

Corrosion of cans in collections: the CANS project

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Abstract – This paper presents the results of the CANS project (Conservation of cAns in collectioNS), an interdisciplinary research aiming at proposing conservation strategies for full cans, still retaining their original contents, in museums and collections. The paper includes the outcomes of the condition report carried out on 150 cans from 5 Swiss collections, the correlation between state of conservation, content and age of the can and the extensive characterization of the cans' materials for a better understanding of the corrosion mechanisms.

I. INTRODUCTION

Cultural heritage consists in artworks (painting, sculpture...) but also in usual and everyday objects (tools, machines...) sometimes unexpected, such as food preserves. Cans are represented in several museum collections as witness to different time periods and significances.

A. The CANS project

This paper presents the outcomes of the CANS project, Conservation of cAns project, an interdisciplinary research that lasted 3 years, funded by the Swiss National Science Foundation. The CANS project was conceived to answer to a precise request coming from museums having full cans in their collections and no guidelines or protocols to face the problems related to the conservation of these complex objects. In fact, the conservation of cans in collections is particularly problematic as severe corrosion phenomena occur due to interaction with environment as well as between the organic content and the metallic container.

This interdisciplinary project is based on gathering the results of a study on the significance of cans in collections, a research on the long term corrosion of cans and degradation of the content and the proposal of methodologies of conservation and restoration of cans in museums. It involved 10 people from 4 different institutions, including a PhD student:

- HE-Arc CR, project leader, experts of conservation and restoration

- MEN, experts of cultural values and collections
- EPLF, TIC, experts of corrosion and surface analysis
- HES-SO Valais, ITV, experts of food packaging and food degradation and ISI, experts of mechanical engineering

The goal of the project was to define conservation solutions for cans still retaining their original content, like the ones illustrated in Figure 1 as example. The project was built on 3 research axes:

- The human sciences on one side, aiming at defining the cultural values linked to cans or their constitutive parts (label, container, content) and at locating the museums having cans in their collections.

- The hard sciences on the other side, aiming at studying the long term corrosion mechanisms of tinplate in contact with food and the degradation of food contents.

- In the middle, linking the other parts, the conservation-restoration strategies, aiming at proposing adapted protocols for the conservation of these composite objects in their integrity.



Fig. 1. Example of cans belonging to Swiss collections.

B. Cans technology

To historically locate the cans, a timeline is illustrated in Figure 2. Nicolas Appert is considered as the father of cans, since he discovered in 1795, in France, a method for conserving the food for long periods by boiling it in hermetically sealed glass bottles. Appert however never used metallic containers for the conservation of food. It is the Englishman Peter Durand who patented in 1810 the tin-plated iron canisters as a food containers. In 1812, Bryan Donkin and John Hall opened the first can factory in Great Britain. The can industry underwent many important transformations since 1812 to nowadays. The most representative are the invention of the double seaming machine in 1898 allowing to close the cans by crimping the metals, without soldering, and the introduction of the electrolytic process for the tinning in the 1930's [1].

A can is a composite object, composed by:

- an external label, which can be made of paper or directly printed or painted on the container
- the food content
- the metallic container that in turn is a composite material composed by a mild steel base covered on both sides by tin and often covered by a polymeric coating to isolate the metal from the food

Each part of the can is important and the can should be conserved in its integrity.

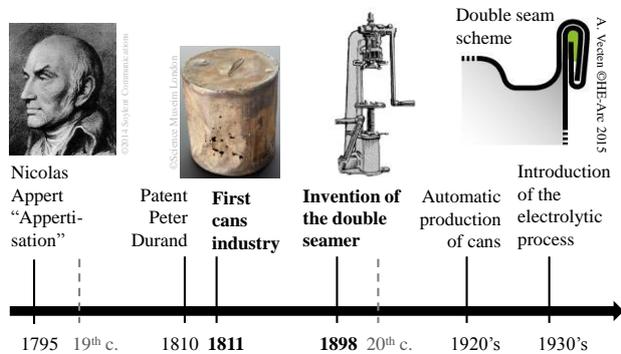


Fig.2. Timeline of cans technology evolution.

C. Cans in museums

In addition to their materiality, cans own important cultural values like, historical, social, artistic, symbolic and research value.

For this reason cans are present in different kind of museums:

- museums dedicated to food, nutrition or food industry
- museums dedicated to every day's life
- industrial heritage
- collections of objects coming from Arctic and Antarctic expeditions

- cans can be used as tools, music instruments or toys (distorted cans)
- museums of contemporary art, where cans are often used as symbol

The difficulties of conserving cans in collections are linked to the fact that a can is produced to last from 1 to 5 years (shelf life for human consumption), while in collections there are cans that are up to 200 years old. The materials and in particular the food are not conceived to last for a so long period of time.

For that reason, cans in collections present several different problems like corrosion of the container due to the interaction with the content or non-adapted environmental conditions, swelling, bursting, mold development and biological risk.

Before the CANS project no systematic studies were carried out on cans in collections and there were no adapted protocols or conservation methodologies for full cans in museums.

In order to understand the problems of cans in museums and to develop an adequate protocol, the research started by a literature survey. The few articles in the literature concerning cans refers to objects recovered in the poles, left from explorers expeditions of the 19th and 20th century [2, 3]. The study carried out on those cans are mainly dedicated to the food analysis to verify the presence of lead or botulism toxins or to the authenticity of the food. Some restoration works on cans have been carried out and published by the Antarctic Heritage Trust [4, 5]. Foods other than cans have been studied as part of museum collections, like chocolate [6] or fruit skins [7]. The industrial literature on food packaging widely studied the problem of cans corrosion and interaction with food [8, 9]. However, these studies are limited to the shelf life of the cans and never exceeds 15 years from cans production.

II. CONDITION REPORT

The first step of the CANS project was then dedicated to verify the state of conservation of cans in collections.

For that reason a condition report was carried out on around 150 cans belonging to 5 different collections, with the aim of identify the main degradation problems and correlate the observed degradations with the age of the can and its content [10].

Surveys were conducted on the following collections:

- The Alimenterium in Vevey (Canton of Vaud), opened in 1985. It is the first museum in the world exclusively dedicated to food and nutrition. The museum is managed by the Nestlé Foundation. In addition to permanent and temporary exhibitions about contemporary and ancient eating habits, activities such as workshops and tasting sessions are periodically organized. Cans, either full or empty, are part of both permanent and temporary exhibitions. Around 50 cans were analyzed in

this collection dating from the 1890's to nowadays.

- The municipal Museum Burghalde in Lenzburg (Canton of Aargau) received in 2010 the archives of the Hero Company, including cans with and without their original content. Hero has been an important Swiss brand, founded in Lenzburg in 1886 and producing food goods. Some of the Hero archives were exhibited from 2011 to 2013 at the Museum Burghalde, during the exhibition entitled "Hero, seit 1886 in aller Munde" (Hero, from 1886 on everyone's lips). Around 65 cans were analyzed in this collection dating from the 1940's to nowadays, except one cans produced in 1886 (first day of cans' production by Hero in Lenzburg).

- The Ortsmuseum in Küsnacht (Canton of Zurich) is a small local museum where a historical store ("Tante Emma-Laden"), has been recreated. The store displays products commonly sold in the 1950's, including some concentrated milk cans. Around 15 cans were analyzed in this collection dating probably from the 1970s.

- The HAM foundation in Thun (Canton of Bern) is the museum of the Swiss Army. Within military equipment there are obviously also food ration, including cans. Around 5 cans were analyzed in this collection dating probably from the 1990's.

- The Historical Museum of Bern (Canton of Bern) is a museum dedicated to history. In the collection of this museum there is a lot of food and food packaging dating from the 1990's. There is no trace of information regarding the original exhibition for which these objects were acquired by the museum. Around 10 cans were analyzed in this collection dating probably from the 1990s.

Storage conditions are similar in all the five museums with no temperature and humidity control at the moment of the survey.

In Lenzburg and Küsnacht, cans are stored on wooden shelves. At the Alimentarium, BHM and HAM foundation they are kept in closed or open plastic boxes.

Some of them are permanently displayed in non-controlled showcases.

The cans observed in this survey differ for age, content, shape and dimension.

Concerning the age, the cans date from the mid of the 19th century to nowadays. In fact, many museums are still collecting cans and new or really recent cans are part of the collection.

Concerning the dimensions, the cans of the Swiss collections are situated in these ranges:

- Volume: from 0.12 dm³ to 3.3 dm³
- Weight: from 76 g to 3 kg
- Height: from 28 mm to 253 mm
- Diameter: from 52 mm to 156.5 mm

Most of the cans have the classic cylindrical shape, however, rectangular or oval shapes can be found, in particular for fish or meat products (pilchards, corned

beef, ...). Since cans have been produced by hand for decades, it is not unusual to find cans in collections with really peculiar shapes like truncated cone.

Concerning the content, in Table 1 are reported the contents of the 150 observed cans.

Most of the cans contain fruit, vegetables or prepared dishes. The really high number of milk-based products is linked to the production of typical Swiss products. For the same reason, the number of cans containing fish is really low.

Table 1. Content of the 150 cans observed during the condition report.

Content	Quantity (approximate number of cans)
Vegetables	35
Fruits	25
Meat	<10
Fish	<10
Prepared dishes	25
Dessert	5
Milk	25
Other	15

The main degradation phenomena observed are the following:

- Corrosion (external and/or internal)
- Swelling
- Bursting
- Perforation with or without leakages

In Table 2 are reported the amounts of cans presenting each kind of different degradation phenomena.

The 7% of cans presenting no sign of corrosion are mainly represented by new cans, recently included in the collections.

Even if the number of cans presenting corrosion on the double seam is extremely high (85%), this form of corrosion is not particularly problematic because it is due to a combination of environmental conditions and to the fact that the tin layer is thinner in this point of the container.

The number of cans presenting severe internal corrosion phenomena is quite high, as can be deduced by the number of cans presenting:

- swelling (45%), as a consequence of gas (H₂) development inside the can due to the interaction between the container and the organic content
- perforation (30%) due an advance degree of internal corrosion, as can be observed in Figure 3
- leakages (45%), due to perforation or excessive internal pressure of the gas developed inside the can

Table 2. Degradations observed on cans during the condition report

Degradation	Quantity (%)
No signs of corrosion	7%
Corrosion of the top, of the bottom or both	75%
Corrosion of at least one of the double seams	80%
Corrosion of the cylinder	30%
Perforation	30%
Leakage	45%
Swelling	45%

When the gas inside the can cannot be evacuated, the container could arrive to burst, with damaging consequences for the can itself and for the other objects stored or exposed nearby (Figure 4).



Fig. 3. Can presenting perforations due to internal corrosion



Fig. 4. Can presenting signs of swelling and bursting

Perforations and leakages can also damage the labels of the cans, not only due to unaesthetic stains of spilled content, but also because of the embrittlement of the paper or mold growth.

During the condition report, it was observed that the degree of degradation of the can does not always correspond to its age. In fact, there are cans in the collections that are still in good state of conservation even after few decades from their production and others that are completely degraded just few years after the expiring date. This phenomenon is linked to different factors including:

- Environmental conditions during the cans storage. In fact, the higher is the temperature, the faster is the internal corrosion.

- Nature of the content. Some food are particularly aggressive for the tinfoil and can accelerate the corrosion rate. Between them the most dangerous are nitrates, anthocyanins and sulfur compounds. The pH, and in particular the presence of complexing organic acids, also play a role in the corrosion of the container.

- The quality of the materials composing the can.

Concerning the last point, it is worth mentioning that the thickness of both tinfoil and tin coating decreases considerably respect to the 19th century. The analysis in the 1930's of a can produced in 1824 revealed a thickness of the base steel of 0.47 μm and a thickness of the tin coating of 11.55 μm [11]. Nowadays, the base steel of commercial cans can vary from 0.12 to 0.30 μm and the tin coating reach maximum 1.35 μm [12].

With a tin coating layer that is 10 times thinner respect to 200 years ago it is easily explained the shorter lifetime of the cans produced in the recent years.

III. MATERIALS CHARACTERIZATION

An extensive characterization of the tinfoil was carried out using a multi-analytical approach with the aim of understanding the influence of the materials characteristics on the corrosion mechanisms [13]. Surface analysis (SEM-EDX, Auger Electron Spectroscopy, 3D white light interferometry, XRF) and electrochemical techniques were used for this purpose.

In particular, 4 parameters resulted to be especially critic for the determination of the lifetime of the can:

- tin coating thickness
- roughness of the surface (both base steel and tinfoil surface)
- porosity of the tin layer
- coverage of the tin-iron alloy formed at the interface between the tin coating and the base steel

The tin coating thickness can be determined by means of electrochemical techniques, as defined by the standards [14, 15], or using Auger Electron sputtering. The two methods were compared during this study and

the results obtained are in good agreement [13].

The roughness of the tinplate was evaluated on commercial tinplate samples (D1.4/1.4, D2.8/2.8, D5.6/2.8, D8.4/2.8, D11.2/2.8) as received and after the removal of the tin coating. An example is reported in Figure 5, in which is possible to observe that the striae of the base steel are still partially visible through the tin coating. The effect of the roughness of the base steel is also observable in Figure 6, showing the image obtained at the SEM of a tinplate sample with a thin layer of tin (D2.8/2.8), the smallest allowed by the law for the production of cans for food destined to human consumption.

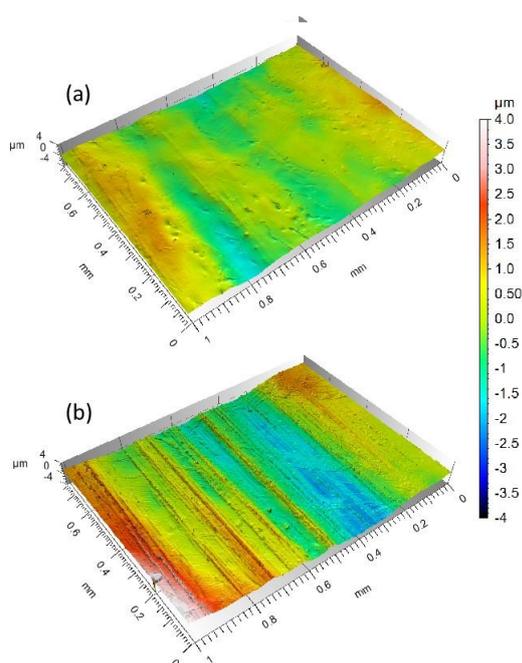


Fig. 5. 3D white light interferometry of the surface of the tinplate (D8.4/2.8) before (a) and after (b) the removal of the tin coating.

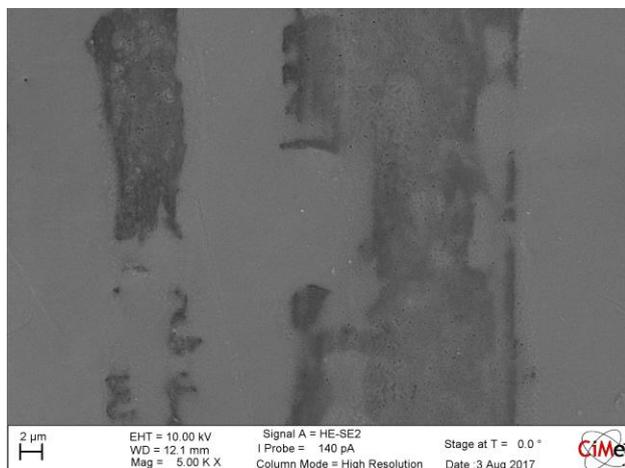


Fig. 6. SEM image surface of the tinplate (D 2.8/2.8) as received.

The porosity of the tin coating was first observed by SEM and then measured using the electrochemical method called Iron Exposed Value (IEV) [16]. Chronoamperometry is performed on a tinplate coupon of 0.7854 cm^2 at 1.3 V vs SCE in a solution at pH 10 of Na_2CO_3 [0.2] NaHCO_3 [0.2] NaCl [0.005] pH 10. The current value after 3 minutes of polarization give the value of the exposed iron.

According to the production process, period and geographical location, the tinplate can present few isolated pores or an extended porosity that can, in the worst cases, exposes also the underlying tin-iron alloy and consequently accelerate the corrosion rate.

The tin-iron alloy, which composition is FeSn_2 , is an interfacial layer formed between the tin coating and the base steel by heat treatment after the electrolytic tinning. It ensures good adhesion of the tin layer on the steel substrate and it is also supposed to be chemically inert and thus to impart further corrosion protection.

SEM analysis of the alloy layer exposed after Auger Electron sputtering (Figure 7) showed that the coverage of this phase is not homogeneous and that the base steel can be directly exposed, between the needle-like structure of the FeSn_2 , to the aggressive environment.

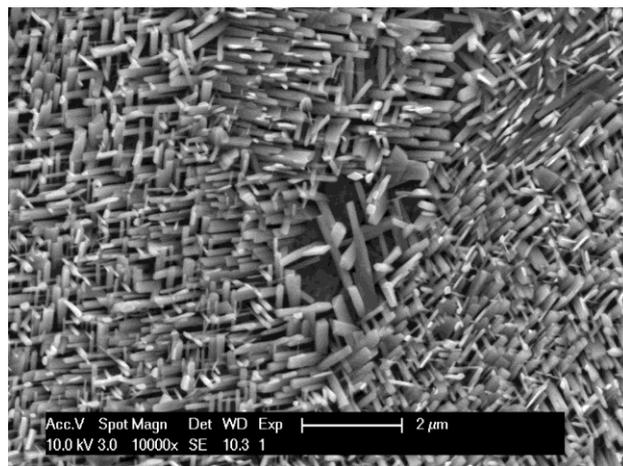


Fig. 7. SEM image of the FeSn_2 alloy.

Most of the cans produced nowadays, are internally protected by a lacquer or a polymeric coating. This layer allows to furtherly separate the food and the container using an organic barrier instead of a thick layer of pure tin.

On the short term (shelf life), this protective layer is really efficient, but on the long term (decades), it reveals to be clearly less efficient than a thick tin coating. Examples can be observed in Figure 8, where it is shown how the failure of the polymeric coating, in particular the one protecting the soldering can have devastating consequences on the label due to a massive leakage of the content.



IV. CONCLUSIONS

The degradation of cans in museums' collections depends on many different factors:

- Environmental conditions
- Content
- Can's materials characteristics

The last parameter is the most critical, because corrosion of cans is highly dependent on real tinplate structure (Sn thickness, porosity, ...).

However, the tinplate structure is extremely variable depending on production process, production periods, geographical origin and costs of the materials. It is not always possible to define the structure of the tinplate in a univocal way.

For this reason, a precise characterization of tinplate material structure is necessary for the prediction of cans lifetime

To propose adapted conservation solutions for cans in collections, the knowledge of all the above mentioned factors is necessary.

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