the most damaging chemicals. This agreement identified the "Dirty Dozen" of organic pollutants of which nine are pesticides. It is more than likely that residues of some exist in historic agricultural equipment.

Consideration must also be given not only to the artifacts, but to the variety of biocides which have been used in the past by museums and collectors to control infestation problems. Undoubtedly DDT is present, but also PDB, cyanide, arsenic, mercury and benzene hexachloride. Boric acid, a pesticide and fungicide, is commonly used today in the construction industry and the pest control industry where it is applied in dust or powder form to likely habitats in buildings.

Pharmaceuticals can be present in collections of medical technology. Most of these substances have lost their potency, but a few will have crystallized to leave more potent concentrated residues. Reactivating them in order to solubilise and remove them can be problematic. Before any intervention, the contents should be researched using lists of historic chemical terminology [5]; and a Merck Index or a pharmacopeia of the appropriate age, which will give fairly accurate chemical information about toxicity and disposal information.

Printing inks, photographic developing chemicals: photographic solutions contain a whole range of acids and bases, some quite concentrated. Ammonia was also used as a processor. In addition, vaporized mercury was used to process the silver plate so mercury residues may be present. Printing inks can include toxic pigments such as lead, cadmium, chromates of zinc strontium and lead; cobalt, manganese and mercury.

Refrigerants are present in a number of artifacts in a collection of technological history: rail coaches, aircraft, automobiles, buses, streetcars and some early computers; as well as domestic refrigerators. From 1902 to 1930, the refrigerants most commonly used, were ammonia, sulphur dioxide, carbon dioxide and methyl chloride. These were used in centrifugal compressor technology, invented in 1902. By 1923, most refrigerators were using SO2, methyl chloride and ammonia. [6] By the 1950s, mass production of refrigerators increased the prevalence of these products and therefore their threat to health and the environment. All of these are hazardous, but from a museum point of view, most have likely dissipated or leaked over time. Since the 1930s, CFCs, trade-name Freon, was the most commonly used. More environmentally friendly HFCs were introduced in 1990, following the Clean Air Act Amendments in the US.

Author

Sue Warren
Conservator
Canada Science and Technology Museum
swarren@technomuses.ca

Finalizing comments

Diversity, commonality and connectivity

Moderator speech by George Prytulak

Before this conference, I suspect a lot of us thought of industrial conservation as a field devoted mainly to industrial artefacts like transportation vehicles and large machinery. But as we've learned in the talks of this conference, it also encompasses the *objects* that were mass-produced by manufacturing machinery. And as if that weren't enough, now I find it also refers to large-scale, modern industrial processes like mass deacidification, cold storage, the application of flame retardants to textiles and digital documentation and copying.

Ironically, as our first key speaker pointed out, industry has created many of the problems that we face and industry is now coming back to help us solve these problems. You could say things have come full circle, but it would probably be more accurate to describe it as an upward (or perhaps downward) spiral. Every new solution that industry bestows upon us seems to create more problems for the future, and it is virtually certain that industry will come to rescue us from all the imperfect advances in technology and materials that are in store. And on and on it goes.

When you look over the program, the scope of our work really is absolutely breath-taking. It ranges from huge industrial sites like the mines and buildings at St.Just in Cornwall, the pulp and paper mill at Klevfos, Norway, the open air museum at Den Gamle By and the Carlsberg brewery to individual buildings containing machinery, like the Zollern Colliery in Dortmund, Germany. It encompasses large individual artefacts, like the vehicles at the Science Museum in London¸ the *SS Great Britain* in Bristol and the *USS Monitor* in Newport News, Virginia, all of which contain a large number of individual machines and mechanical devices. The scope extends even further to include small individual items like Swiss watches, canvas paintings, phonograph records and players, paper documents, woodworking tools and celluloid films. Physically, these individual items are small compared to the large outdoor objects and sites, but what they lack in size they make up for in sheer numbers. And make no mistake: dealing with thousands of deteriorating wrist watches, tons of paper or truckloads of film is every bit as challenging as dealing with a corroding iron bridge, and I would argue, no less important. Truly it's a measure of our character that we face these Herculean tasks on a daily basis, and it's incredible that we carry on, unbowed and undefeated, if not always openly optimistic. This conference could well have been called "Incredible Industrial Conservators."

The diversity of materials we deal with in this field is no less incredible than the scope. We must deal with traditional materials like wood, leather, metals, glass and textiles. But we also must learn to handle the new materials like polymers that have appeared during the past fifty years, as we saw in quite a number of papers. In this case, the real challenge isn't so much size as it is complexity and magnitude. Again, what binds us together is our fortitude and in facing these immense challenges. And it is precisely this diversity that makes us strong. Between us, we can handle almost anything.

Surprisingly, in spite of all this diversity, there is also incredible commonality in our field. As we saw in a number of papers, similar materials can and do emerge in some of the most unexpected places. Cellulose nitrate is a good example. Most people wouldn't think the finish on a 1930s automobile, a reel of film, a doll and an early sound recording would have anything in common, yet they were all made from the same material and they all face similar forces of deterioration and destruction. Another example is woven canvas: a painted sheet of canvas under tension has a lot in common with the painted fabric stretched over the frame of an early airplane, and many aircraft textiles were also treated with flame retardant chemicals. Who would expect a colliery engine house to have stained glass windows? And who would have dreamed 50 years ago that the original vellum and paper plans for the construction of the *USS Monitor* would prove so valuable in the later preservation of this underwater archaeological artefact?

Regrettably, there isn't a lot of interaction between the many specialized fields of conservation, and I think this is a serious problem that needs to be addressed. One vital thing is lacking, and that is connectivity. Too many of us work in hermetically sealed bubbles, with little interest in what the others are doing in different disciplines. Many of us – and I include myself here – have a blinkered view at times, either because we are over-specialized or we aren't interested in a particular material or type of Artifact. In general, Paper labs have little interest in conserving paint brochures; no one in fine arts specializes in how to consolidate the painted decoration on a 19th century threshing machine; and very few textiles conservators have any desire to deal with aircraft fabric or automobile upholstery. I would love to see this change. That's why I believe conferences like Big Stuff and Incredible Industry, with eclectic programs and a diverse mix of conservators are on the right track. I think we should stop thinking of ourselves as specialists and start thinking more of ourselves as broadminded conservators capable of tackling virtually any problem and staying open to new interests, influences and perspectives.

We are all too isolated. We need more interaction and greater connectivity. All of us have incredible potential; all of us have unique skills and talents and perspectives and imaginations. Together we can do almost anything.

The real value of conferences like this isn't finding specifik solutions to our problems; it is more about gaining a new awareness and appreciation of the work that is being done in our field and about gaining a new respect for our colleagues, wherever they may be.

Moderator

George Prytulak
Conservator of Industrial Artifacts
Canadian Conservation Institute
1030 Innes Road
Ottawa, Ontario, Canada K1A 0M5
George.Prytulak@pch.gc.ca

Short statements from the panel

Panel participants

George Prytulak, Industrial Conservator, Canada
Winnie Odder, Organizing Committee, Denmark
Tannar Ruuben, Conservator, Finland
Yvonne Shashoua, Conservation Scientist, Denmark
Jeremy Hutchings, Conservator, Norway

Winnie Odder:

We have surely all found food for contemplation and new understanding of complexities during this conference. To mention one thing that I particularly liked I would mention the approach put forward by Jacob Bjerring-Hansen who urged us to change the auto-focus that we carry from our various educations and institutions which may be more or less broad minded – to get away from only focusing on the unique and beautiful that we are all so attracted to. We will need to acknowledge the fact that we are here as professionals because we like our job. A completely relevant outset and I think we all – with time – will grow to like the ugliness and the anonymity of the "masses of objects" coming into our working life with the objects of industrialism, and that we will learn to appreciate their profound difference from our tradition work field.

During this conference I have been strengthened in my fundamental approach to our profession: the importance for us to regularly pose ourselves and colleagues the basic questions: why are we doing this? What do we want to achieve by our actions? Will we reach the desired goal by this action? And not least: how can we disseminate all the knowledge and joy we receive by working with this to others?
A number of lectures brought about the necessity of reaching out for our clients, the public – to make them participate on this journey into preserving the history that belongs to all of us.

We as conservators will never be workless – but what we as individuals can accommodate is very limited. But can we reach a broad variety of people out there to take care of our common cultural heritage, and by doing so we will have achieved something both lasting and valuable, and of a much grander scale and scope than what we as individual professionals can ever reach.

Tannar Ruuben:

With my background as a physicist and a paintings conservator I first assumed that there would be very little for me I can relate to in this conference; but contrary to this I have very much enjoyed being immersed into this broad variety of subjects that all in one way or the other connects to what I do on a daily basis. In my work as a teacher in paintings conservation I feel implied, after attending this conference, to make a comparison between a miniature and a ceiling painting; because what strikes me mostly is the really, really large scale we are talking about when we are talking about industrial heritage.

During the days I have noticed the high emphasize on documentation: to leave a permanent memory of what we cannot really preserve. We have a huge amount of documentation already to take care of, and besides this, we ourselves generate more and more documentation (to be taken care of) on top of the work we do. We as profession solve problems and we also create new ones thereby. We are not always closing the case, but opening new ones.

Considering plastics as part of Modern Art makes me reflect on our role in this field: we cannot preserve plastics really, only prolong it's life, and I wish to propose a campaign in art schools and academies making artist aware of the fact that the materials what they are dealing with are in many cases highly degradable, in contrast to their own belief of creating something for prosperity. They often consider their works very durable – and then they are gone in few years. This is a great opportunity for cooperation and spreading of knowledge in institutions teaching both art and conservation.

I found a very valuable piece of information for thinking in the presentation from Robert Turner, regarding The Ship and the Bridge. We often discuss reversibility and re-treatability; even while treating the object we consider how quickly and how easily we may reverse the treatment. It is also important for us to think that the treatment we do should last, be something durable, that we should not have to treat the object again soon after.

Yvonne Shashoua:

When I arrived at the conference Monday morning I was met by the stunning news that the media had taking up on the conference theme, and that now it was all over town that conservators fought for the life of Barbie. How could Barbie and Incredible Industry come together?

I have attended a number of big scale industrial conferences, and enjoyed case-studies on preserving coalmines, ship wharfs etc. But I have never before taken part in a conference dedicated to conservation of industrial heritage, where the focus has been on materials including plastics and their industrial application as a result of mass production. It has been highly interesting to learn about watches, coatings and other things that turned out to be plastics despite a different look.

As a comment to Tanner Ruuben on teaching in Art Schools about how plastics deteriorates I can compliment with a personal experience; as I have learned that The Royal Danish Academy of Fine Arts, Schools of Visual Arts does not want this included in the curriculum, as it is considered a barrier to students creativity. I hope this will be a matter of debate in the future.

I very much enjoyed the two extremes of approaches to conservation treatment:

Should we do nothing? Should we treasure the original surface and then do as little as possible to preserve it or should we try to restore it, to achieve appearance that the public, our consumers, expect to see it and take pride in seeing a nice shiny coating?

Also: should we store film and books in cold storage or mass-deacitify? These interesting discussions of risk analyse and costs are not often heard.

The success of this conference I feel is the diversity of materials and approaches. I personally have learnt from objects and case stories, which I never would have imagined to find interesting, as they are not in my area.

Jeremy Hutchings:

I came here with the intension to see how to take things forward, discover where there are gaps and room for future research. Research into lubricants and other ephemeral components are obvious candidates.

Within the field of commercial antique dealing the current trend in taste appears to more towards retaining original finishes, which we must take as glad tidings for the preservation of original surfaces.

Research into traditional maintenance methods has for a long time, been focused upon by The National Trust. I feel this is one issue from this conference that is yet to be fully addressed. For example, the ethical continuation of in-use maintenance regimes for industrial objects - both to maintain the objects themselves and to continue the knowledge and skills that this practice requires.

I wonder: Can comparison be made between Industrial heritage and build heritage still in use? Is there room in industrial heritage for the concept of the honest repair, alteration and reuse? These are concepts that are firmly entrenched in the build heritage.

Finally health and safety issues need further focus in developing policies and procedures both in terms of the safety of the objects, the people working with them and those involved in operating them.

Remarks from the floor and panel (abbreviated)

Robert Turner: I have on several occasions being called as conservator consultant involved in commissioning new works of art; a position where artist are wonderfully flexible, and where we as specialist are able to offer an incentive to artists to do better, material wise.

Yvonne Shashoua: I hope to start a project at the National Gallery in Copenhagen; where artists will be able to receive professional consultancy in their creational process. They often lack knowledge and don't know where to turn for it, as manufacturer's data sheets are often incomprehensible and they are not taught the basics of plastics and other modern materials during their education.

Natalie Jacqueminet: We are discussing whether we need more interaction between conservators. I see a lot of people attending this conference with little or no background in industrial conservation; but indeed with a keen interest, so I do think conservators are ready to interact, amongst our fellow colleagues.
I think the big issue of needed interactivities for our profession regards other specialised fields of knowledge. We should be more visible, getting people interested in what we do, make a presentation of conservation to students of ethnology, history, engineering, chemistry. We need partners from other areas of knowledge; we cannot do it all ourselves.

Winnie Odder: A very limited percentage of the industrial heritage is in the hands of museums – the rest is out there – and that has to be dealt with as well. We do indeed need co-partners to solve this grand task.
As Cornelius Götz pointed out today: one reason for making a heritage site out of an old industrial plant could well be the saving of money for the needed environmental clean-up!
We will have to be brave enough to act. We do have a multitude of solutions to choose from each day, and not only lean on the "safe" position of documenting ourselves passed difficult solution. We should not renounce from acting in utter fear of doing something wrong. Life is going on and we are all part of it.

Karen Stemann Pedersen: During the many different presentations we have heard a lot about conservation ethics: How to stabilizing an object and still making it worth while looking at; the decision making process, the collaboration between partners, the different goals of action. I think this proves we are NOT in a bobble; we have actually been able to present to each other a great variety of issues, and have shared in very broad fields the status of today's accomplishments.
We are just like every body else children of our age, and we will inevitably make marks today that will become problems for the coming generations.

Winnie Odder: A lot of the things we work with are related to the past, but many of our actions have an important impact on what is going to happen in the future. All the many energy consuming systems that we device to protect the past might not be very relevant in the long term, foreseeing a situation in the world that might be very different from today.
I think we should focus on more research into low energy consumption systems better suited for the world of tomorrow. And we should bear in mind, that with all our nice theories and well made research on this and that, we shouldn't go out in the world to implement something that in the end might not be durable but rather on the contrary find something that tends to be energy saving.

Eric Nordgren: Talking about the need for research into new and old coatings, lubricants and sealing's
I wonder if anyone is aware of any current research projects on that?
If there is anything approaching a Historical Database regarding use of materials on industrial machinery?

George Prytulak: Not to my knowledge: the chemistry involved in analysing historical samples may just be too complex, and accurately dating a certain product may quickly turn into a blind path I imagine

In terms of developing new products, I am concerned that we do not duplicate the research taking place in industry today; their active research, backed with million-budgets could be another reason for the proposed connectivity to this field.

Eric Nordgren: We made some attempt to comparison between old samples and current scientific samples. There were elements that were consistent but others were missing, maybe due to deterioration.

Oil companies do often have archives, some though with a low priority in use and handling. But they do still exist, and their current research could be of potential value for us.

Jeremy Hutchings: Trying to find the right kind of lubricant is a jungle; even to get to the point of asking for the right thing when looking for information is sometimes very difficult, especially when we try to find a modern equivalent products that can substitute those no longer in production.

We generally don't have the knowledge and the information needed to undertake a successful search.

George Brock-Nannestad: There is in fact a lot of literature to be had. From the 1860es and onwards there is a huge amount of information to be found in specialist's journals. The majority of recipes were of course trade secrets; but an awful lot of experimenting took place in these early days, and much of this is actually reported. The key problem is that solutions are not off the shelves anymore; and you will have yourselves to experience with the information you find.

George Prytulak: I strongly recommend everyone to use the amazing tool of our time: The Internet Archive.

This contains more than 500.000 technical books and trade publications, which are word searchable, and in the public domain. All the material can be downloaded for free.

Phenomenal amount of information is now becoming available online.

This treasure hub – and Flickr, the digital photo-sharing web site that I mentioned in my presentation – is truly a giant leap forward for those of us searching for historical documents.

Index of Athors

Acknowledgements

The conference is sponsored by

NATIONALMUSEET

The National Museum of Denmark

The Royal Danish Academy of Fine Arts,
School of Conservation

ARBEJDERMUSEET
& ARBEJDERBEVÆGELSENS BIBLIOTEK OG ARKIV
The Worker´s Museum

Nordjyllands
Historiske Museum

Knud Højgaards Fond

KUL
TUR
ARV

The Heritage Agency of Denmark

norden
Nordic Culture Point

norden
Nordic Culture Fund

Organising committee

Andersen, Vivi, Nordic Association of Conservators, Denmark
Borchersen, Karen, Nordic Association of Conservators, Denmark
Knudsen, Lise Ræder, Konserveringscentret i Vejle, Denmark
Nygaard, Signe, National Museum of Denmark
Odder, Winnie, Nordic Association of Conservators, Denmark
Pedersen, Nanna Bjerregaard, Nordic Association of Conservators, Denmark
Rasmussen, Michael Højlund, Nordic Association of Conservators, Denmark
Ringgaard, Maj, Nordic Association of Conservators, Denmark
Ritterband, Susan, Nordic Association of Conservators, Denmark

Scientific committee

Hermerén, Karin, Kulturmagasinet, Helsingborg, Sweden
Hutchings, Jeremy, University of Oslo, Norway
Newey, Hazel, Science Museum. UK
Ruuben, Tannar Metropolia University of Applied Sciences, Finland
Ryhl-Svendsen, Morten, National Museum of Denmark
Shashoua, Yvonne, National Museum of Denmark

Conference assistants

Gelting, Unn, School of Conservation, Denmark
Gulløv, Mads, The Workers Museum
Henriksen, Henriette Vinther, School of Conservation, Denmark
Ipsen, Camilla, School of Conservation, Denmark
Mogensen, Pernille Holm, School of Conservation, Denmark
Sandahl ,Maja Dissing Forsom, School of Conservation, Denmark
Sonne-Hansen, Katja, School of Conservation, Denmark
Spile, Sanne, School of Conservation, Denmark
Steinrud, Micka, School of Conservation, Denmark
Taarnskov, Bodil, National Museum of Denmark

NATIONALMUSEET

SIGILLUM REGIÆ ACADEMIÆ PICTOR·SCULPTOR·ARCHITECTORUMQVE

ISBN 987-87-990583-2-7