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The conservation of polymers used in horology since the end of the 19th century. A multidisciplinary approach.

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Abstract:

Since the nineteenth century polymers have slowly been introduced into horology. From the 1960's almost all parts of timepieces use these new materials. Integration of plastic means conservators face new problems. This raises issues about choices to make before any intervention and about the intervention methods to use.

The University of Applied Sciences of Western Switzerland, located in the so-called "Watch Valley", has necessarily developed an interest in timepiece heritage and preservation. The university is currently engaged in a research project to understand better the impact of plastic integration in the horology field and to develop techniques of polymer conservation. This article presents some results of the multidisciplinary project involving conservators, historians, ethnologists and chemists.

The research is based on historical and ethnographic enquiries conducted in the Jura region industries and on the study of objects selected from the Musée international d'horlogerie MIH) of La Chaux-de-Fonds collections.

Results show how the introduction of plastic, a bottom-of-the-range material, brings a complete change in the industrial organization, socio-economic context and representations of watches and plastics. The technical part of the paper includes identification and conservation of plastics contained in the selected artifacts.

Key words: plastic, horology, timepieces, history, ethnology, conservation

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Introduction

More than an innovation, the use of plastics is a real revolution of the twentieth century. We speak of the "plastic age" as we do the "bronze age" (Marais 2005). Man looks at the world through plastic (glasses, lenses). He inserts it in his own body (prosthesis, implants). From birth to death plastics accompany us and become more and more intimate.

Plastics also constitute one of the major materials used in horology (Baillod 1971). However many people consider them as bottom-of-the-range materials. If metals are associated with luxury and durability, plastics evoke "cheap" and "disposable".

In the case of timepieces made of plastics, what should conservators in charge of preserving our heritage do? Must we and can we make these objects made of perishable materials last? These are the questions we attempted to answer by developing a research project in collaboration with the Musée international d'horlogerie of La Chaux-de-Fonds (MIH - international museum of timepieces), the Ecole d'ingénieurs et d'architectes (the college of engineering and architects) of Fribourg and the Institut d'ethnologie (ethnology institute) of the University of Neuchâtel.

The mission of conservators is to assure the preservation of heritage objects, from a material point of view, as well as their social and cultural context of manufacture and use. Strategies of preventive and curative interventions require a knowledge of the materials forming the objects, both on physical/chemical and historical points of view. This knowledge based on both the physical and human sciences is essential to justify conservators' work, propose adapted treatments and respect the objects' history, and their authenticity (Berducou 2001; Bergeon 1997; Duchein 1997; Oddos 1995).

Up until the twentieth century metal was the primary material used in timepiece production, therefore research and conservation care has mostly focused on this. Since the nineteenth century new materials, polymers, have gradually been introduced into the timepiece industry. Polymers were used as coatings, cover layers, wire insulation and electric coils, watch faces, cases, and as mechanical parts. Except for the balance, spiral and barrel, all the parts of a watch have now some plastic composition.

Integration of these modern materials leads to new problems conservators must face. The issues are about the choices to make before any intervention.

Decisions on the conservation of plastics used in horology require a better understanding of the context of introduction of these materials and their significance. Is the introduction of polymers a simple technical innovation, among many others in the history of horology? Or is it a real rupture in terms of history and culture?

Answering this question is even more urgent as people involved in timepiece industry with the experience of innovation of these materials are growing older and there is a possible risk of losing this specialist knowledge.

In addition, polymers used in horology since the end of the nineteenth century have never been systematically identified; consequently museum artifacts have not been documented accurately. The variety of chemical composition of polymers, in particular the numerous additives developed, makes their conservation or restoration even more difficult. These materials degrade fast and lack of information on their composition makes it difficult to propose treatments and slow down degradation. Identification of polymers is crucial to improving conservation techniques. In some cases, there is no other choice than to replace damaged plastic parts. Electric insulation parts must be replaced, for obvious safety reasons if objects are still working. The problem is that many parts in timepieces are actually regularly replaced as "maintenance". This runs the risk of losing the fundamental cultural dimension of the object and an essential part of their authenticity (Ducatel 1999; Hallam 1995).

The conservation of horology heritage constitutes a major cultural stake all around the world, particularly in Switzerland and the Jura region, which is the cradle of the timepiece industry. Institutions in charge of conserving this heritage are faced with the issue of polymers and their preservation. The MIH houses the most important timepiece collection in the world, a large number of pieces dating from 1870 to 1990 which are today threatened by polymer degradation. Conservators have more and more watches and clocks partially composed of polymers to take care of. The issue of treating polymers touches not only everyday timepieces, but also some exceptional artifacts for which conservation is a priority. The acquisition by the MIH in 2002 of the Vachey's monumental clock revived the problem of polymers conservation (Droz 2005).

Figure 1 Vachey's monumental clock © MIH

[insert A_Vuissoz Fig1 here]

Main objectives

This project is based on the study of a selection of objects from the MIH’s collection. The main objectives are to:

- Analyze the historical and cultural dimensions of the introduction of plastics into the timepiece industry of the Jura region;
- Identify polymers used in the selected objects;
- Characterize these polymers with respect to physical and chemical properties and degradation processes;
- Survey the knowledge of preventive and active conservation procedures;
- Assess the condition of these plastics parts and make a diagnosis, in order to propose appropriate conservation treatments.

As far as we know, to date no large study has been devoted to the study of polymers used in horology. By identifying the materials, conservators working on horology heritage will be able to use the knowledge of degradation processes and conservation of these materials.

This project is also original because of the multidisciplinary approach. It deals with anthropological research on polymers, through the eyes of historians and ethnologists as well as from the material point of view of conservators, necessary for preserving the meaning of artefacts..

Organisation of the project

For the purposes of this research ten pieces from the MIH were selected to illustrate the three primary uses of polymers in timepiece manufacture, which is: solid/external cases, electrical insulation (ie cables, insulation plates, plugs and isolation of coils), and glass replacement.

In order to represent a large selection of plastic conservation issues, according to period and use of the objects, the following timepieces were selected (chronologically sorted):

- Favre electrical clock (end of nineteenth century);
- Vachey’s monumental clock (manufactured between 1938 and 1968);
- Thorens alarm clock (1940-1950s);
- Omega watch (1950s);
- Oscilloquartz quartz clock (1950s);
- Smiths timer (1960s);
- Secticon clock (1960s);
- Junghans alarm clock (1960s);
- Favag electrical clock (1960s);
- Swatch watch (1990s).

Selected objects also represent various types of damage due to their use (worn, transported, manipulated, subjected to particular environments). They include the everyday (kitchen timer, alarm clocks, Swatch watch) to the more prestigious (Omega watch) or unique (Favag, Oscilloquartz and Vachey clocks) timepieces.

Figure 2 Part of the objects selection. From left to right: red Secticon clock, green Smiths timer, white Thorens alarm clock, Omega watch, orange Junghans alarm clock, and Swatch watch © HEAA Arc AVU/TSC
[insert A_Vuissoz Fig2 here]

The study is based on a collaboration of researchers from four institutions:

Haute école d'arts appliqués Arc (HEAA Arc) of La Chaux-de-Fonds (University of Applied Sciences of Western Switzerland):

Cécile Aguillaume, historian; Julita Beck, chemist; Pierre-Yves Châtelain, historian; Nathalie Ducatel, conservator, project supervisor; Agnès Gelbert Miermon, ethnologist, archaeologist, coordinator of research within the institution; Tobias Schenkel, horologer, conservator; Annick Vuissoz, conservator, project leader.

Ecole d'ingénieurs et d'architectes de Fribourg (College of Engineering and Architecture of Fribourg):

Jean-Nicolas Aebischer, chemist; Vincent Adamo, chemist; Gaëlle Théodoloz, chemist.

Musée international d'horlogerie de La Chaux-de-Fonds (MIH) (International museum of timepieces):

Ludwig Oechslin, curator and director; Jean-Michel Piguet, associate curator.

Institut d'ethnologie of the University of Neuchâtel (Ethnology institute):

Christina Akré, ethnologist; Jacques Chapatte, ethnology student; Philippe Geslin, ethnologist; Denise Wenger, ethnology student.

The project contains a technical and a humanities section. The humanities section is dedicated to the historical and ethnologic study of the introduction of polymers into the timepiece industry and results of this section will be presented first.

The technical section is about chemistry and conservation. It is still ongoing. Preliminary results are presented in the second part of the paper.

The introduction of plastics in horology: historical and ethnologic approaches

Objects made of plastic still have a negative image. Some people even think plastics don't deserve any investment, in terms of conservation. With this research we have tried to explore the historical and cultural dimensions of the use of plastic in timepieces, to show what makes them an essential part of our heritage.

This section consists of an historical study to define the major steps involved in the introduction of plastics in Swiss Jura region industry and an ethnologic study of this innovation process. The first was conducted by Cécile Aguillaume (Aguillaume 2006) and Pierre-Yves Châtelain (Châtelain 2007). Denise Wenger and Jacques Chapatte (Wenger and Chapatte 2007), with the help of Christina Akré, Agnès Gelbert Miermon and Philippe Geslin, undertook the second.

Methodology and presentation of the study

The research focused on the Swiss Jura region, from Geneva to Basel, which is the cradle of the Swiss timepiece industry (Cardinal *et al.* 1991, Cop 2003). Historians have primarily worked on specialized written sources: horology journals and documents from the museum of timepieces, as well as interviews. It has not been possible to have access to companies' archives. Ethnologists investigated the field by leading semi-directive interviews. About 30 individuals representing the whole production process (from chemist to watch seller), privileging old actors who experienced the huge technological transition of the large introduction of plastics into timepiece manufacture (from the end of the 1950s to the end of the 70s) were interviewed. Investigations cover a wide range of horology production, from cheap to prestigious timepieces.

Main results

1. Historical context

There are two phases involved in the introduction of plastics: a first between 1860 and 1960, and a second from 1960 until today (Aguillaume 2006; Châtelain 2007).

The first phase (1860 to the end of the 1960s) corresponds to discrete but capital appearance of plastics in timepieces (glass replacement, wires insulation). According to historians it is difficult to precisely document the arrival of first plastics in timepieces from the end of the nineteenth century. Specialized journals communicate very little about it. There is more precise information about the use of Poly(methylmethacrylate) (PMMA) for glass replacement in (used since 1930s), and joints and circles date from the 1940-50s.

The second phase (1960s to present day) is characterized by the arrival of quartz watches and the increasing use of plastics in the timepiece industry.

Two products marked this innovation:

- The Astrolon watch (1971) was presented as the "first mechanical watch made of plastic"; all components except the balance, spiral and barrel are made of plastic; it is a technical success but a commercial failure.
- The Swatch watch (1982) is a great success. All the parts constituting the support (watch case) are in plastic. The integrated production mode allows the watch price to decrease.

2. The innovation steps

The implications of the two steps of introduction of plastics are very different.

During the first phase, the horology field seems to be only slightly affected because it didn't induce any major change in the production process. Plastic pieces were actually provided by subcontractors. No consumer could imagine there were present within watches, as there were concealed. The introduction is progressive and enthusiastically received by horologers. They are interested in these new materials and test them. Historians thus speak of 'non-event' (Aguillaume 2006).

Since the 1950s plastics become visible and their use increases. Changes occurred at various levels: know-how, production and technical processes/machines, social organization of the profession and education. The consumers' perception of watches changed dramatically. (Châtelain 2007; Chapatte and Wenger 2007).

This evolution coincides with the introduction in wrist watches of quartz technology, known since the 1930s (Forrer *et al.* 2002). This evolution led to a revolution after the huge 1970s crisis of the horology field.

3. The innovation process

This revolution is of course perceived at technical and economic levels, but thanks to ethnologists at social and cultural levels, as well (Chapatte and Wenger 2007).

Major technical changes

The fast development of plastics in horology occurred at the same time as another technical innovation: the introduction of quartz in watches.

This combination allows huge quantities of extremely prestigious watches to be produced. Indeed, plastics permit large manufacture of complicated parts, with less rejects than would occur with metal. Production costs therefore decrease. Plastics are useful for insulating electrical parts in quartz watches, especially micro-motors-coils. They also allow the creation of wrist watches with digital display (without moving parts) at unthinkable costs compared with metal.

An economic challenge

Swiss horology presented the first quartz wrist watch – the Beta – in 1967. The Japanese released a Seiko model at almost the same time, and supplanted the Swiss in the industrial phase. Quartz watches, which ally precision and low price, impose themselves.

In the 1970s the Jura region industry experienced a major crisis. To avoid bankruptcy of this paramount field a massive strategic investment was engaged in bottom-of-the-range watches. The creation of the Swatch in 1982 rescued Swiss horology (Aguillaume 2003; Carrera 1992). This cheap electric watch consists of less components (51 pieces vs. 100-120 for a traditional watch) for the highest percentage of plastic.

This huge crisis obliged horologers to innovate to survive. They had to find a way to counter Asian competition. Plastic was the answer thanks to the combination of low cost and multiplicity of colours and shapes it allows (Chapatte and Wenger 2007: 16).

An evolution of the social and cultural context

A technical innovation also has a social and cultural implication. Indeed, it involves producers and consumers who are integrated into a network of social interactions and embedded in a specific cultural context (Akrich 1998; Latour and Lemonnier 1994; Lemonnier 1993).

The increasing use of plastic corresponds to a deep change in the social function of watches and in cultural representations associated with them. Two categories of watches then emerged: high-end, and bottom-of-the-range. The first is expensive, valuable and rejected plastics. This kind of watch is usually offered at special occasions (communions, weddings). The second is cheap and treated as an accessory and is influenced by fashion and mass consumer needs. Plastic is accepted and is even a selling point.

These two categories respond to different social goals, and convey different representations of the watch itself and of plastics.

The social function

Such a physical, material and concrete object 'as a watch' is actually what we make of it. Performances we expect are relative. Increasing use of plastics, since the end of the 1950s, corresponds with major changes of the accessory watches social function.

Plastics fulfil these new watches requirements in terms of comfort – they are lightweight, allergy free and hygienic , resistance – they are impermeable, tight, supple and insulating – and fashionable – they are economic (low cost allows a regular renewal to be up to date), easily coloured and formed, which offers many possibilities to designers.

The traditional drawbacks of plastics in terms of prestige and continuation don't obstruct new social aims of these accessory watches.

Representations

Among the variety of factors influencing the innovation process, 'social representations' are very important as they can accelerate or slow down the innovation process (Bromberger and Chevallier 1999: 6).

The human relation to material is concrete, physical and, on the other hand, symbolic (Chapatte and Wenger 2007: 82).

Overall, plastics have a bad image. Is it because they are omnipresent in our lives and thus trivialized (Beaune 1999), because they are synthetic (Dagognet 1997), often disposable (Beaune 1999; Norman 1988) or manufactured in mass? How do common sense representations reflect themselves in the field of horology?

High-end companies will avoid talking about plastics. It is even a taboo (Chapatte and Wenger 2007: 74). High-end watches have an evident social role to play, as this Patek Philippe advert illustrates:

«Vous songez à acquérir une montre Patek Philippe. À ce titre, vous appartenez au cercle des admirateurs de l'excellence pour qui un garde-temps représente bien plus qu'un instrument qui donne l'heure.»

Materials must be either traditional or high tech; and know-how is between tradition and modernity, for a question of prestige. That is what high-end companies express.

On the other hand companies selling cheaper watches will clearly mention the use of plastics, affirm their presence in their products, and totally assume it (Chapatte and Wenger 2007: 74).

The Swatch Company even goes further. The success of Swatch is due to symbolic value the company gave to its product. Originators attributed to it a new status with new marketing concepts. Swatch introduced its watch as a fashion accessory. It is associated with a lifestyle. Swatch watches must be up to date, frivolous, futile, consumerist and trendy (Chapatte and Wenger 2007: 86). To wear a Swatch is a distinction sign, as it is to wear a beautiful mechanical watch. With the same wish for rarity Swatch regularly releases limited editions. To make plastics more valuable Swatch associate disposable watches with prestigious materials. For instance, Swatch recently encrusted diamonds in a limited edition Skin watch (Chapatte and Wenger 2007: 86-87).

A material 'in the air'

To understand better the success of plastic watches, cultural context must be assessed. The plastic revolution wasn't the monopoly of the timepiece industry. Toothbrushes, pens, dishes, everything can be made out of plastic and become disposable. Cheap ephemeral products are multiplying. This is the archetype of the consumer society (Bartoloni 1995; Chapatte and Wenger 2007: 22).

This change is evident in the economic field, but also in the artistic world, with the New Realism (Martial Raysse, César…) and contemporary with American Pop'Art (Claes Oldenburg, Allen Jones…).

Do plastic watches belong in museums?

The MIH answered this question positively by exhibiting Swatch watches and Tissot's Astrolon watch. Our project confirms the relevance of this choice, demonstrating that the use of plastics in horology was an essential innovation of the nineteenth and even more the twentieth century. Thanks to the work of two historians and two ethnologists, who met witnesses, searched archives and undertook fieldwork in Jura region industries, this project allows us to know more about this innovation, the historical steps and cultural impact.

In the 1990s mechanical watches were back in favour. As the Swiss timepiece industry is strongly focused on high-end products, plastics still seem taboo. There is incompatibility between a quasi 'eternal' product and material ephemeral by nature.

Plastic upset the timepiece industry and our attitude towards watches by imposing itself during the last century. It then became a part of the history of horology, of our history and therefore earned it place in a museum.

The introduction of plastics in horology: technical and conservation issues

MIH's objects: identification and condition assessment

Besides surveying the context of the introduction of plastics into the horology field, timepieces containing these materials have been studied from another point of view. (Vuissoz, Schenkel Beck and Ducatel 2007).

The main object in this study is the monumental Vachey's clock. This clock was built over a period of 30 years, from 1938 to 1968. Its significance is that it encloses the three categories of plastic use (case, electrical insulation and glass replacement), and this is what led to the selection of the corpus of objects.

Figure 3 Example of Vachey's clock's part containing various types of plastic used as electrical insulation © HEAA Arc AVU/TSC

[insert A_Vuissoz Fig3 here]

A conservator has especially been hired by the MIH to take care of this particular object. He disassembled the various mechanisms, before starting conservation treatments. That allowed our team's conservators to study the plastic parts found inside every timepiece. The museum hasn't yet planned to conserve or restore any of the other selected objects.

As in every conservation process, preliminary documentation of the study collection has been completed. Each artifact is described by provenience, historical context, period, materials, technical horological information, conception and use. An inventory of the plastic elements has been undertaken.

Plastics contained in artifacts have been systematically analyzed. Where possible, polymer identification has been noted. A correct identification will allow better understanding of the plastic degradation processes, and thus assist in choosing the most suitable and efficient conservation treatments.

Chemical analyses performed at the Ecole d'ingénieurs et d'architectes of Fribourg led to results along with information about their condition, e.g. degradation signs (Vuissoz, Schenkel, Beck and Ducatel 2007).

Table 1 Identification and condition assessment of plastics present in selected timepieces, according to the three predefined categories of use. An '?' indicates that samples haven't been identified.

[insert A_Vuissoz Table1 here]

Some analysis could be performed on material's surface, others required sampling. As a rule, non-destructive analytical methods are preferred. Fourier Transform Infrared spectroscopy (FTIR), Raman spectroscopy, Atomic Force Microscopy (AFM), and Differential Scanning Calorimetry (DSC) were used, as well as chemical spot tests.

Note: These results are only representative for our selection of objects. Some pieces haven't been identified. No identification was performed on plastic parts of clocks on display, i.e. Favre clock and quartz clock, either on Favag clock, or on internal parts of Secticon clock. They couldn't be disassembled nor transported to analyses labs.

After chemical characterization, the condition was assessed for each object, focusing on the condition of plastics of the three categories. With the help of stereomicroscope, microscope and observation with UV light, several degradation signs were repeatedly observed.

Results:

Globally all objects were covered with a thin layer of dust. Stains, fingerprints and deposits of material (eg welding substance) were visible on many artifacts. Scratches were present on most of the objects' external surface of cases and glass replacement parts.

The surface of some plastics was dull and in some cases rough. Slight opacification had occurred to few of transparent plastics used as glass replacement. Discoloration, was evident for every kind of plastic.

Figure 4 Discolouration of a plastic wheel in Vachey's clock © HEAA Arc AVU/TSC

[insert A_Vuissoz Fig4 here]

The rate of yellowing varies from an object to another. The following example illustrates the very high yellowing of Acrylonitrile Butadiene Styrene (ABS). The plastic used to build the case was originally transparent and colourless.

Figure 5 Yellowing and detail of crazing of ABS used for Swatch watch case © HEAA Arc AVU/TSC

[insert A_Vuissoz Fig5 here]

This object also shows crazing in the centre of the watch-case. This sign is also frequent in plastics used as glass replacement for watch faces, for instance in the Junghans alarm clock and Omega watch.

Cracks are observed in many artifacts. Few have broken parts and occasionally there are pieces missing.

Most of the flexible plastics, used as electrical insulation (cables) in big clocks, have hardened. In a few cases permanent deformation has been induced. Several cables are burnt or melted at their extremity.

Rust stains are visible in the surrounding of a screw fixing the base to the Smiths timer. Adhesive was used in that area to fix the base, as the screw is missing.

Diagnosis

Various causes generate plastic degradation. A 'natural' degradation phenomenon first occurs (chemical and physical degradation), influenced by the plastics composition (polymer, additives, impurities) (Quye and Keneghan 1999). Polymer identification is essential to understand specific degradation processes. Other factors may also influence the condition of plastics in objects.

The selected objects collection is overall in a relatively good condition.

In some cases design and manufacture induced plastic degradation. Crazing is typical on watch faces. Indeed, these parts are inserted in cases with a certain tension, producing crazing when released, but crazing also occurs under long-term tension. Cracks and broken parts are other good examples, but they can also be imputed to the use, the function and the handling of objects.

Everyday use of alarm clocks and watches induced scratches on the objects external surfaces. The particularity of watches, for example, is they are worn at the wrist on an everyday basis, with exposure to cosmetic products, sweat, water, sun, and atmospheric pollutants. Alarm clocks are manipulated and likely subjects to fall when waking people up. Timers can undergo the same kind of dangers, and if used in a kitchen encounter additional factors of degradation, i.e. heat, grease and other substances. Impact is likely to be the cause of the broken base of the Secticon clock and of the Smiths timer and also to have fissured the case of Thorens clock.

The electrical parts in the biggest clocks, such as the Vachey, Favag, Favre and quartz ones, may have damaged the insulating plastics by producing heat. As they are made of metal they interact with plastics causing harm. When cables, composed of metal covered with plastics, are welded, plastic is likely to melt and sometimes burn.

Corroded metal may suggest that the plastic of the Smiths timer has gradually released acids. However no weeping was observed. On the other hand use in a kitchen could also make the metal corrode and stain the plastic nearby..

Although storage is known as plastic degradation factor it didn't cause any specific damage in our case. Dust was present on almost all objects, but display and storage conditions are good enough to prevent objects from an accelerating degradation. Indeed, MIH collections are stored in the dark, on Compactus® storage shelves. Overall climate is stable.

Conclusion

Historians and ethnologists determined that there were two phases in the introduction of plastics in timepieces industry. They studied the social and cultural impact of plastic introduction and the change of status of watches.

Chemists were able to identify most of the samples, helping conservators to better understand plastics degradation processes and to propose adapted treatments to conserve damaged artifacts.

Thanks to diverse aspects and collaboration the project showed that plastics are worth being conserved. It also led to a realisation of the presence of plastic, its material aspect, its cultural meaning and its specific needs. A better understanding of this material and uses in timepieces will allow a better preservation of this type of heritage.

From disposable, plastic became a trace of cultural, industrial and technological evolution. From bottom-of-the-range it became high tech, even in horology field. Little by little, plastic's status changed.

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Endnote

1. Translation: 'You are thinking of acquiring a Patek Philippe watch. For this reason you belong to admirers of excellence for whom a timepiece represents much more than an instrument giving time.'

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She received her PhD in ethnology – with a prehistory option - from the University of Paris X Nanterre under the direction of Alain Gallay, professor at the University of Geneva.

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Table

Table 1: Identification and condition assessment of plastics present in selected timepieces, according to the three predefined categories of use. An "?" indicates that samples haven't been identified.

Figures

Figure 1: Vachey's monumental clock © MIH

Figure 2: Part of the objects selection. From left to right: red Secticon clock, green Smiths timer, white Thorens alarm clock, Omega watch, orange Junghans alarm clock, and Swatch watch © HEAA Arc AVU/TSC

Figure 3: Example of Vachey's clock's part containing various types of plastic used as electrical insulation © HEAA Arc AVU/TSC

Figure 4: Discolouration of a plastic wheel in Vachey's clock © HEAA Arc AVU/TSC

Figure 5: Yellowing and detail of crazing of ABS used for Swatch watch case © HEAA Arc AVU/TSC

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