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Make it work?

The restoration of a Green Ray Television Wonder, a 1930s Fortune-Teller slot machine from the Deutsches Technikmuseum Berlin

Thesis submitted by Augustin Duc

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Hes·so
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"Your scientists were so preoccupied whether they could, they didn't stop to think if they should."

Jurassic Park, 1993, directed by Steven Spielberg

Commitment

"I certify that this work is the result of my own creation and that it has not been presented to any other jury either in part or in whole. I also certify that in this text any statement that is not the fruit of my personal reflection is attributed to its source and that any passage copied from another source is furthermore placed in quotation marks."

Date and signature:

07.09.2020, 

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Summary

In this work we are interested in the restoration of a Green Ray Television Wonder belonging to the Deutsches Technikmuseum in Berlin. It is a coin-operated automaton from the 1930s which supposedly allows the user's mind to be "read" by means of television technology. This object is part of the technical heritage, more precisely electromechanical; conservation-restoration professionals are subject to challenges specific to this type of heritage, due to its functionality and composite nature.

In the first part of our work, we explore some of the issues related to the restoration of functional objects and study the different approaches to it with a view to highlighting an approach that is based on respect for material integrity and the associated cultural values.

This report will aim to provide a basis for documentation on this object as the museum does not have one. In the second part, we therefore present the documentation of the object: its historical context, the study of its functioning by reverse-engineering, the description of its state of conservation, the cultural values associated with it and its material history, as well as the diagnostic part.

The conservation-restoration interventions and their justification are documented in the last part of the work. Due to the presence of asbestos in the object, we have carried out a treatment in order to be able to reintegrate the object into storage and exhibit it to the public in the future. The painting of the object presents liftings due to the corrosion of the ferrous elements, so we have stabilised the metal surfaces and refixed the paint layer. We also studied the possibilities of a functional restoration on this object, its impact, and we evaluate whether such an intervention is desirable for this object. The choice that has been made for this object is the presentation of a video of the object in operation for a future exhibition. The object will therefore be exhibited and stored in a static condition.

Zusammenfassung

In dieser Arbeit interessieren wir uns für die Restaurierung eines Green Ray Television Wonder, das dem Deutschen Technikmuseum in Berlin gehört. Es handelt sich um einen münzbetriebenen Automaten aus den 1930er Jahren, der angeblich mittels Fernsehtechnik das "Lesen" der Gedanken des Benutzers ermöglicht. Dieses Objekt ist Teil des technischen Erbes, genauer gesagt des elektromechanischen Erbes; die Fachleute für Konservierung-Restaurierung sind aufgrund seiner Funktionalität und seines zusammengesetzten Charakters besonderen Herausforderungen unterworfen, die für diese Art von Erbe spezifisch sind.

Im ersten Teil unserer Arbeit untersuchen wir einige der Fragen im Zusammenhang mit der Restaurierung funktionaler Objekte und untersuchen die verschiedenen Ansätze dazu, um einen Ansatz hervorzuheben, der auf der Achtung der materiellen Integrität und der damit verbundenen kulturellen Werte beruht.

Dieser Bericht soll als Grundlage für die Dokumentation dieses Objekts dienen, da das Museum über kein solches verfügt. Im zweiten Teil präsentieren wir daher die Dokumentation des Objekts: seinen historischen Kontext, die Untersuchung seiner Funktionsweise durch Reverse Engineering, die Beschreibung seines Erhaltungszustands, die mit ihm verbundenen kulturellen Werte und seine materielle Geschichte sowie den diagnostischen Teil.

Die konservatorisch-restauratorischen Eingriffe und ihre Rechtfertigung sind im letzten Teil der Arbeit dokumentiert. Aufgrund des Vorhandenseins von Asbest in dem Objekt haben wir eine Behandlung durchgeführt, um das Objekt wieder in die Lagerung eingliedern zu können und es in Zukunft der Öffentlichkeit ausstellen zu können. Die Bemalung des Objekts zeigt Aufhebungen aufgrund der Korrosion der darunter liegenden Eisenelemente, daher haben wir die Metalloberflächen stabilisiert und die Farbschicht neu fixiert. Wir haben auch die Möglichkeiten einer funktionellen Restaurierung dieses Objekts und seine Auswirkungen untersucht, und wir bewerten, ob ein solcher Eingriff für dieses Objekt wünschenswert ist. Die Wahl, die für dieses Objekt getroffen wurde, ist die Präsentation eines Videos des in Betrieb befindlichen Objekts für eine zukünftige Ausstellung. Das Objekt wird daher in einem statischen Zustand ausgestellt und aufgelagert.

Résumé

Dans ce travail nous nous intéressons à la restauration d'un Green Ray Television Wonder appartenant au Deutsches Technikmuseum de Berlin. Il s'agit d'un automate à pièces des années 1930 qui permet supposément de « lire l'esprit » de son utilisateur grâce à la technologie de la télévision. Cet objet fait partie du patrimoine technique, plus précisément électromécanique ; les professionnels de la conservation-restauration sont soumis à des défis spécifiques à ce type de patrimoine, du fait de sa fonctionnalité et sa nature composite.

Dans la première partie de notre travail, nous explorons certaines des questions liées à la restauration d'objets fonctionnels et étudions les différentes approches de celle-ci afin de mettre en évidence une approche qui repose sur le respect de l'intégrité matérielle et des valeurs culturelles associées.

Ce rapport visera à fournir une base de documentation sur cet objet, le musée n'en possédant pas. Dans la deuxième partie, nous présentons donc la documentation de l'objet : son contexte historique, l'étude de son fonctionnement par rétro-ingénierie, la description de son état de conservation, les valeurs culturelles qui lui sont associées et son histoire matérielle, ainsi que la partie diagnostique.

Les interventions de conservation-restauration et leur justification sont documentées dans la dernière partie de l'ouvrage. En raison de la présence d'amiante dans l'objet, nous avons effectué un traitement afin de pouvoir réintégrer l'objet en stockage et l'exposer au public dans le futur. La peinture de l'objet présente des soulèvements dus à la corrosion des éléments ferreux sous-jacents, nous avons donc stabilisé les surfaces métalliques et refixé la couche de peinture. Nous avons également étudié les possibilités d'une restauration fonctionnelle sur cet objet, son impact, et nous évaluons si une telle intervention est souhaitable pour cet objet. Le choix qui a été fait pour cet objet est la présentation d'une vidéo de l'objet en fonctionnement pour une future exposition. L'objet sera donc exposé et stocké dans un état statique.

Introduction

In this work we will focus on a particularly special object from the technical heritage: it is a Green Ray Television Wonder belonging to the Deutsches Technikmuseum Berlin. This object is an arcade coin slot machine that "reads the mind" of its operator with the technology of television and writes his/her character on a small card with an electromagnetically controlled pen, or at least it is how the object advertises itself with the fancy inscriptions it displays to attract people passing by. This object was built in the 1930s in England and used in exterior in fairs or arcades at that time but has since then undergone many modifications and repairs. In the first part of this work, we will explore the reason why it is common to find such interventions on technical heritage objects and how in certain conditions it can be damaging for the sustainability of these objects as cultural heritage artefacts.

The museum possesses a rather sparse documentation about this object; it was acquired because it could contain television technology, but the object was never opened by the museum. In the main development of this work, we will therefore aim to enrich the documentation and comprehension of this mysterious box by doing research about its historical context, observing its materiality and studying its functionality with the reverse-engineering approach.
The object was exhibited in exterior for a great length of its life, it has undergone degradations linked with this direct exposure to degradation agents such as water. The object is heavily corroded in some areas, this has led to many paint losses and the paint layer is lifting due to the underlying corrosion products. When we opened the object, we also found the presence of asbestos, which will require a treatment if the object has to be exhibited to the public and placed in storage, because of the health risks it is linked to. The second objective set by the museum is therefore to execute a conservation-restoration treatment to be able to put the object safely back into storage, with the eventually that it will be presented in a future exhibition.
Because this object is a functional object, we will determine in the last part of this work if making the object operational again would be possible, under which conditions, and assess if an intervention in this aim would be desirable for this object.

1 The conservation-restoration of functional objects

1.1 Basic notions

First of all, what is a functional object? The answers to this question may vary because many objects can be used and have a function, but is a sundial as much a functional object as a tower clock or a quartz watch? Ashton and Hallam tried to give a broad definition that we will use during our reflection: a functional object is "an object containing mechanisms designed to work in some form"[1]. A functional object can therefore take many different forms and sizes, which we will group under the same banner of technical heritage here. But then, what is a technical object? For Roland-Villemot, any object can be a technical object because it can be an evidence of a technical background in a museographical discourse. We will therefore have to do the distinction here between the objects resulting of a technical operational chain and which does not contain any mechanism, and the objects whose functionality can be examined[2]. This is on this second type of artefacts that we will focus here.

There are many difficulties in preserving functional heritage artefacts, due to their intrinsic materiality or because their functionality raises an ethical dilemma. One of the main difficulties in conserving technical heritage is that it was often not intended to last for long periods of time and without a regular maintenance[3]. These objects are often made of multiple parts made in different materials to constitute the functionality, but what happens when one or more of the parts is missing or that the ageing of the materials compromises the structure as a whole? Should the problematic pieces be replaced, what happens to the authenticity and integrity of the object?

Many objects are operated to illustrate how they work, the interpretation of these objects can therefore require a degree of interventive treatment which would be considered as unacceptable for other types of collections: their operation causes wear to the original parts leading to their replacement and loss of technical and historical information[4]. Because the mission of museums is to preserve this heritage, how can they allow to run objects and slowly but surely destroy them? Should we value the functionality as a means of interpretation and continue operating these objects at the risk of losing historic traces forever?[5]

[1] Ashton and Hallam, 1990, p.19
[2] Rolland-Villemot, 2001, p.16
[3] Mirambet, 2011, p.28
[4] Newey, 2000, p.137
[5] Ashton and Hallam, 1990, pp.19-20

1.2 Evolution of the conservation-restoration of technical heritage

In the beginning of the 20th century, the object conservation discipline focused mainly on the archaeological artefacts; this resulted in the preservation of technical heritage by engineers, metalworkers or woodworkers, whose aim was to restore the objects to their former glory and make them work again[6]. It led many amateurs and even professionals to think that they can treat these objects as if it were their own, this attitude caused many interpretations and regrettable repairs[7].

Brenni notes that many technical objects collectors have the temptation to repair and use their objects, whereas arts collectors have a different attitude: "No collector of antique porcelain would consider drinking tea from a three-hundred-year-old cup"[8]. These collectors would never restore their artefacts themselves, but technical objects collectors often do[9]. This leads to a tendency to replace the broken or missing pieces, and to undertake aesthetic interventions such as repainting or removal of the original surface finish by polishing. All of these actions can badly damage the artefacts if they are not undertaken with a good understanding of the object, because the objects no longer look like they did originally, and they lost a great part of their historical value[10]. In certain cases, the historical value of objects that reaches present day can even be questioned: their fabric was so much interpreted that we could as well be in the presence of a replica[11]. This consideration for technical objects could be partly explained by the fact that these artefacts can often seem familiar because even if the technology has evolved greatly since their creation, they are quite recent and did not have time to get a particular aura with which we could consider other types of heritage[12]. The loss of historic information due to these interventions only started to be considered as important with the emergence of industrial archaeology as a recognised academic discipline in the 1950s-60s[13]. But still in 1990, the restoration of this cultural heritage is stated by some as the same as art restoration in the 1920s, where unscientific and traditional treatments were the norm in many collections[14], we are entitled to ask ourselves why.

Even if restoration work is always well intentioned, it is a high-risk period for an object, and it can be greatly damaging for the long-term preservation of the objects[15]. Restoration work for functional heritage is often considered inconsistently in regard to standards of practice which are commonly accepted in other fields of the conservation-discipline, such as paintings and fine arts[16].

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[6] Newey, 2000, p.137
[7] Thurrowgood and Hallam, 2004, p.2
[8] Brenni, 1999, p.20
[9] Brenni, 1999, p.20
[10] Brenni, 1999, p.20
[11] Thurrowgood and Hallam, 2004, p.3
[12] Thurrowgood and Hallam, 2004, p.2
[13] Newey, 2000, p.137 and Rolland-Villemot, 2001, p.13
[14] Ashton and Hallam, 1990, p.19
[15] Thurrowgood and Hallam, 2004, p.3 and Odell and Karp, 2005, p.1
[16] Odell and Karp, 2005, p.1

Perhaps an element of answer can be found in the fact that the conservation-restoration theories developed in the middle of the 20th century were based mainly around art history criteria, where aestheticism and history were predominant[17]. There were significant changes in the notion of cultural heritage, which greatly expanded during the end of the 20th century and was enriched by ethnographic, scientific and technical collections; domains which are not mainly governed by the previously mentioned values[18]. Furthermore, the deontology of conservation-restoration based on the theory of Cesare Brandi[19] was built around the unique work of art and authenticity, applying these notions to technical heritage artefacts can be complex, because they are rarely unique, and are not works of art in the proper meaning of the term[20].

If we considered two objects roughly the same age, one coming from technical heritage and one coming from ethnological heritage, it would be common to see differences in the way their treatment is considered. During their lifetime, technical objects will often have been repainted multiple times and parts will have been replaced, sometimes making it difficult to distinguish what is original and what was added[21]. The sustainability of a technical object is compromised if original features are removed during a reparation in order to make it work again[22], and it is often the case with contemporary technical objects which contain elements with limited lifespan, such as electric lightbulbs[23]. The replacement of these components to make the object work again would certainly be considered as a repair, because the components used to bring back the function are modern and completely different from the original ones. As Brenni says it: "We can repair an ancient bow with a nylon rope, but who would do that in an ethnographic museum?"[24].

The conservation-restoration of the ethnological heritage is governed by well-established deontological principles which are internationally recognised, whereas in the case of technical heritage, there are no such recognised standards[25]. In practice, ethical principles created for other types of works of art can be applied to technical heritage[26]. Geindreau postulates that a technical heritage artefact is intrinsically an ethnographic object; a machine is significant of an ethnic group, since it is part of a culture, beliefs, modes of actions, institutions, which are singular and specific of a society[27], so why do we notice such a clear difference in their treatment?

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[17] May, 2009, [Online]
[18] May, 2009, [Online]
[19] Brandi *et al.*, 1963
[20] Geindreau, 2013, [Online]
[21] Staelens and Morris, 2010, pp.3-4
[22] Staelens and Morris, 2010, pp.3-4
[23] Brenni, 1997, p.40
[24] Brenni, 1997, p.40
[25] Tomsin, 2007, [Online]
[26] Tomsin, 2007, [Online]
[27] Geindreau, 2013, [Online] and Geindreau, 2014, [Online]

1.3 To use, or not to use, that is the dilemma

At the end of the 1980s, two schools of thought concerning how we should conserve and restore technical objects were in confrontation. On one side, there is the "conservative view": because the purpose of a museum is to preserve the material evidence, it is wrong to risk the loss of this evidence by wearing it out during the operation. Kühn defends this approach by saying that the traces that time left on the objects are part of its life, therefore their destruction would lead to irreversible loss of its historical significance, restoration should then carefully avoid destroying these traces[28]. If they occurred during the period when the object was in use, all the modifications and repairs are considered to be a part of its history[29]. For Kühn, the most important thing to keep in mind is that "no measure of restoration can improve on the authentic state or bring back the original character of an object once it has been lost. At its best, a restoration measure does not diminish the authentic state or the original character of a piece"[30]. Kühn explains that under no circumstances should we attempt to make an object functional again, because it would be at the detriment of the historic state the artefact has acquired[31].
Even if it is a logical argument, Mann criticises this approach because it implies that the only evidence in the artefact is of material nature[32]. He defends the other opinion which is the "working view": technical objects should be running regularly and kept in good condition in order to do so. Mann explains that catastrophic destruction is rare comparatively to cumulative degradation, which takes place over a long period of time and is due to wear or replacement of used parts. Problematic parts can be replaced, and modifications can be done in an attempt to reduce this cumulative degradation, sometimes even preventively to assure a better reliability of the demonstration[33].
There is a paradox to which technical museums are faced: they need both to preserve material evidence and to demonstrate objects, and this situation leads to uncertainty on the course of action to follow[34].
For Mann, the most appropriate ethic for technical museums is to make the object run for the benefit of the public, rather than simply conserve the material evidence. It is the sacrifice of one type of evidence to reveal another "more important" evidence: the functionality[35].
The dilemma presented with these two points of view leads to two extreme positions: keep the object working and wear it out or do nothing with it[36].

[28] Kühn, 1989, p.389
[29] Kühn, 1989, p.393
[30] Kühn, 1989, p.393
[31] Kühn, 1989, p.392
[32] Mann, 1989, p.370
[33] Mann, 1989, p.378
[34] Mann, 1989, p.383
[35] Mann, 1989, p.383
[36] Ashton and Hallam, 1990, p.20

1.4 Realistic approaches in the restoration of functional heritage

What are the realistic options for the restoration of a technical heritage artefact? Surely, camping on one or the other previous options is not recommended, because it is the object which dictates the conservation-restoration problematics and not the contrary[37]. Practically, there are three choices: restoration, maintenance in working condition (the "storage and occasional use scenario") or maintenance in static condition[38].

From an ethical standpoint, function needs to be conserved and it should be considered as a factor as significant as the material attributes during the decision process[39]. The functionality of an object does not necessarily mean that it will be operated until it breaks or until historic traces are lost[40]. Therefore, it should not be classed as a deterioration agent because it is a viable option available for the interpretation of the object through the "storage and occasional use scenario"[41].

The decision between functionality and materiality should be seen as a scale where we have to choose the relative importance of form and function, depending on the significance of the object; one will be conserved at the detriment of the other, even if both should be conserved[42]. We have to keep in mind that sometimes it is preferable not to restore an object to working condition because other aspects of its significance are more important relatively to the functionality[43]. Many factors can also contribute to the importance of a technical object besides the aesthetic, artistic and economic value. Acquiring a better understanding of the object allows to make the best choices for the preservation of the object[44], therefore when restoring these objects, we should consider all the different aspects of the significance in order to avoid removing important traces which attest of the "life" of the object[45]. Each artefact is a unique case when it comes to restoration, many problems can arise, each one having multiple solutions; the choice has to be made between these solutions to find the most adapted to the object and the role that we associate to it in the museographical discourse[46]. Furthermore, there are sustainable alternatives to the operation, such as replicas or multimedia presentation, which we will discuss further later when it comes to the choices that were made for the Green Ray. As Hallam and Thurrowgood said: "Conservation is not just about preserving the form a piece of matter takes, it is also about ensuring its significance is retained and meaning perpetuated."[47]

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[37] Geindreau, 2013, [Online]
[38] Ashton and Hallam, 1990, p.20
[39] Brunott, 2010, p.427
[40] Brunott, 2010, p.424
[41] Brunott, 2010, p.427
[42] Hallam, 2007, p.42
[43] Brenni, 1999, p22
[44] Brenni, 1999, p.23
[45] Brenni, 1999, p.20
[46] Le Breton, 1997, p.9
[47] Thurrowgood and Hallam, 2004, p.6

2 Description of the object

2.1 Technical specifications

Table 1: Technical specifications of the object

Designation/type:	The Green Ray Television Wonder, fortune-teller arcade slot machine
Owner:	Deutsches Technikmuseum, Berlin
Inventory number:	1/2009/0861
Manufacturer:	Hope, Bradshaw & Co./Ltd, London; Company marketed by Granville Bradshaw
Date:	post 1931 (the year the Green Ray was first patented)
Dimensions:	1905 mm x 643 mm x 555 mm (see Annexes p.82 for further details)
Materials:	metal – glass – paper and cardboard – plastics – leather – rubber

Fig. 1: Photographs of the sides and roof of the Green Ray

2.2 Construction

We will now examine the constituting materials and how they are assembled. The panels and the roof of the Green Ray are fixed on a steel frame, which constitutes a casing for the object. This frame is supported by 4 cast iron feet, each one is attached to the frame by three bolts and nuts.

Different types of steel sheet panels form the sides of the "box" (see *Fig. 2*):

- The back side is constituted of a single sheet of steel riveted to the frame. There is a metal bar fixed on it horizontally, probably to attach the object to a wall.
- The lower front and left sides are single steel sheets riveted to the frame; a rectangular opening is present in the front panel.
- The upper left and right sides are made of a sheet of steel, with a glass pane in the centre. The panels are fixed with hinges riveted to the frame; they have a lock and can be opened.
- The upper front panel and lower right panels are completely removable, they also have a lock mechanism. The upper front panel also has a glass pane, slightly larger than those on the side panels.

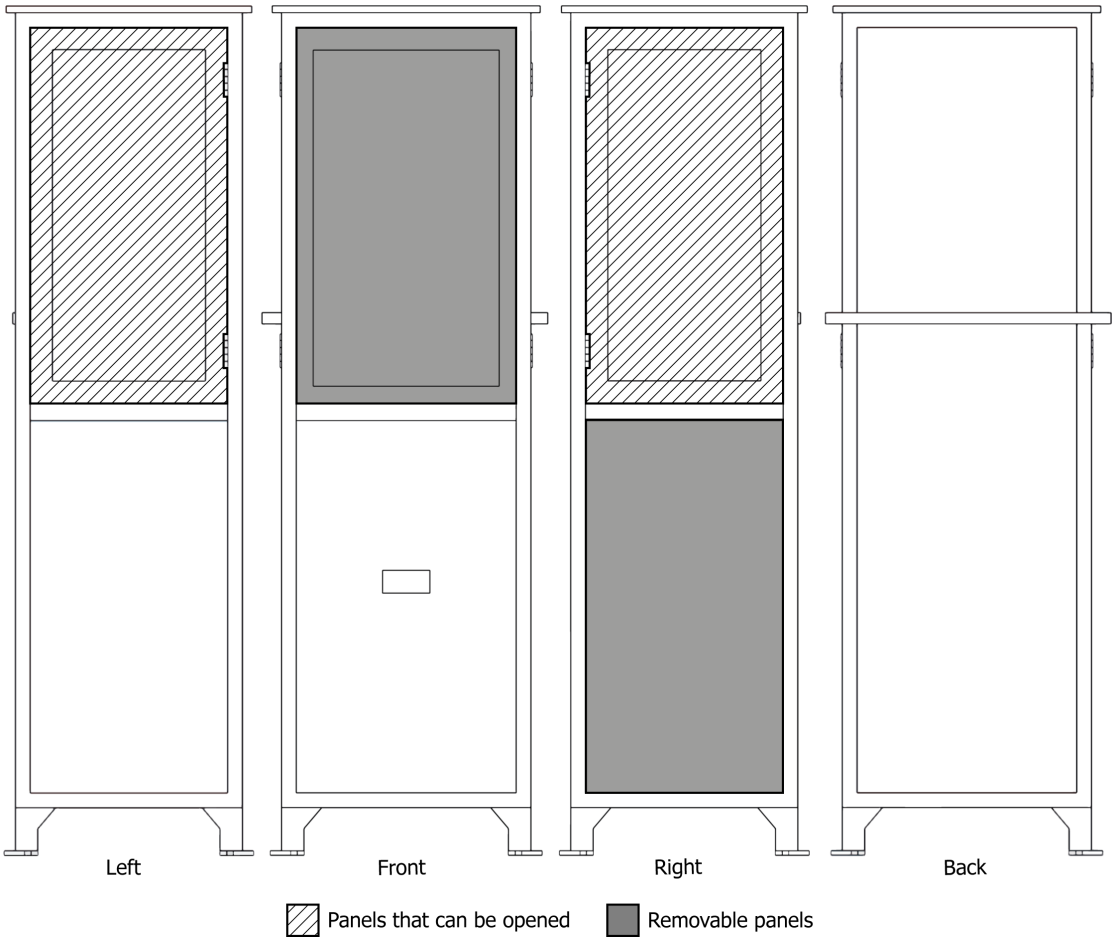

Fig. 2: Schematic representation of the four moveable panels

The upper side panels are constituted of different steel parts which maintain the glass (see *Fig. 3* and *Fig. 4*), they are screwed in the outer frame of the panels. The upper front panel also has glass and is constituted of the same elements as the side panel with a few modifications: the lock is placed at the top of the panel, and there are no hinges, but two hooks on the bottom of the trim cover allow the panel to stay in place when closed.

Inside the object, there are two compartments (see *Fig. 7*). A single steel sheet is constituting the base of the lower compartment, it is fixed to the frame by the same bolts as the feet.

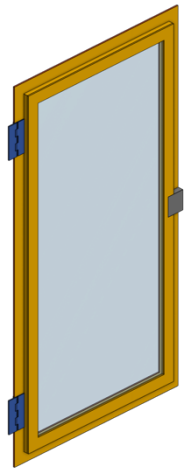

Fig. 3: Schematic view of the upper left-side panel, the screws are not shown

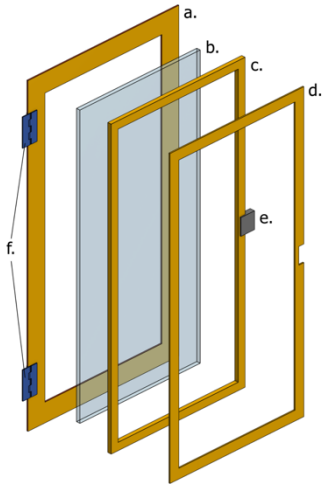

Fig. 4: Exploded view of the previous schematic a. outer frame b. glass pane c. casing d. trim cover e. lock f. hinges

A plywood panel is used in the middle of the object to support the front display panel and the elements of the mechanism which are fixed onto it with screws and bolts. The ceiling of the upper compartment is a plywood panel of the same type as the one used for the middle separation; it is covered by a steel sheet on the exterior which forms the roof.

On the roof, there are holes perforated in the metal sheet (see *Fig. 5*): five holes on a line along the right side; six holes on a line along the left side; ten holes on a circle in the middle, with two small holes in the centre, with one bigger hole inside the circle. The roof is fixed on the frame with four screws, one in each corner.

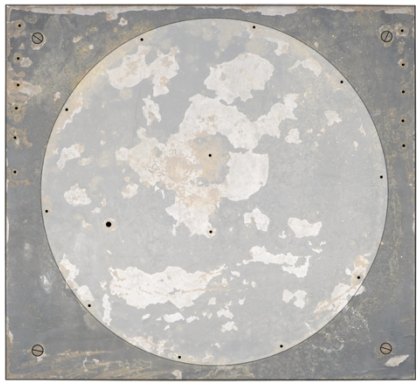

Fig. 5: Optimised photograph of the holes and the circular zone

The base of the Green Ray is also perforated with multiple holes, probably to prevent the stagnation of water inside the object during rainy days when the object was exhibited in exterior; there are more perforations on the side of the removable panel (see *Fig. 6*). The front display panel is an agglomerated wood panel on which the main features of the object are visible, it is where the show happens. It is supported by four black painted metal sheets encasing it and creating depth (see *Fig. 8* and *Fig. 9*).

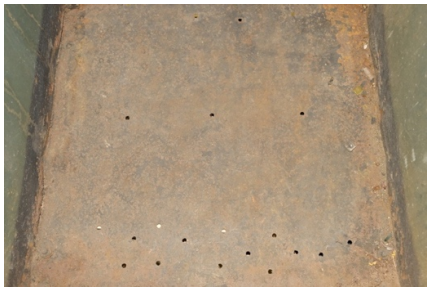

Fig. 6: Perforations in the base of the object (view from the right)

The top metal sheet has three round openings for lamps and the bottom one has a rectangular opening where the pen is located. On the backside of the agglomerated wood panel,

some aluminium-based alloy supports for the lamps are bolted, as well as other functional elements that we will explain later in the point 4.3 Sub-systems and components explanation.

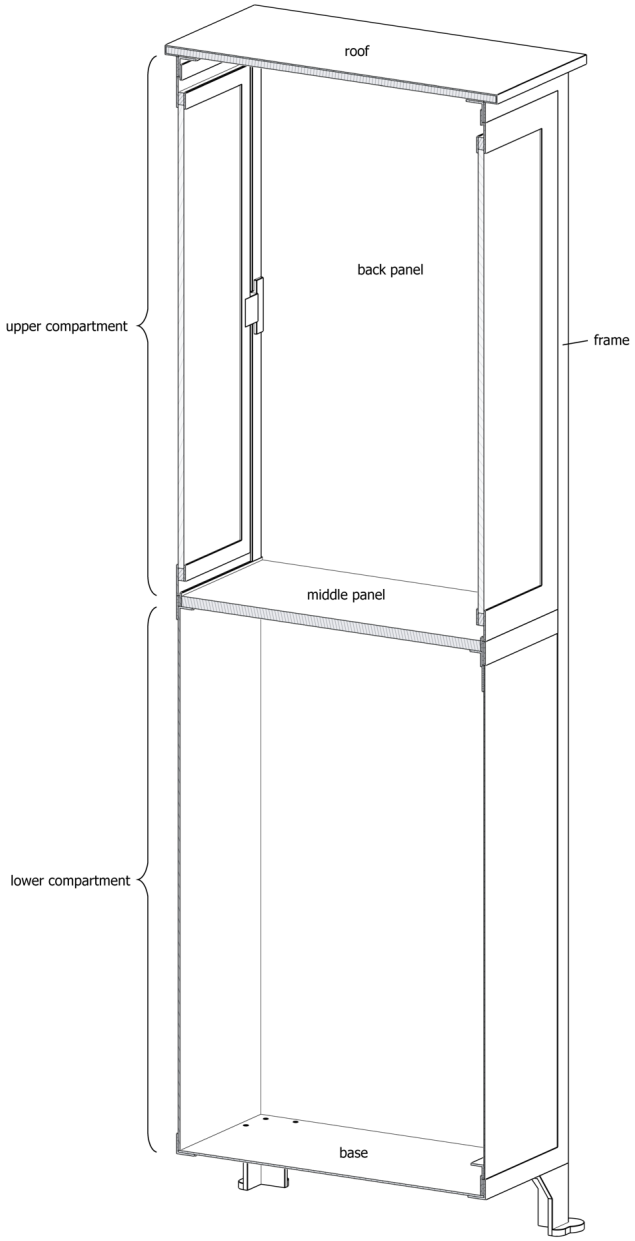

Fig. 7: Schematic section view of the structure of the Green Ray, without the internal elements

Fig. 8: Front display panel, without the upper front panel

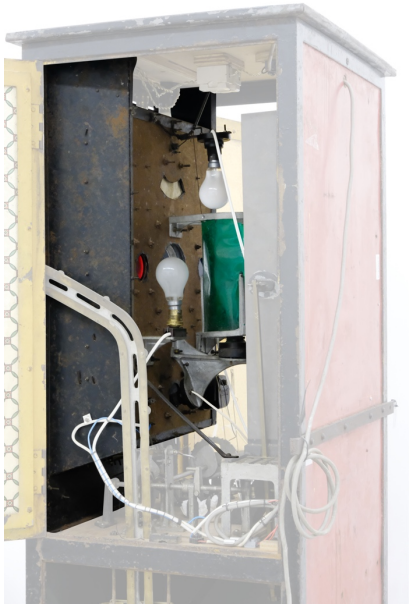

Fig. 9: Optimised photograph of the front display panel, view from the right side

2.3 Inscriptions

2.3.1 Inscriptions related to the function

To understand the function of this object, we should interest ourselves in a few of the advertisement inscriptions it displays.[48] The largest inscriptions can be seen on the upper right-side panel (see *Fig. 10*). The size of the characters makes the inscription clearly visible from afar, introducing the name of the machine as well as giving an idea of its function.

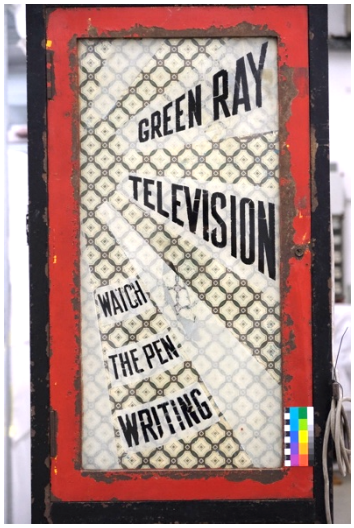

Fig. 10: Inscriptions on the upper right-side panel

Once we get closer and standing in front of the machine, we are greeted by more inscriptions which explain how the machine works and how to use it (see *Fig. 11* below).

The central sign (f.) seems to be in ebonite; it is giving instructions on how to operate the Green Ray and it warns the user that all the instructions must be followed in order to have a proper reading. The other inscriptions are printed on paper, except for the inscription (e.) which could be in Celluloid (it has an ivory look)[49]. The largest inscription (g.) is in cardboard.

Fig. 11: Inscriptions on the front display panel

a. The Green Ray can read you like an open book – The electric pen writes your character.

b. Television is the latest science. – Perfectly harmless. – No shocks.

c. Watch the electrically controlled magnetic pen writing.

d. Handle your card carefully on damp days as the special ink which has to be used does not dry very quickly.

e. ? Is this an illusion or a television wonder?

f. For a true reading insert one penny in the slot and stand in front of the Green Ray until the card is delivered from the pocket below – If you fail to carry out these instructions the reading will be a poor one

g. Have your mind read by television

[48] In this chapter we will not take into account the inscriptions found on the components of the electric circuit, they will be described later in the point 4.3.7 Electric components

[49] Shashoua, 2008, pp.20-22

We can notice in *Fig. 12* that the number "442" was added with a pencil under the text of the inscription a., it could eventually be the production number of the Green Ray.

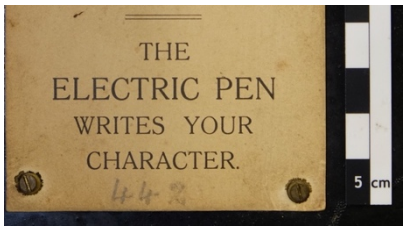

Fig. 12: Number 442 written with a pencil

After reading these instructions, we can conclude that after a coin is inserted, this machine "reads the mind" of the operator with the technology of television, and then writes the character of the operator on a small paper card with an electro-magnetically controlled pen; the card is dispensed to the operator by the machine at the end of the show (we can see one of these cards in *Fig. 13* and *Fig. 14*). Some of the cards are printed and come from a later exhibition of the object see *Fig. 15* and *Fig. 16*.

The majority of the cards display positive and supporting messages, whereas a few are telling the user that he was not concentrated enough and should try again with more focus. A list of the inscriptions on these cards can be found in Annexes p.83.

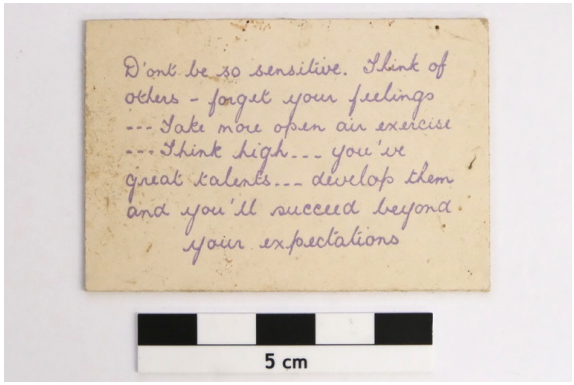

Fig. 13: Side of the card on which the character of the observer is written

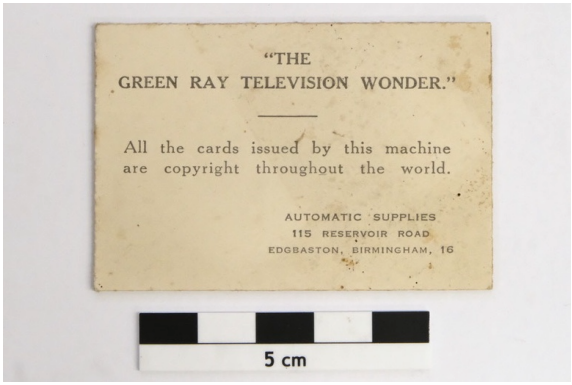

Fig. 14: Backside of the cards

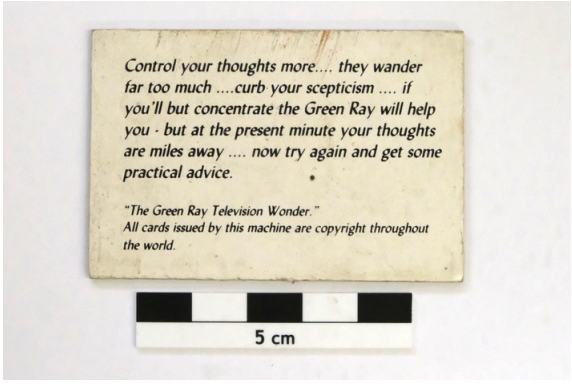

Fig. 15: Printed card

Fig. 16: Backside of the printed cards

Some labels are present on the object (see Annexes in p.85). They show the provenance of the object, which was bought in a Bonhams auction by the Deutsches Technikmuseum in 2009 (lot 690, The Michael Bennett-Levy Early Technology Sale, September 30th, 2009). The letter "W" was added on one of the labels, as we can see in the *Fig. 17*.

Fig. 17: Labels from the auction sale

There are four locks maintaining the panels of the Green Ray shut, three of them display the "CORBIN" brand (see *Fig. 18*) and one the "UNION" brand (see *Fig. 19*); It is a model 4143 "Cylinder Cupboard Lock" still in sale today, as found by comparing the pictures and measurements of the lock to the reference from the manufacturer (see Annexes p.87). The "CORBIN" locks were stamped with the inscription "THL11".

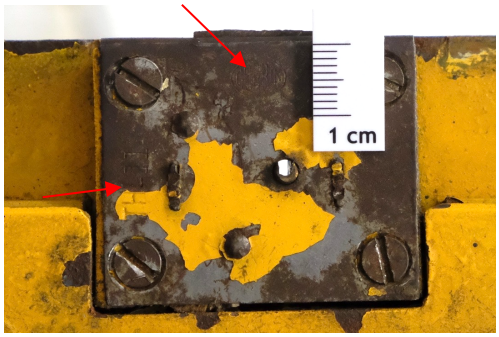

Fig. 18: "CORBIN" lock with the "THL11" stamp (upper right-side panel)

Fig. 19: "UNION" lock on the lower right-side panel

Inside the object, a cardboard box (see *Fig. 20*) was found containing some of the cards (see *Fig. 21*). On the inner side of the box was printed "Magnet – Universal Voltage Electric Iron – Cat. No. D5828. – Weight 3 lbs. - Consumption 300 Watts. – Please read carefully enclosed Folder giving instructions for Use. – Made in England. – Replace Element No. D3828. – Price 4/- each."

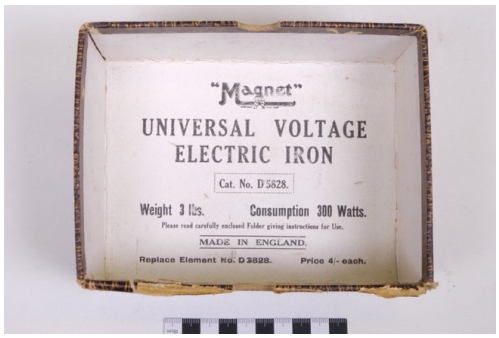

Fig. 20: Inner side of the cover of the box

Fig. 21: Cards inside the base of the box

In the lower compartment, the leather collecting bag for the coins has two "WRS" handwritten inscriptions, one on each side (see *Fig. 22*). In the upper compartment, gradation marks were done on the card dispenser where the cards were stocked, in order to know easily their quantity (see *Fig. 23*).

Fig. 22: "WRS" inscription on the collecting bag

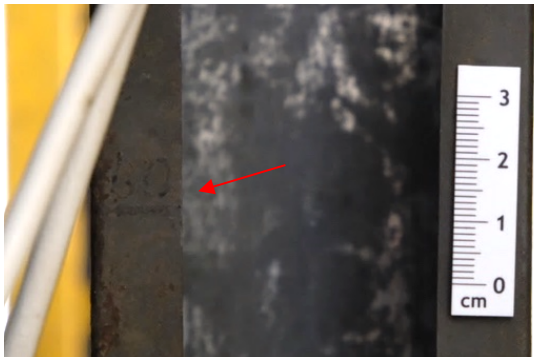

Fig. 23: Gradation mark for 60 cards in the card dispenser

3 Historical context

3.1 The birth of television

As the most observant readers have noticed, the *Green Ray Television Wonder* is intricately related to the concept of television. To understand this special relation, we will have to explain the historical context in which the object was created.

When this arcade slot machine was introduced in English fairs since 1931, the invention of television had just been announced by John Logie Baird[50].

At the time of its announcement and even later when it was more broadly released, television was seen as a technological wonder. The concept of television fitted into progressive ideas of spirit and magic: the scientific and the miraculous were perceived as identical by most of the people, electricity and television were seen as the miracles of the time[51].

The first experimental television service with daily programming was launched in late 1936 by the British Broadcasting Corporation (BBC), but the majority of the population did not have access to it, because of both a relatively small transmission distances and the purchase price of a television set, excluding the vast majority of people beyond the middle class[52]. We can therefore deduce that the public didn't fully grasp what television meant but people had already heard of it; this machine exploited the mystery surrounding this new concept, easily endowing the television technology with fortune-telling properties[53].

[50] Bennett-Levy, 1994, p.5
[51] Taylor, 2012, p.143
[52] Whitaker, 2016, p.214, and Taylor, 2012, p.143
[53] Sotheby's, 1998, lot 6, and Bennett-Levy, 1994, p.5

3.2 A few words about the inventor and its invention

The Green Ray Television Wonder was created by an English engineer called Granville Bradshaw who was widely known for his works on internal combustion engines[54]. In 1928, he was engaged by two people from the automatics world to design a machine that would be allowed to work in the streets despite the prevailing anti-gambling law. His inventions being successful, he became a partner in *Hope, Brashaw & Co.* by 1931, promoting the Green Ray Television which was first patented the same year in England under the number 28494/31[55], and by late 1932 the company was operating an arcade called *SpinFrit* in London[56]. The Green Ray was supposedly a thinly disguised copy of the "Human Analyst" designed by the Original Amusements Co[57]. The gambling machine patents and businesses held by Granville Bradshaw made him rich, unluckily he lost his fortune in a business deal, he then had to do his post-war work with limited resources[58].

Fig. 24: Fletchers Arcade at Gypsy Lane, Leicester in 1950. A Green Ray is used as a leaning post, we can notice the original artworks on the glass side panel. ©Joe Fletcher

The Fortune-Teller machines such as the ones previously mentioned were really common at the time in arcades and piers (see *Fig. 24*) and were as successful as real mediums[59]:

> "One observer collected forty-three different machines' character or palm readings on the same day. […] In the representation of his character, he found little with which he could disagree. Every phrase can refer equally to people of any age and either sex. The machine readings are vaguer and less elaborate than those given personally. But in terms of quantity, you get about six times better value for a penny inserted into a machine as per penny of your half-crown for the medium. None of these machines ever tells you anything about your future, except in the vaguest terms or as regards length of life. In fact, the penny card is no more than a statement of your character. […] Clearly people do not regard these machines simply as a joke. Mediums and clairvoyants charge half-a-crown. Even at a penny with the machines, there isn't much of a joke about it. There is no field for skill, competition, seeing something, laughter, or prize winning. It is the experience of observers that the great majority of people who patronise the occult believes in it. Often, they profess scepticism or mild disbelief, but the words that they have heard or read about themselves nevertheless have their effect."

[54] Braithwaite, 1997, p. 51
[55] Braithwaite, 1997, p. 51
[56] Braithwaite, 1997, p.72
[57] Braithwaite, 1997, p.72
[58] Bickerstaff, 2015, [Online]
[59] Cross, 2005, p.123-124

4 How the Green Ray works

4.1 Comprehension by reverse-engineering

Because we did not find any documentation relative to the working principle of the Green Ray, the most precise description of its functionality at our disposal came from the inscriptions on the object. By reading them, we can deduce that the electro-magnet controls the pen, which writes the character of the operator on a little card (we can nonetheless emit strong doubts concerning the mind-reading properties of the Green Ray…).

To understand how it really works, we need to open the object and use the reverse-engineering method. This way of proceeding is quite common for undocumented technical heritage, it consists in observing the components and parts forming the mechanism and electric circuit, in order to extract information, deduce their function and finally gain a complete comprehension of how the object operates. The visual description methodology used is taken from *SCHEMATEC*, a tool developed at the HE-Arc CR (see Annexes p.88).

4.2 Overview of the functionality

4.2.1 Photographs

Fig. 25: Upper front panel of the Green Ray, with the coin slot visible on the frame at the right

Fig. 26: Interior of the Green Ray viewed from the left side

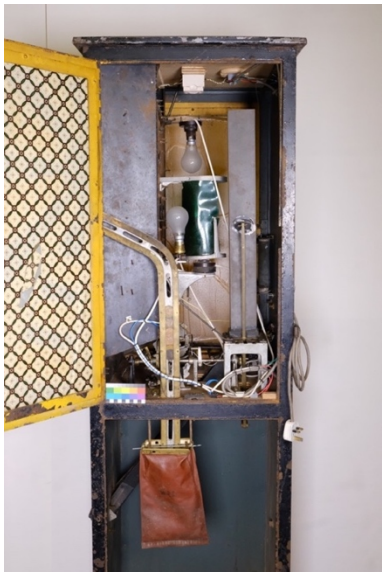

Fig. 27: Interior of the Green Ray viewed from the right side

4.2.2 Function diagrams

In order to facilitate the global understanding of the functionality, a useful tool is the realisation of function diagrams. The Green Ray could be represented as a box with inputs (consumables, energy supply, etc.) and outputs (product and other outputs) which allow the object to serve its function (see *Fig. 28*).

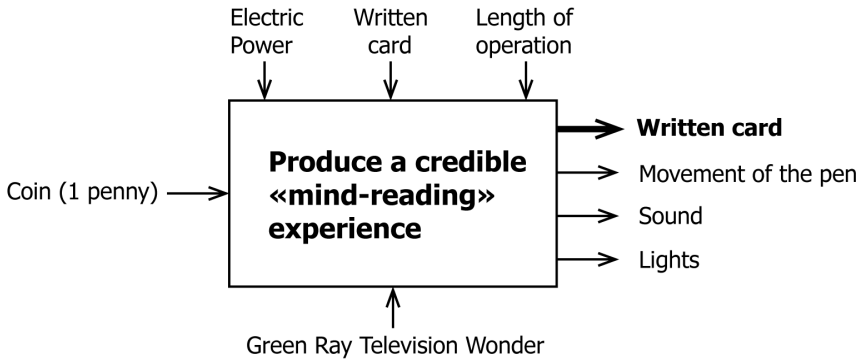

Fig. 28: SADT (Structured Analysis and Design Technique) function box of the Green Ray

The input from the left side is a coin, which is "consumed" by the object to trigger the function. The other necessary inputs for the proper use of the object are placed on top of the schematic, they are controlled by the owner of the machine. These inputs are electric current which will power the mechanism and electric components, an already-written card stock ready to be dispensed to the operator (here is the trick!), and the control of the speed of the operating cycle, influencing the time length of the operation (or "mind-reading" experience). Besides the card, the outputs displayed are the movement of the pen, the lights and the sound during the operation.

Fig. 29: Graphic version of the previous schematic, with the different interaction types

Another visual way of showing this level of description can be seen below in *Fig. 29.* There are two types of interactions with the object: the operator inserting a coin in the hope to have a mind-reading experience, and the owner of the machine or person responsible for its maintenance who adjusts the length of the mind-reading experience (it was probably set by the manufacturer, but each owner had the possibility to modify it) and inserts the written cards which will later be distributed to the operator.

4.2.3 Illusion or television wonder?

Fig. 30: Glass lens on the front of the Green Ray

The functionality of this object could be divided into two interconnected circuits: a mechanical circuit or mechanism, and an electric circuit. Some of the functional components are electromechanical, it means that they will play a role in both of these circuits, such as switches which let electric current pass only when they are activated by a cam, or a motor which transforms electricity into mechanical movement. This type of objects is relatively easy to apprehend because their components are often clearly recognisable, whereas the technical objects manufactured a few decades after can be more difficult to decrypt. In the course of the 20th century the larger electromechanical components were put aside from technical objects for the use of electronics, miniaturisation and computers. These objects often became impenetrable black boxes, which can nor be opened nor be repaired by the user, who knows only the function and not the working principle of the object[60].

After we opened the object and we observed the mechanism and electromechanical parts, we uncovered the real working principle of this machine: an already-written card is simply dispensed out of the machine, after a motor activated cams switching on and off intermittently the different lightbulbs and buzzer, and mechanically moved the pen via a network of gears and axes. What could look like a cathodic tube in the front is in reality a simple glass lens (see *Fig. 30*), illuminated from behind by a lightbulb when it is operating. There is no electro-magnetic device controlling the pen. Furthermore, nearly all the front electric components that we can see from outside are decorative only, being linked to nowhere in the electric circuit (see chapter 4.3.8). The manufacturer of the Green Ray displayed decorative electromechanical components (see *Fig.* 31) and deceitful inscriptions to make the users believe that there was an electro-magnet controlling the pen, and that the object was more complex than it really is.

What is really interesting with the Green Ray is that it plays with these two notions of easily recognisable electromechanical components and closed black box. The outside is selling a mind-reading experience, by displaying recognisable decorative components and deceitful inscriptions which lead the operator to trust the presence of futuristic technology, when in reality most of the work inside the box is done electromechanically with a "simple" analogue technology, which was carefully kept away from the sight of the operator.

Fig. 31: Decorative cables and metallic elements simulating the presence of an electro-magnet

[60] Brenni, 1997, pp.29-30

4.2.4 Mechanism

We will first look at an overview of the mechanical circuit. The mechanism is located on the wood panel in the middle of the object. The alloys used for the mechanism are mainly brass with a metallic coating, and the pieces which are subjected to most mechanical resistance are made of steel. The motor casing is in aluminium-based alloy. In the following *Fig. 32* and *Fig. 33*, we can see the mechanism from both sides, with the sub-systems which have been colour coded.

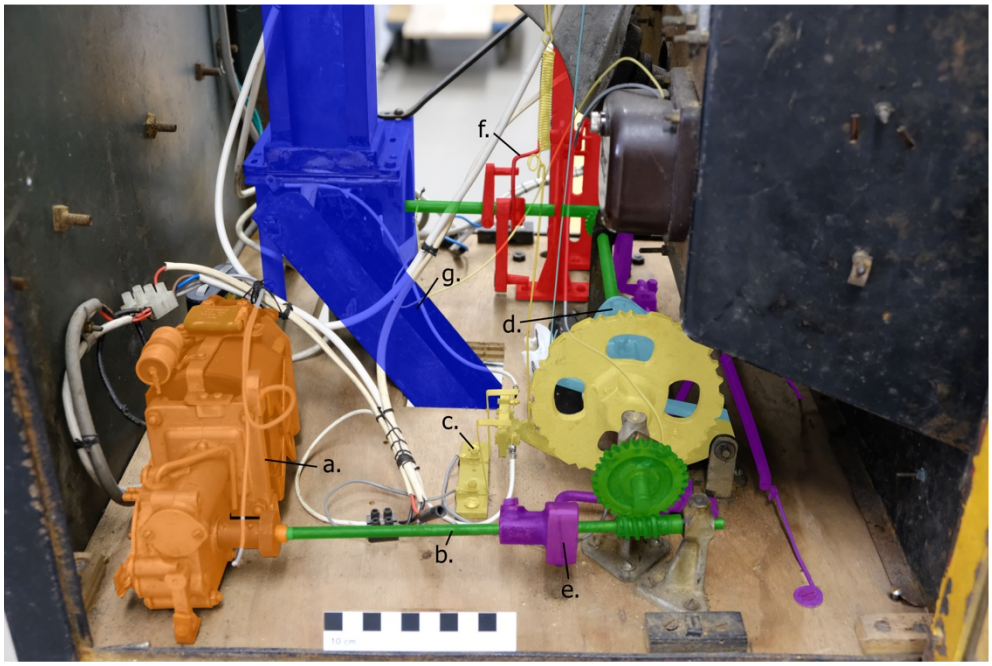

Fig. 32: Optimised photograph of the mechanism from the left side, we can see that the card ramp goes through the middle panel; a. motor, b. axes, c. mechanical switch, d. neuro-lectrons detector, e. pen movement system, f. mercury switch assembly, g. card dispenser

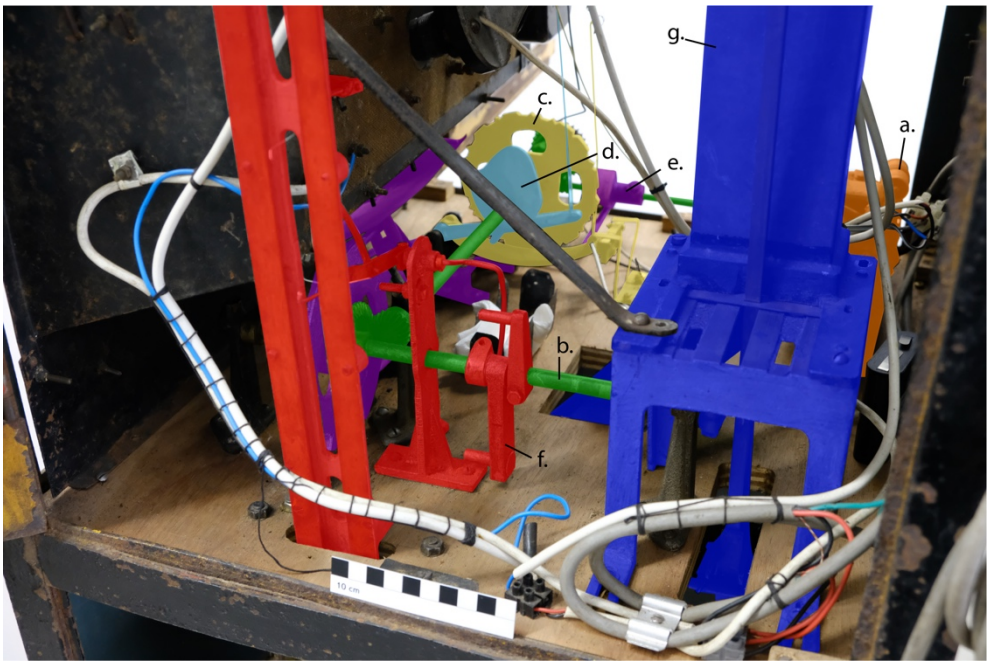

Fig. 33: Optimised photograph of the mechanism from the right side

On the basis of these images, we created a schematic illustration viewed from above to hopefully make their location easier to apprehend (see *Fig. 34*).

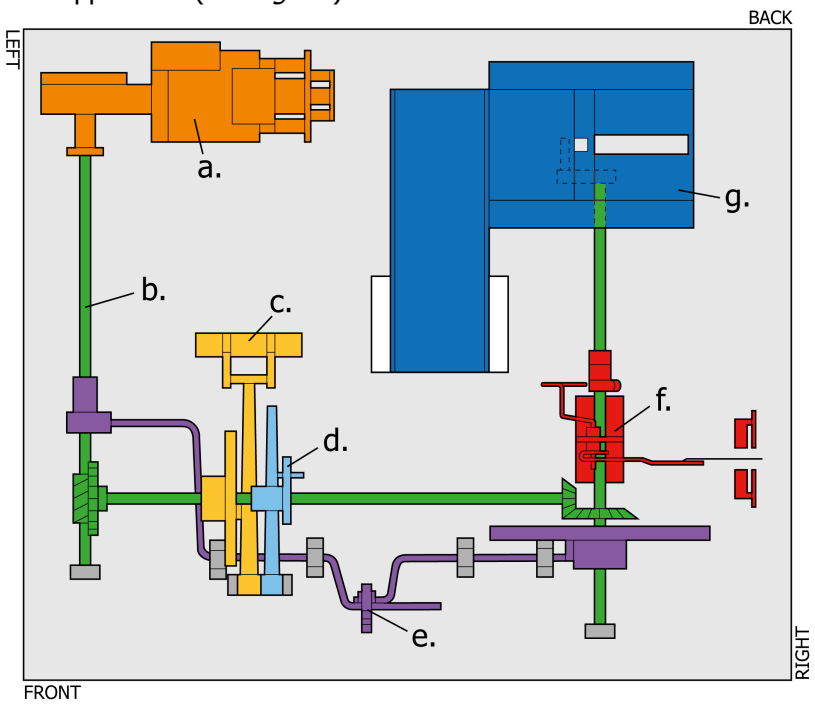

Fig. 34: Schematic representation of the middle panel with the location of the sub-systems, viewed from above

Fig. 35: Coin slot situated on the frame

To make it operate, a coin has to be inserted in the Green Ray in the coin slot present on the right of the front display panel, on the frame (see *Fig. 35*). It then falls along the coin slide (it is part of the mercury switch sub-system f.), and it activates the mercury switch, which will allow the electricity to power the motor (a.) (the relations between the different sub-systems will be explained further into details in the next points). The motor will move all the other organs via the three axes (b.). These organs are the mechanical switch (c.), which will trigger elements in the electric circuit; the neuro-lectrons detector (d.), which moves the needle of said detector which is visible on the front display; the pen movement system (e.), allowing the vertical and horizontal movements of the pen. At the end of the operating cycle, an already written card is delivered to the operator through the card dispenser (g.). The card will be pushed on the ramp and slide down until it reaches the pocket in the lower front panel, where the operator receives it.

4.2.5 Electric circuit

Now that we have an idea of the electromechanical components and their role in the functionality, we will explain the electric circuit. In order to operate, the object has to receive electric power from an alternative current source. There are a lot of messy cables inside the object, and we need to understand how the electric components are linked together to understand how the object works.

We drew an electric circuit diagram, allowing us to simplify the representation of the circuit. The first diagram of the electric circuit we did was a representation which represented the components and wiring the way they are observable (see Annexes p.88). This type of representation is a useful step in the process of producing a normalised wiring diagram because it differentiates the different cable colours or types and where they are divided, it is easier to link mentally to our physical object. On the basis of this first representation, we verified if the components were connected by using a multimetre on the two extremities of the segments we wanted to test. It can prove really useful when the cables are difficult to follow due to the low access or if they are attached together. The final electric circuit wiring diagram is presented in the *Fig. 36* below:

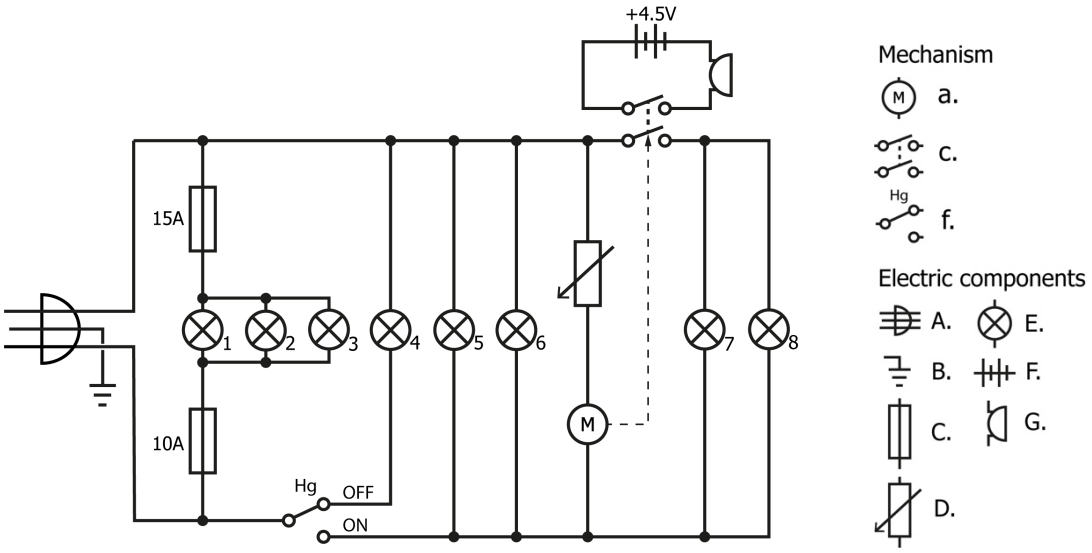

Fig. 36: Electric circuit wiring diagram, a. motor, c. mechanical switch, f. mercury switch; A. plug, B. grounding, C. fuse, D. rheostat, E. lamps, F. battery, G. buzzer

As we can see, when the plug is connected to a source of power, some of the lamps will be illuminated by default, without the operating cycle being started by the mercury switch. These lamps are the number 1, 2, 3, protected by fuses which are fixed under the roof of the Green Ray, and the lamp 4.[61]

When a coin is inserted in the object, the mercury switch is flicked to the ON position. The electric current will power what we could call the operating circuit: the "show" lamps 5, 6, 7 and 8 will we be powered, and the motor will start rotating thus activating the mechanism.

As we discussed in the previous point, some of the components are electromechanical and play a role in both circuits, it is the case of the mechanical switch. This switch is open by default, but the movement of the motor closes it intermittently via a cam, resulting in the flickering of the lamps 7 and 8 and the jolting activation of a buzzer, powered by a separate 4.5V battery.

There is a rheostat in the electrical circuit, it plays the role of a variable resistance; by modifying the value of the resistance, the rotation speed of the motor can be adjusted, which will result in a shorter or longer time of the operating cycle.

[61] See point 4.3.7 Electric components to see where they are located on the object.

4.3 Sub-systems and components explanation

We will continue the description of the object by representing the interactions between the different organs and sub-systems which allow the "box" to go through with its function (see *Fig. 37*). Each sub-system is represented with a box and the interactions between sub-systems are represented with arrows. The interactions within the different sub-functions can be a link (mechanical, electrical, etc.) or a flux (material, energy, etc.).

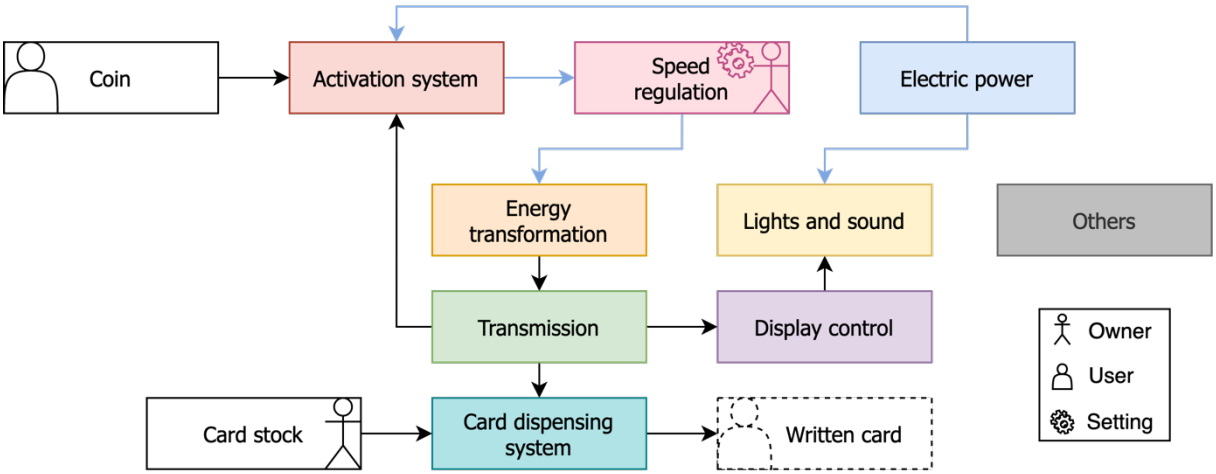

Fig. 37: Organigram of the sub-functions of the Green Ray, black arrows signify a mechanical movement or input, blue arrows are electric current; the white boxes are the physical inputs, and the physical output is represented with the dotted lines

The grey "Others" box contains all the other elements of the object which do not directly take part in the functionality, but still assure a certain function in the object, such as decorative elements, structural elements, protective elements.

In the *Fig. 38* below, we associated the previous sub-functions to the parts of the object which will be described more thoroughly in the next points.

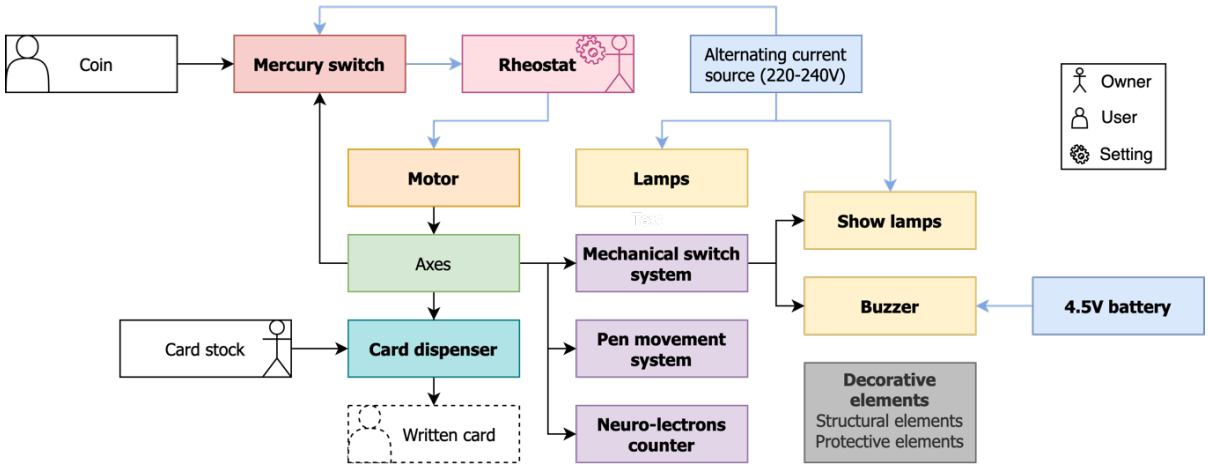

Fig. 38: Organigram of the sub-systems of the Green Ray, with the sub-systems we will describe in the next chapter in bold characters

4.3.1 Mercury switch

Fig. 39: Mercury switch on the front display

The operation if the object is regulated by the mercury switch visible on the front display panel (see *Fig. 39*); it is the organ which lets the current pass through the operating circuit or not: the electrically conductive mercury inside of it can flow and depending on the tilt of the switch, it will connect the middle wire to either the left or the right wire. On the other side of the front display panel, the assembly is visible (see *Fig. 40*). The three wires visible in the front of the Green Ray are connected on the back of the panel; we did not show the links of these cables to the electric circuit in the following figures, we only indicated which cables were the ON/OFF for the operating circuit.

In the *Fig. 41*, we can see that when a penny (a.) is inserted in the Green Ray, it falls along the coin slide (b.) on the activation lever (c.), which tilts the mercury switch by pulling the arm (e.). The mercury switch is then tilted in the ON position. The gravity makes the mercury flow and make contact between the middle wire and the ON wire, in order to transmit the electric current between them and activate the operating circuit.

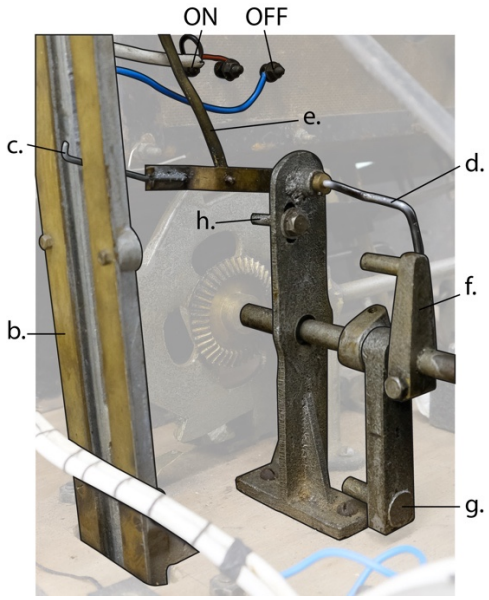

Fig. 40: Optimised photograph of the mechanism of the mercury switch assembly inside the object

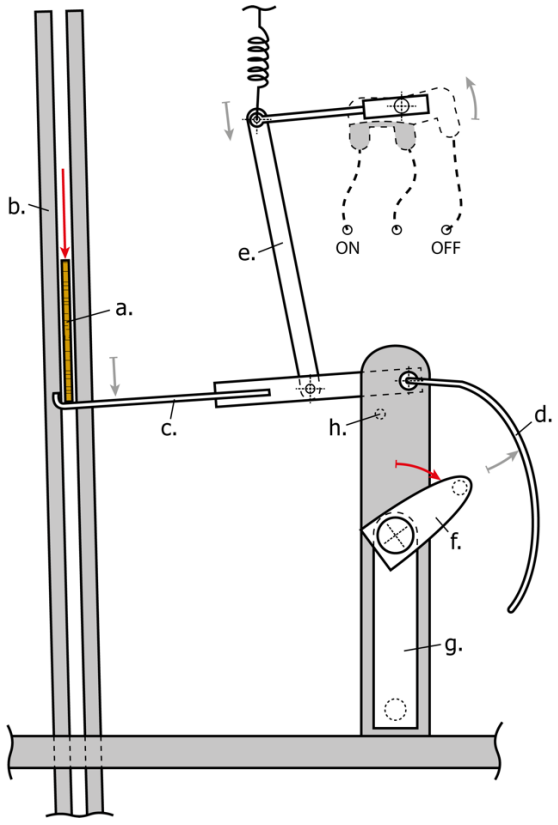

Fig. 41: Functional schematic representation of the mercury switch during the activation and start of the operation; the red arrows are leading movement; the grey arrows are followed movement

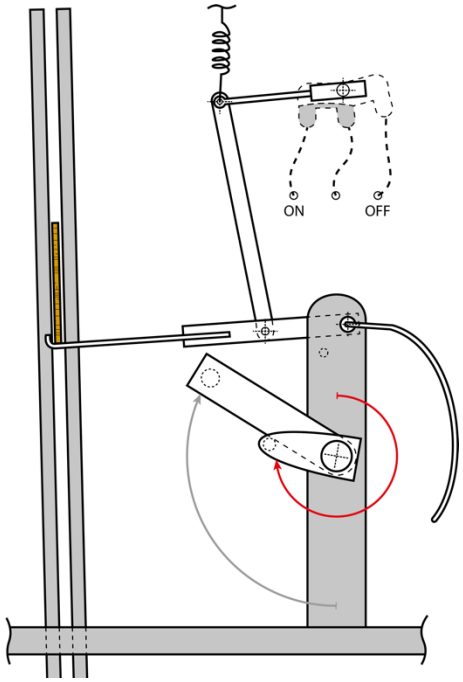

Fig. 42: Functional schematic representation of the mercury switch; the operation cam lifts the free stop cam when it rotates

When the operating circuit is activated, the axes and the operation cam (f.) fixed on it start rotating under the action of the motor. While it starts the second half of the full rotation, the operation cam (f.) pulls the stop cam (g.) along in its course (see *Fig. 42*), because the stop cam is not fixed on the axis and is free to move around it. During the whole operation, the coin is maintained on the lever (c.) and keeps the mercury switch in ON position.

Once the operation cam (f.) reaches its initial position after a full rotation (see *Fig. 43*), the stop cam (g.) falls back down due to the action of gravity. During its fall, it pushes the stop lever (d.), which then tilts downwards the activation lever (c.) up to the stopper (h.), freeing the coin and letting it fall in the collecting bag in the lower compartment.

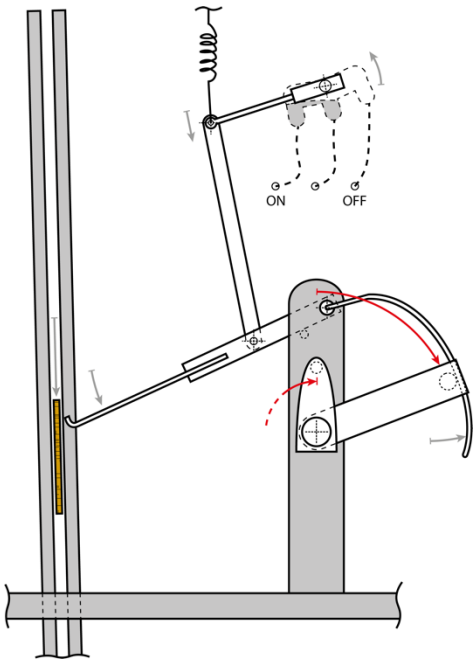

Fig. 43: Functional schematic representation of the mercury switch; the stop pushes the stop lever in its course, freeing the coin

Because the coin is not sitting on the activation lever (c.) anymore, this one can get back to rest position (see *Fig. 44*) thanks to the spring linked to the arm (e.). The mercury switch is back in OFF position, which means that the electric current does not power the operating circuit anymore. Because the operating circuit is unpowered, the rotation of the motor, axes and cams is stopped.

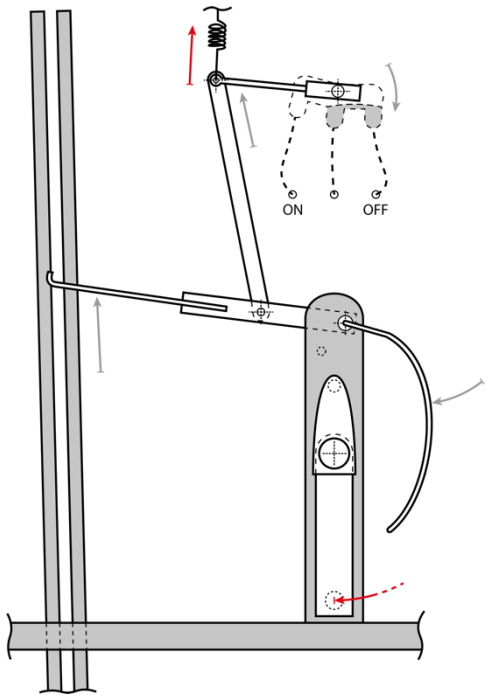

Fig. 44: Functional schematic representation of the mercury switch; return to rest position (OFF)

The cycle is ready to restart when a new coin is inserted in the Green Ray.

4.3.2 Motor

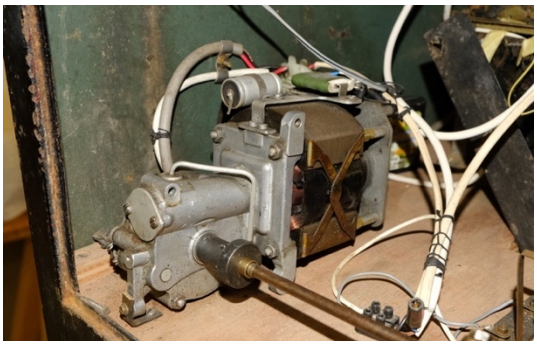

Fig. 45: Motor inside of the Green Ray

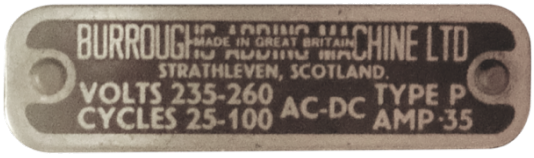

Fig. 46: Inscription sign on the motor

The motor in the Green Ray (see *Fig. 45*) has the role of transformation of the energy: it is powered by electric current and transforms this energy into kinetic movement. The motor in this object is a single-phase motor, also called universal motor because it can work both with direct and alternative current.[62]

When the electric current powers the operating circuit through the activation of the mercury switch, the motor which is present in this circuit is powered and starts the rotation of the axes, thus rotating all the cams previously mentioned in the previous sub-systems.

The electric motor present in the Green Ray was manufactured by Burroughs Adding Machine Ltd., in their Strathleven factory in Scotland (see *Fig. 46*). This information reveals us that the motor cannot be dated earlier than 1947[63], the year when this factory was opened. The Green Ray was patented and sold in the early 1930s, it is therefore a later addition taken from another machine created by the Burroughs company; we can see an example of one of these machines with a similar motor in the *Fig. 47*. Underneath the motor, we found another inscription, as we can see in *Fig. 48*.

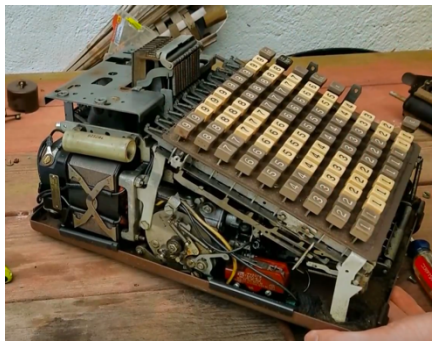

Fig. 47: Photograph from a Burroughs 1940s Class 3 Adding Machine ©bss1250

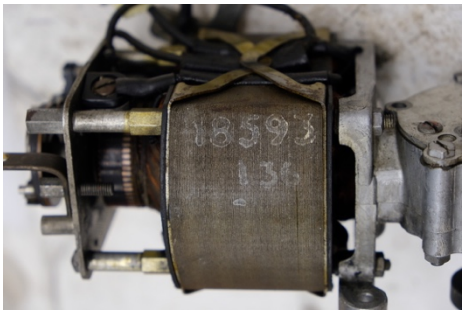

Fig. 48: Numbers 18593-136 written on the motor

[62] Jeanrenaud, 1973, pp.160-162 and p.339

[63] Vale of Leven, 2020, [Online]

4.3.3 Pen movement system

This system mimics the movement of a pen writing by moving its support. It is constituted of two sub-systems (see *Fig. 49*): the horizontal movement (H) and the vertical movement (V). The horizontal movement is constituted of a ratchet (c.), a lever (d.), a hook (i.) and a rubber washer (j.), and a spring (e.); the vertical movement is constituted of a cam (f.), a lever (g.) and a spring (h.).

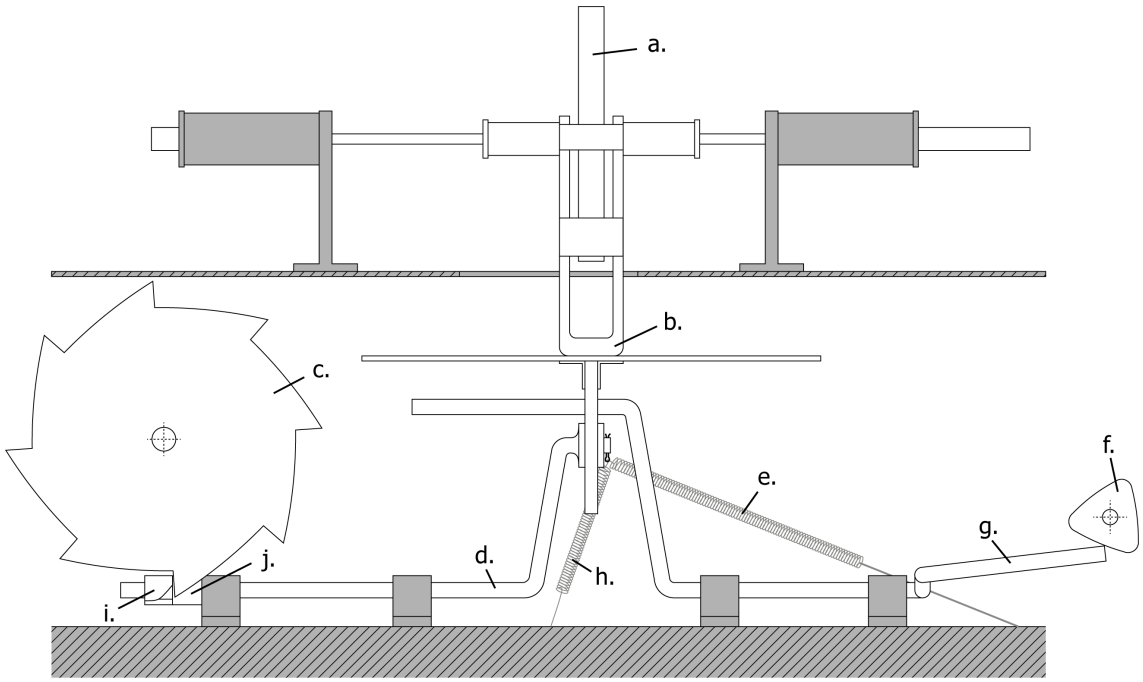

Fig. 49: Functional schematic representation of the pen movement system at rest, viewed from the back. a. pen, b. support, c. ratchet, d. lever (H), e. spring (H), f. cam, g. lever (V), h. spring (V), i. hook, j. rubber washer

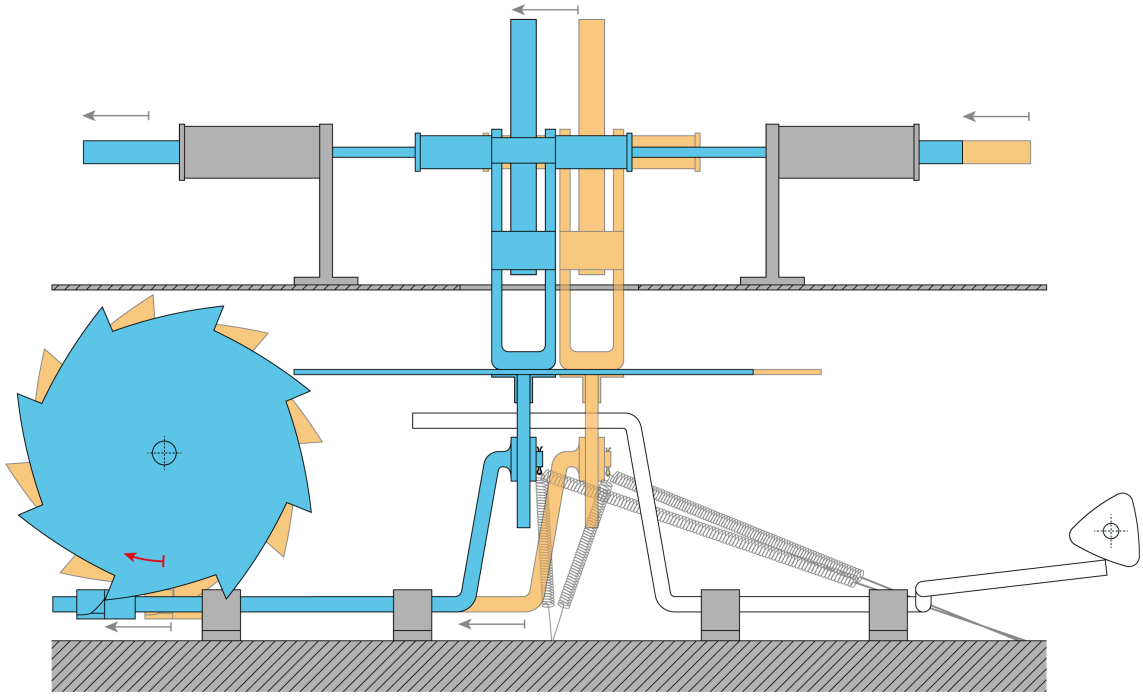

Fig. 50: Sequential functional schematic representation of the pen movement system after 1/8th of the ratchet rotation (in blue), viewed from the back; the orange represents the initial position

When the operating circuit is powered with electric current through the mercury switch, the motor rotates the axes and thus ratchet fixed on it. The teeth of the ratchet pull the hook of the lever (i.) and thus make the pen move horizontally (see *Fig. 50*). When one of the eight teeth of the ratchet is no longer in contact with the hook after pulling it, the pen is allowed to move back to its original rest position by the force of the spring (e.), the ratchet will then continue its rotation and restart the pen's movement. The shock of the lever (d.) returning to its position is absorbed by the rubber washer (j.).

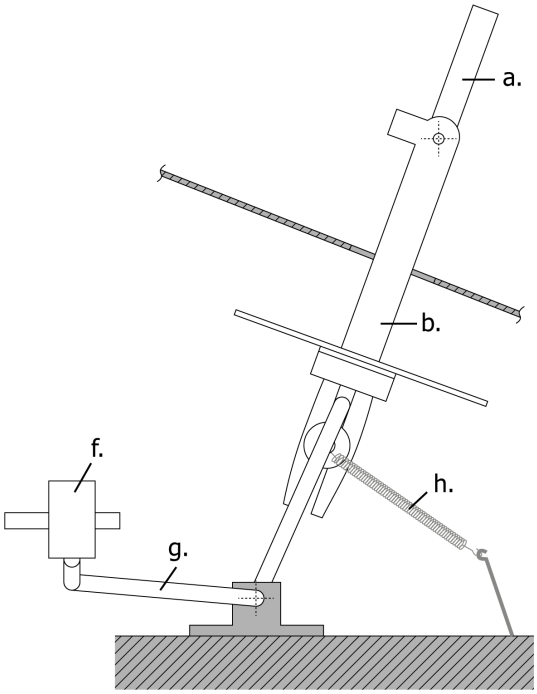

Fig. 51: Schematic representation of the pen movement system in rest position, viewed from the left.

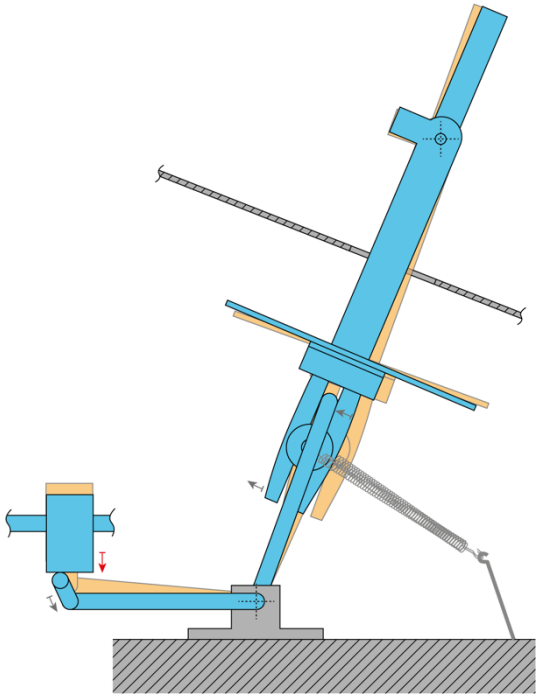

Fig. 52: Sequential functional schematic representation of the vertical movement during operation, viewed from the left.

For the vertical movement, the cam (f.) rotates and pushes down the lever (g.), which tilts the support (b.) and the pen (a.) fixed on it. The system goes back to its rest position by the force of the spring (h.).

4.3.4 Mechanical switch system

The mechanical switch system (see *Fig. 53*) allows the blinking of the show lamps and the intermittent activation of the buzzer. The cables visible are linked to these elements.

It is made of a cam (a.), a lever (c.) and metallic surfaces for the transmission of electric current. Two bent metallic strips (d.) are connected to the secondary circuit, and on the end of the lever a metallic bar (e.) is connected to the primary source of power.

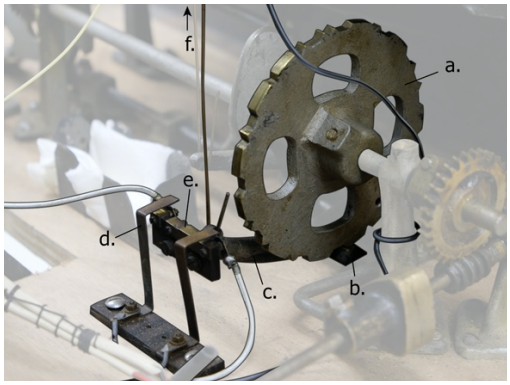

Fig. 53: Optimised photograph of the mechanical switch

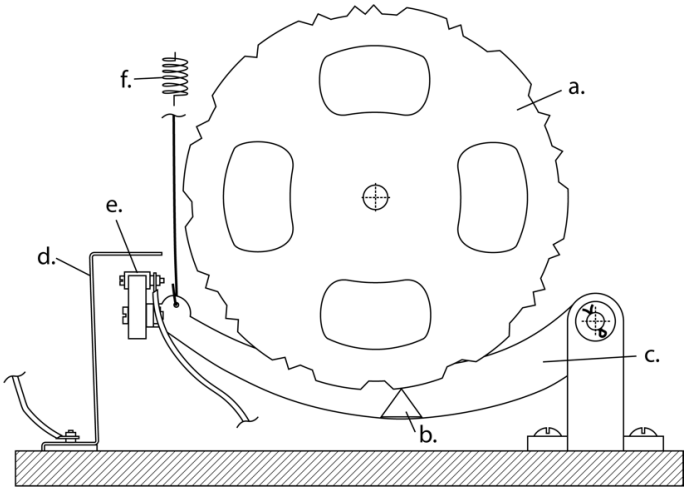

Fig. 54: Functional schematic representation of the mechanical switch in rest position

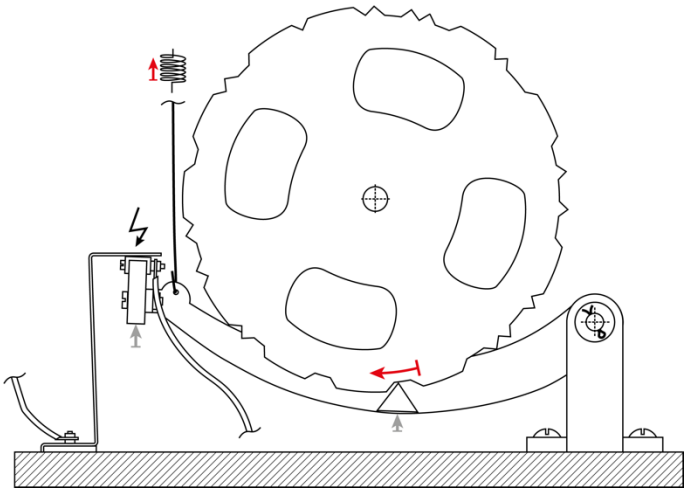

Fig. 55: Functional schematic representation of the mechanical switch when it is in the ON position

1. OFF position

When the machine is not activated (see *Fig. 54*), the cam (a.) is maintaining the sensor (b.) of the lever (c.) downwards, the metallic surfaces (bent metallic strips (d.), bar (e.) at the end of the lever) are not in contact and therefore no electric current is allowed to pass. During the operation, the profile of the cam will create a pattern of activation/deactivation.

2. ON position

Once the operating circuit is powered by electric current through the mercury switch (see *Fig. 55*), the motor rotates the axis on which the cam (a.) is placed, which leads to the movement of the cam itself. Due to the profile of the cam, the lever (b.) is sometimes allowed to be pulled upwards by the spring (f.), creating a contact between the metallic surfaces (d. and e.). The electric current can then pass and the switch is activated.

4.3.5 Neuro-lectrons detector

Fig. 56: Photograph of the detector on the front display

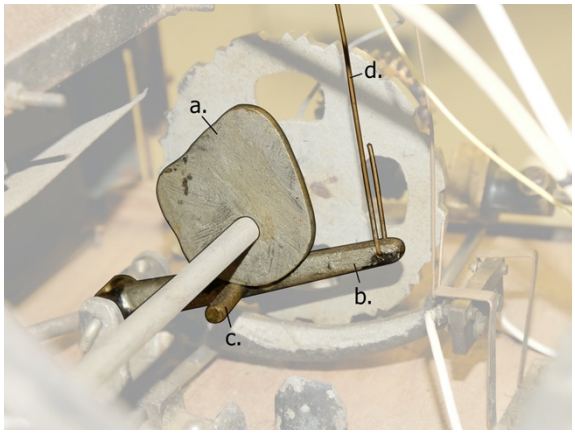

Fig. 57: Optimised photograph of the cam and lever of the neuro-lectrons detector

The neuro-lectrons detector is a device present in the front display of the Green Ray (see *Fig. 56*). The role of this organ is to make the operator believe that the Green Ray is reading the mind of the operator, by displaying a moving needle on the detector.

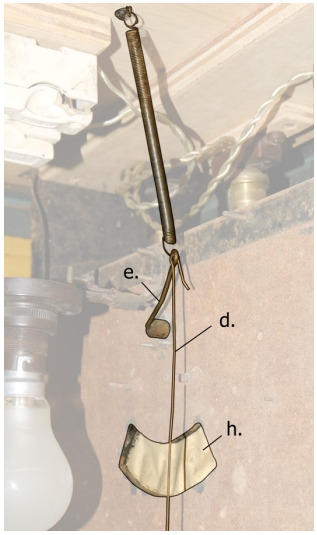

Fig. 58: Optimised photograph of the neuro-lectrons detector, view of the back panel

This sub-system consists of two parts: a red needle (f.) visible through the glass (g.) of the detector on the front display panel, with a graded paper on the back (h.); and a lever (b.) and a cam (a.) situated next to the mechanical switch in the mechanism (see *Fig. 57*).

We can see the back side of the detector on the display panel in *Fig. 58*.

When the object is in operation, the cam rotates with the axis it is fixed on, and it pushes the sensor (c.) of the lever in its rotation (see *Fig. 59*). A steel wire (d.) is linked from the lever to the arm (e.) of the needle on the back of the front display panel, and to the spring fixed on the ceiling of the upper compartment. The sensor of the lever is always in contact with the cam because it is pulled up by the spring.

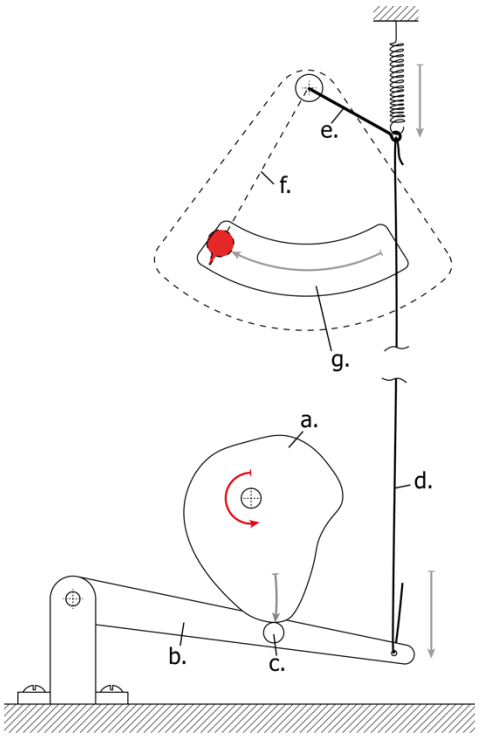

Fig. 59: Functional schematic representation of the neuro-lectrons detector activated by the cam during the operation

4.3.6 Card dispenser

Fig. 60: Optimised photograph of the card dispenser, view from the left side

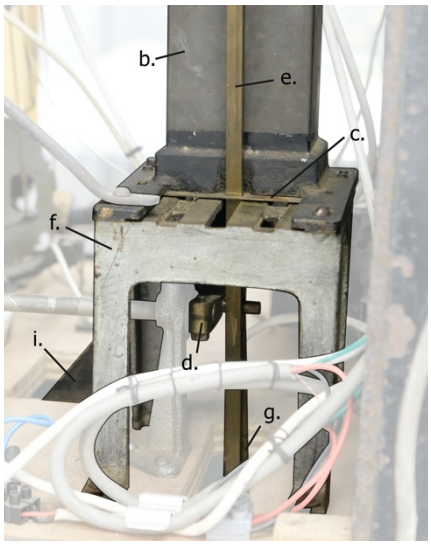

Fig. 61: Optimised photograph of the card dispenser, view from the right side

The card dispenser is the system which distributes one card of the already-written cards to the operator at the end of the show. It is constituted of many different elements which are located inside the object, the only one visible from the exterior is the card pocket on the middle of the lower front panel.

In the *Fig. 60* and *Fig. 61*, we can see the different elements constituting the card dispenser. Before the operation of the object (see *Fig. 64*), a stock of cards (a.) has to be placed inside the container (b.), with a weight (j.) on top of it as we can see in Fig. 62. The cards will lay on top of the pushing plate (c.), which is traversed by the pushing lever (e.) in a square hole inside it.

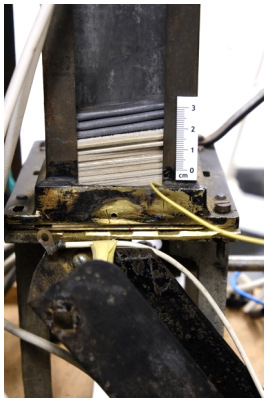

Fig. 62: Detail of the card stockpile with the weight on top, (left side view)

The first phase of the movement takes place when the operation starts: the cam (d.) rotates and moves the pushing lever (e.) and the pushing plate. At the half of the rotation, the card pile will be able to descend directly on the surface of the support (f.) (see *Fig. 65*). In the second phase of the movement, the cam will push the return lever (g.), and by extension the pushing lever (e.) via springs (h.). The pushing lever and the pushing plate are moved forwards, the card at the bottom of the pile will be pushed in the ramp (i.) by the plate (see *Fig. 63*). The weight (j.) on the cards ensures that the bottom card is flush with the pushing plate and is moved in the ramp. At the end of the cycle, the card dispenser returns to its rest position again and the cam has done a full rotation. The card is delivered to the operator in the card pocket situated on the lower front panel, at the bottom of the ramp.

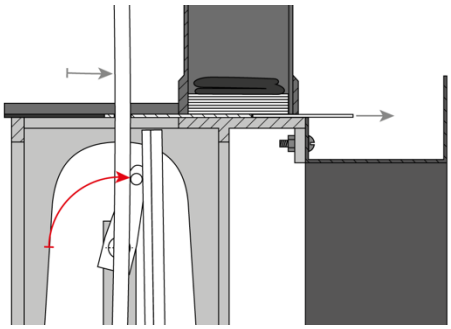

Fig. 63: Detail of a functional schematic representation of the card dispenser, when a card is pushed in the ramp

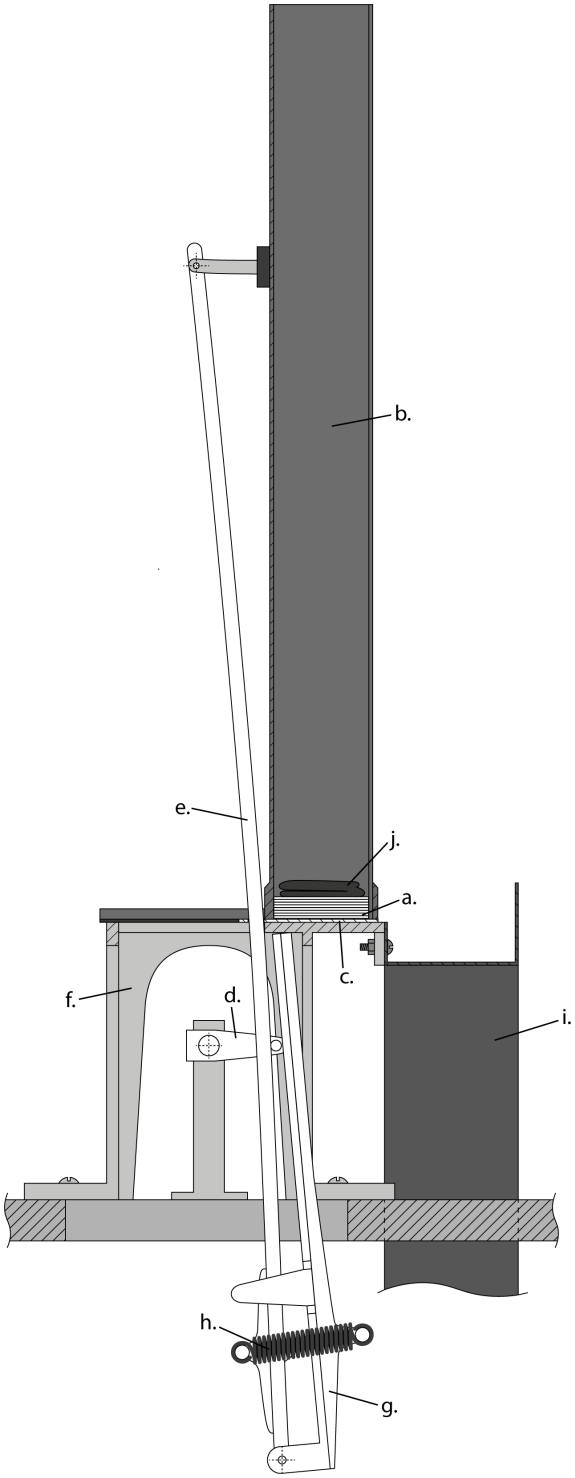

Fig. 64: Functional schematic representation of the card dispenser in rest position

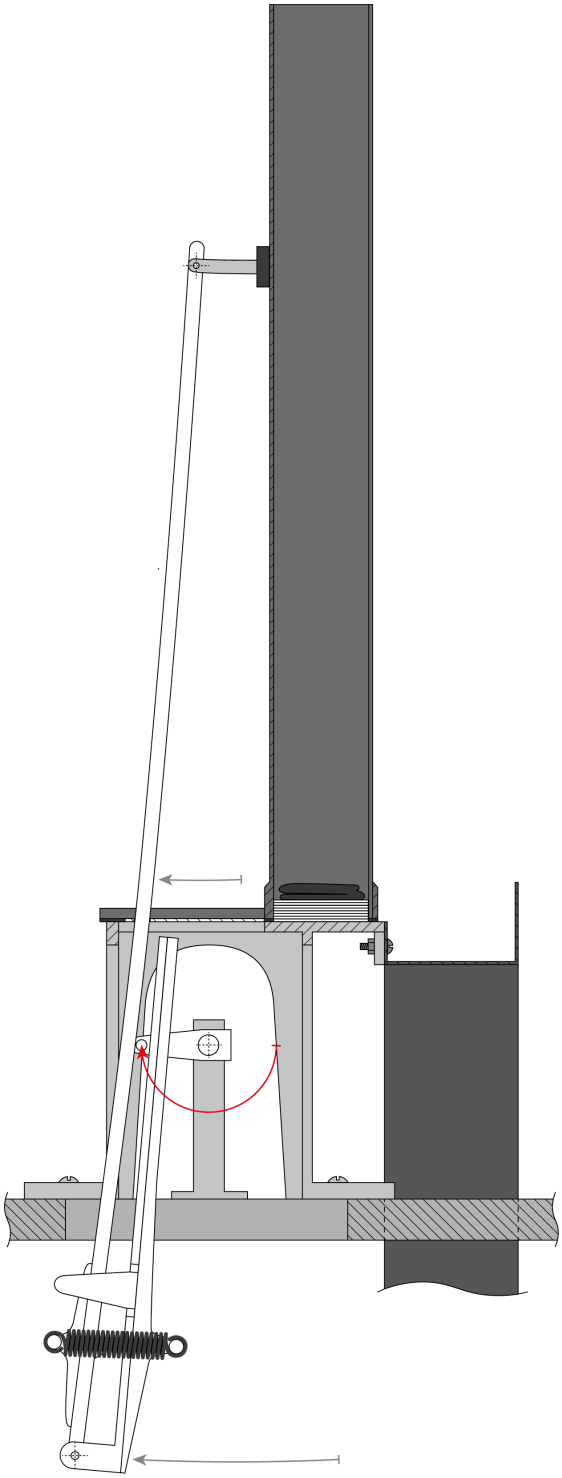

Fig. 65: Functional schematic representation of the card dispenser after half of the length of operation cycle

4.3.7 Electric components

Electrical plug

Fig. 66: The plug at the end of the grey cable, back view

To be powered with electricity, the Green Ray has a plug to receive an alternative current (see *Fig. 66*). This plug has three pins (it has a earth "E⏚", neutral "N" and line "L" wires) and is a 13 amperes plug type G (see *Fig. 67*). It has the inscription "BS 1363" (BS for British Standard), this type of plugs was introduced in 1947.[64] The most likely original plug type used when the object was created was either BS 317 (1928) (see *Fig. 68*) or BS 372 (1930) (see *Fig. 69*). Both of these earlier plugs had two versions, one with only two pins (unearthed) and one earthed with three pins. Because the wiring of the object has been replaced in its integrality in previous interventions, we cannot be sure that the Green Ray was initially earthed.

Fig. 67: The BS 1363 plug of the Green Ray

Fig. 68: Three pins BS 317 plug (earthed) ©www.theiet.org

Fig. 69: Two pins BS 372 plug (unearthed) ©www.theiet.org

Fuses

Fig. 70: Location of the fuses inside the Green Ray, left view

There are two fuses fixed on the ceiling of the upper compartment of the Green Ray (see *Fig. 70* and *Fig. 71*). They are protecting the first lamps 1, 2, 3 against overcurrent. Inside of the fuse boxes, there is a metal thread that will melt if the electric current is too strong and risking damaging the electric components. The inscriptions on the fuses are the following: Left: "Ω – NEATA – 10A – 250V." Right: "MEM ENGLAND – MEM – 15AMP MAX – KANTARK – 250.V. – WIRE 26 S.W.G."

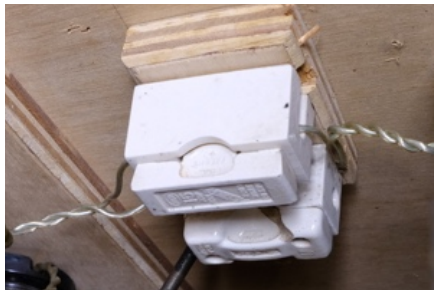

Fig. 71: The fuses fixed on the ceiling of the upper compartment

If a current is excessively strong, the fuses will melt, preventing the damage it could do to the electric components. The way it is linked now only protects the first three lamps, this could have been caused by successive and maybe inattentive modifications.

[64] Peacock, 2013, p.19

Rheostat

Fig. 72: Location of the rheostat inside the Green Ray, left view

In the Green ray, the rheostat is fixed with two bolts on the inside of the back panel (see *Fig. 72*).

The rheostat plays the role of a variable resistance. In the electric circuit, it is linked in series with the motor, allowing it to regulate the rotation speed of the motor and thus the length of the operation cycle. Gradation marks help to set up the resistance, and inscriptions are written underneath it (see *Fig. 73*). The white fibers that we can see next to the coils on *Fig. 74* are asbestos, a material which can be dangerous for health, we will speak of this matter in the chapter 9.2 Undergone interventions.

Fig. 73: Inscriptions under the gradation marks

Fig. 74: Rheostat located on the back panel

Lamps

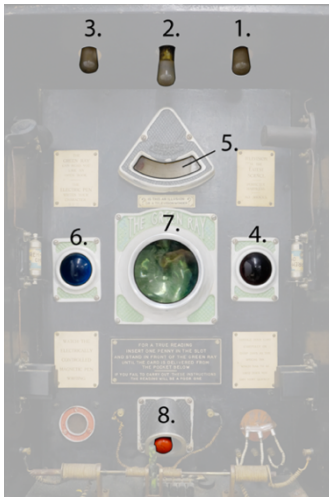

Fig. 75: Optimised photograph of the lamps in the front display

On the front display, there are eight visible light sources which can be powered by the electrical circuit (see *Fig. 75*). The lamps are present to light the elements of the front display panel, and some of them will blink during the operation (7. and 8.), to emphasise the mind-reading experience.

At the front, there are four lightbulbs directly visible (lamps 1., 2., 3., 8.), the others are placed behind the front display panel. The lamp 5. is visible through the graded paper of the neuro-lectrons detector, and the lamps 4., 6., 7. are seen through colored glass lenses. Their bases are all "double contact bayonet" type. The lamp 7. possesses a support with a green translucent plastic film (see *Fig. 76*).

Fig. 76: Lamps 4.-7. (right side view)

Table 2: Inscriptions on the lamps

1, 2, 3:	"Crompton – Vacuum 26 – 200V-260V – Made in England"
4, 5:	"GE – 240V – 40W – H3"
6:	"Lampways – Tripleplus – 60W – 240V – Made in EEC"
7:	"Osram – 240V – 60W – Made in Crve5"
8:	"Crompton – 15W – 200/250V – u 3E k"

Buzzer and battery

Fig. 77: Location of the buzzer inside the Green Ray, left view

The buzzer is located on the back of the front display panel (*see Fig. 77*). On the front display panel, a cover is visible and evokes a loudspeaker (see *Fig. 78).* The role of the buzzer is to emit sound and make more believable the mind-reading experience for the operator. It is from the "Magnet – Registered Trademark" and was made in England (see *Fig. 79*). The buzzer emits a sound at the same time that the "show" lamps are activated (lamps 7. and 8.), because they both are present in the circuit activated intermittently by the mechanical switch (see *Fig. 36*). The buzzer emits sound from the vibration of a magnetic blade attracted by an electro-magnet when it is powered with direct current. Because it necessitates a direct current source to work, it would not be activated by the main alternative current source powering the rest of the components, thus it needs to be powered by an additional battery providing direct current.

Fig. 78: Buzzer cover on the front display

Fig. 79: Buzzer on the back of the display panel

Fig. 80: Front of the battery

Fig. 81: Back of the battery

The battery is a 4.5V, we found it on the middle panel next to the ramp of the card dispenser, and it was unconnected to the rest of the circuit.

The inscriptions on it says: "golden power – 4.5V – G3R12 – Greenergy Heavy Duty Battery – Made in China" (see *Fig. 80*) and "///Maplin – ZB63T – 4.5V Zinc 313 Batt" (see *Fig. 81*). There is a slot on the middle panel for a former bigger battery, where a paper towel was added to adapt it to the battery which is present now (*Fig. 82*). There were two loose wires in the circuit, one of which coming from the buzzer and the other from the mechanical switch. Both of these cables have an adhesive tape indicating "buzzer", they should be attached to the battery.

Fig. 82: Battery slot with the mark of the battery on the paper

4.3.8 Decorative components

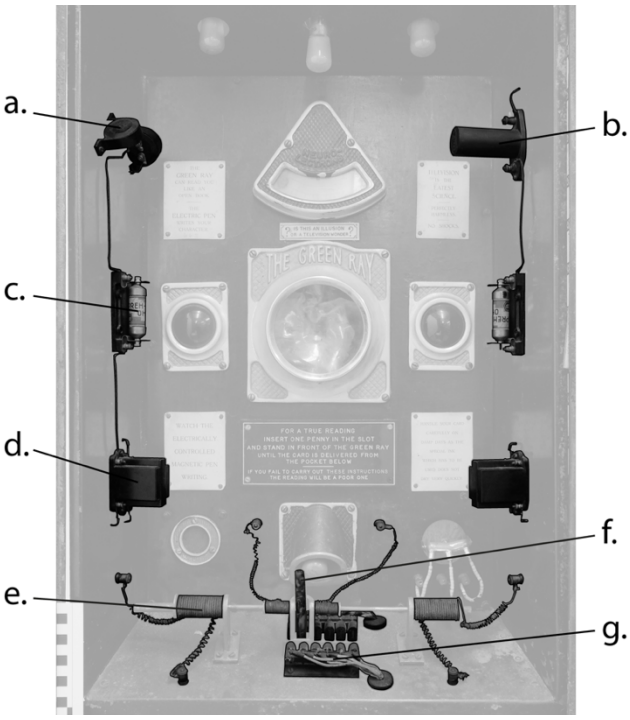

Fig. 83: Optimised photograph of the components on the front display: a. Lissen RF choke, b. Elektra HF choke, c. Preh-ohm wire wound resistance, d. LF transformer, e. cables, f. pen, g. electro-magnet

Some of the components present on the front display of the Green Ray are only there as a decoration and do not play any role in the functionality, because their wiring is cut as soon as it goes through the panel (see *Fig. 91*). On other Green Rays[65], we noticed that these components were present but in other cases they were replaced by lamps, which attests the decorative role that they have.

These components are not functional in the Green Ray, but it is important to note that the majority of these elements (a. to d. on *Fig. 83*) were commonly found in 1930s radios. These six components (there are two identical c. and d.) are therefore functional elements of radios, which are used in the Green Ray as a decoration. These decorative elements are present to emphasize the mystery surrounding the object, to make it look more complex than it is.

The electro-magnet is a decorative construction and its wiring does not lead anywhere on the inside of the object (see *Fig. 90*). The pen is also decorative (see *Fig. 88*), it cannot write and it is placed on a support moved by the motor. Both the pen and its action are here to fool the operator.

The majority of the radio components (a., c., d.) has a Bakelite casing, and the resistances (b.) are held on a Bakelite support; this material was commonly used at that time to manufacture these components.

Fig. 84: a. Radio Frequency (RF) choke from the "Lissen" brand

Fig. 85: b. High Frequency (HF) choke from the "Elektra" brand

[65] See Annexes p.92

Fig. 86: c. Wire wound resistance from the "Preh" brand

Fig. 87: d. Low Frequency (LF) Transformer

Fig. 88: f. Pen

Fig. 89: View of the electro-magnet from above

Fig. 90: Wiring of the electro-magnet on the inside, we can clearly see that it is cut

Fig. 91: Wiring on the other side of the display panel

The wires between the radio components are simply a rigid metal thread with a gutta-percha sheath; they are going for a few centimeters on the other side of the front display panel and are cut, as we can see in *Fig. 91*.

It shows that these components were not intended to be used as functional elements in the Green Ray.

5 Description of the alterations

5.1 Alterations of the materials

5.1.1 Exterior

The exterior of the Green Ray has undergone serious degradation. The paint layer is altered, as well as the metal substrate underneath, but only in certain definite zones. A mapping of the paint layer alterations of the exterior sides of the Green Ray can be found in the Annexes p.85, and photographs of the stratigraphy of the paint layer in Annexes p.89.

The roof is the part where the paint layer is the most altered, as well as the lower part of the object, the edges of the frame and panels. On the roof and on the protruding edges of the sides of the machine, there is a high level of dust (see *Fig. 92*). We can highlight the fact that on the roof, the alterations of the paint layer and the metal are more pronounced in the centre. The corrosion on the roof resulted in rust spots on the paint layer (see *Fig. 93*).

Fig. 92: Dust on the roof, with the lifting of the paint layer and presence of corrosion spots

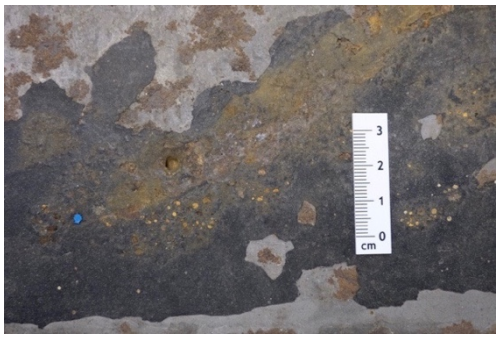

Fig. 93: Corrosion on the roof and rust stains on the paint layer

The main alterations of the paint layer are the loss of paint in certain areas, leaving the underlying metal exposed to the environment, and the lifting of the paint layer in the zones adjacent to the lacunas (see *Fig. 94*). On the left panel, the lacunas in the paint layer are smaller around the glass pane; there is a red underlayer visible in these areas.

Fig. 94: Lifting of the red paint layer near the losses

Fig. 95: Black traces on the red paint

Other noticeable alterations of the paint layer are scratches, where some of the layers of paint are removed in a thin line, and there are black traces and soiling visible on the red panels (see *Fig. 95*).

Where there are scratches, the yellow undercoat is often the most visible one. Some additional traces we could find on the red surfaces were black paint drips (see *Fig. 96*). On the lower panels, there is a soiling of the surfaces, especially on the back side of the object.

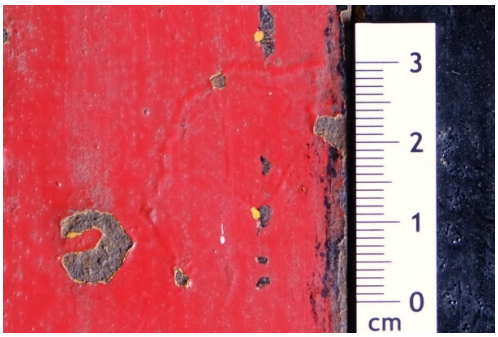

Fig. 96: We can notice a kind of filiform corrosion, black paint drips, and the yellow paint layer is visible

Fig. 97: Some of the residues from old labels or adhesive tape on the back panel

On some of the painted surfaces where there is a paint loss or lifting of the paint layer, we noticed what looks like filiform corrosion and blistering There are some old label or adhesive tape residues on the back panel, in the top left and top right corners (see *Fig. 97*). Ferrous corrosion products are visible in the areas where there is a paint loss, and some zones mainly in the bottom corners of the object present delamination (see *Fig. 98*).

Fig. 98: Delamination with loss of the paint layer

Fig. 99: Seal on the left panel

Fig. 100: Seal on the right panel

Between the glass and the metal panels, the seal is reticulated. On the upper left panel, the seal expanded for the most part, and has a brownish colour (see *Fig. 99*). On the upper right panel, the seal has undergone great losses, in many areas it is also cracked. This seal was initially covered in red paint on this panel, where there are losses and cracks, we can observe it has a white appearance (see *Fig. 100*). On the back of the object, some holes are present and disposed on a line and with the same distance as the screws holding the transversal metal bar a few centimetres higher, which indicates that there were two of these and the lower one is now missing. On the surface of the aluminium-based alloy card pocket at the front, there is some white-brown soiling; one of the screws fixing this piece is missing. The coin escutcheon has lost part of the metallic coating and has residues of red and green paint (see *Fig. 101*).

Fig. 101: Coin escutcheon

5.1.2 Inner walls and side panels

Inside the Green Ray, the main alterations are similar to the ones present on the exterior: a high dust level, corrosion and paint losses. The paint layer of the panels which can be opened or removed is the most affected. The lower right panel has undergone the most damage, especially its lower part where there is a substantial amount of corrosion coupled with a loss of paint (see *Fig. 102*). The upper side panels and front panel were affected by the same degradations as the lower panel, but in a lesser fashion and these alterations were distributed more evenly on the interior of the panels. On the lower right panel, we can notice that the lock was replaced and adjustments were made to make it fit (see *Fig. 103*).

Fig. 102: Important loss of paint at the bottom of the lower right panel due to corrosion

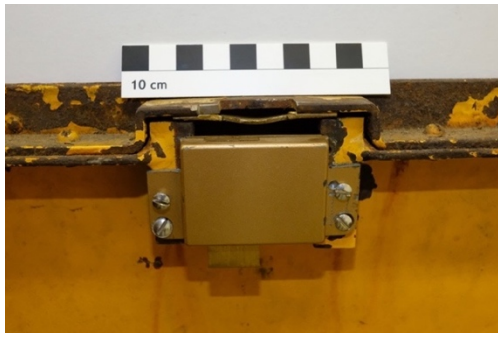

Fig. 103: The lock which was replaced on the lower right panel

The paint layer on the other interior walls of the object is relatively well preserved, with only few paint losses and corrosion. The main alteration on these surfaces is the presence of darker streaks running down from the card pocket opening and from the side panels openings. There is also the presence of old adhesive tape on the back panel, in the lower compartment. There is a red paint drip going down from a hole in the back panel.

Fig. 104: Missing parts of the letters and blue residues on the borders

On the glass panes of the side panels, the pasted paper has undergone relatively important degradations. On the left panel, the paper was poorly pasted to the glass, there are now wrinkles leaving a small space between the glass and the paper, where dust and deposits accumulated. On the right panel, the inscriptions have missing parts and are scratched, and on the borders of the sunrays we can see that there are blue paper residues (see *Fig. 104*). The background paper also presents wrinkles, but the main alterations there are the important tears of the paper. In the middle of the panel, an area

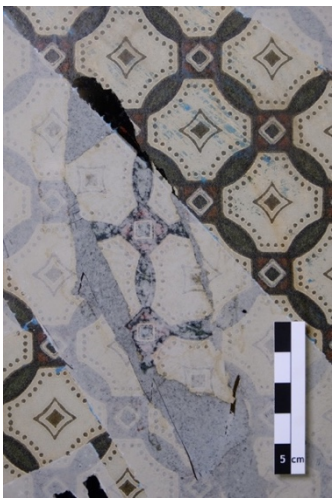

Fig. 105: Piece of paper which was pasted again

of the paper was torn and pasted back to the panel but is not aligned with the motives of the paper surrounding it (see *Fig. 105*).

5.1.3 Inner contents

Inside the object, all the surfaces presented a high level of dust. In the lower compartment we found various elements (*Fig. 106*): a brown towel with adhesive tape, crinkled pages of "the Times" (UK) from March 15th 2009, a "Magnet – Universal Voltage Electric Iron" cardboard box filled with cards delivered by the Green Ray, and a plastic Tupperware closed with adhesive tape on the four sides (see *Fig. 107*).

Fig. 106: Various elements present in the lower compartment

Fig. 107: Tupperware containing some of the coins

The original cards from the Green Ray and a few printed cards from the 1994 exhibition were stored in the cardboard box. In the Tupperware we found a few pennies, the rest of them were either stuck in the coin slide, stored in the leather collecting bag, a metal case or simply on the bottom panel of the lower compartment. The base is heavily corroded, we found a lot of dust and fallen fragments of the paint layer on this surface, as well as free screws and bolts (see *Fig. 108*).

Fig. 108: Unattached bolts found on the base of the lower compartment

The leather collecting bag is in good state and kept its flexibility, there is only some slight moulding on the surface in the form of dry and powdery white spots (see *Fig. 109*). In the front display compartment the most observable alterations are the presence of dust and the degradation of paper material. The four paper labels are in relatively good state, they are yellowed are some creases at the corners, however, the lowest inscription "Have your Mind Read by Television" has undergone more damage (see *Fig. 110*). . It is now stained and yellowed with some tidemarks, some areas are heavily abraded or skinned, there is also some local delamination.

Fig. 109: White spots are present on the collecting bag

Fig. 110: Inscription fixed on the lower part of the front display panel.

The screws and washers used to maintain this inscription present cuprous corrosion products. The graduated paper used for the back of the "Neuro-lectrons" detector has undergone some cockling. The black ebonite inscription plaque in the middle is missing the bottom right screw and washer. The central glass lens does not have screws anymore and can therefore be removed easily. The walls were repainted, it can be noticed because there are some black paint drips on the various display elements which were not removed when the paint was applied. In certain zones of the metallic sheets of the front display, the paint is gone and there is the presence of light ferrous corrosion (see *Fig. 111*). The back side of the metal sheets of the front compartment presents less paint losses but there is slight corrosion of these surfaces anyway (see *Fig. 112*). The front cables holder from the fake electromagnet was broken and there is some white efflorescence where it is in contact with the screw (see *Fig. 113*). We noticed that the "Elektra" HF choke decorative component has been broken and glued back (see *Fig. 114*). On the right side of the front compartment, a fake cable is missing between the lower component and the middle "Preh-Ohm" element.

Fig. 111: Presence of dust and paint losses on the metallic part of the front display

Fig. 112: Corrosion of the front display panel (back)

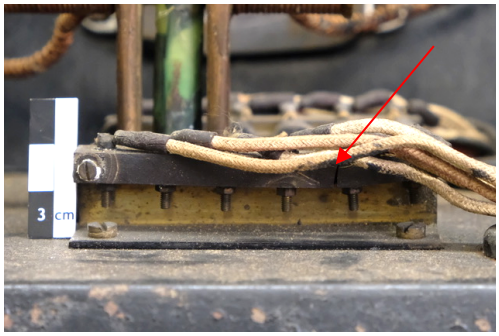

Fig. 113: Break of the decorative electro-magnet

Fig. 114: Broken decorative component which was glued back, we see the adhesive has dripped

5.2 Alterations of the functional elements

5.2.1 Mechanism

Besides being slightly dusty, the electric motor does not seem in bad condition and the rotor can be turned manually. Dust is present on all the surfaces of the mechanism and it is incrusted in the old lubricant residues. The old lubricant is now reticulated and has slightly hardened, its presence causes noticeable resistance to the movement of the pen support. The lubricant is present in larger quantity on the gears transmitting the movement between the axes (see *Fig. 115*).

The brass cam responsible from the vertical movement of the pen is slightly worn by the friction with its lever, but this phenomenon is more noticeable on the sensor of the mechanical switch (see *Fig. 116*). The mechanical switch and neuro-lectrons detector both have noticeable wear on their cams too.

The most worn parts are the hook and the cam used for the horizontal movement of the pen (see *Fig. 117* and *Fig. 118*). Next to it the rubber washer is oxidised.

Fig. 115: Presence of old lubricant on the gears

Fig. 116: The sensor of the mechanical switch is worn

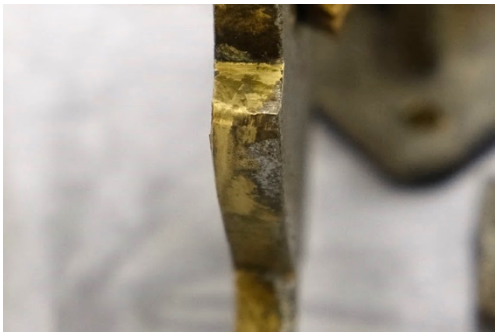

Fig. 117: Cam responsible for the horizontal movement of the pen, it is worn due to friction with the hook

Fig. 118: Hook of the horizontal pen movement, with the oxidized rubber

The mechanical switch cam and one of the supports of its axis have zones where the bare metal is now visible (see *Fig. 119*).

Fig. 119: Abrasion of the non-functional surface

Fig. 120: Repair of the pen

The pen is not maintained anymore on its support, it can therefore be removed easily. The pen was broken in multiple parts, the most damaged area being the middle of the pen. It has undergone a repair in the past: the remaining parts were glued together, and the gaps were filled with a plastic material (see *Fig. 120*). A small fragment of the pen was found under the motor of the Green Ray (see *Fig. 121*), the repair was done without it. On the green plastic film used around the central lamp inside the Green Ray, dust has accumulated and there are mould spots; the plastic has lost a little of its transparency.

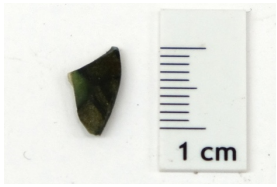

Fig. 121: Fragment of the pen

5.2.2 Electric components

Fig. 122: Fuses with one of the lids broken

Fig. 123: Asbestos from the rheostat

The fuse boxes are slightly dirty, and the lid from one of them is broken (see *Fig. 122*). On the rheostat, some slight surface corrosion products (ferrous and cuprous) were present. The white elements of this rheostat seem to be asbestos (see *Fig. 123*), which is a hazardous material for health[66]. In the case of this rheostat, the fibres seem to be weakly bounded, it means that emissions of fibres could occur.
On the motor, a corner of the ceramic resistance is slightly broken but it is not problematic for its functionality. The buzzer is in good condition but on the inside of the cover, dust and white filaments from mould are present. The mercury switch is still hermetic and presents no leaking. There is the presence of a few centimetres of wiring which was cut (see *Fig. 124*), it is different than the rest of the

[66] Hürlimann, 1998, pp.9-13

circuit which is more modern. After a visual observation of the electric circuit, no wiring or component seems to be problematic. To assess the functionality of these components in a more reliable way, we did a test under static constraint with an ohmmeter.[67] With this test, we deduced that all the conductors and components should be in working condition, because the current was allowed to pass inside them and the resistances values that were measured were coherent for the respective components (see *Table 7* in Annexes p.93). The battery present in the Green Ray still delivers a 4.5 V tension. The electric cables are generally dirty, but they are in working condition.

Fig. 124: Old wire that has been cut, near the lamp 5 on the back of the display panel

When we opened the object, we discovered coins from random dates stuck inside the coin slide, blocked by the mercury switch lever, which means that people tried repeatedly to operate the object without managing to make it work. A picture from the auction sale in which it was sold to the museum in 2009 shows the mercury switch is in the ON position, and should activate the operation of the object, but it was not the case (see Annexes p.91). The reason for this is that the cursor of the rheostat was not properly creating the electric contact in the position it was found in and was not allowing the motor to be powered, even though the operating circuit was powered.

5.3 Synthesis of the condition report

Both inside and outside the object, a high level of dust and soiling can be observed. On the exterior, the object has undergone serious degradations of the metal surfaces and paint layer. The main problems are the lifting of the paint layer and paint losses, especially on the roof, which are caused by the formation of corrosion products on the metal surfaces. On the roof, there are also rust stains on the black paint layer. Inside the object, the same type of degradations – lifting or loss of paint, soiling and dust – occurred on the painted metal surfaces. The paper of the different inscriptions has yellowed, it presents stains and mechanical alterations such as tears.

After the static test of the electrical components and the observation of the mechanical parts, we can assess that they seem to be in working condition, but some parts of the mechanism are worn and there is the presence of dust in the old lubricant.

[67] The methodology used here was taken from Michel, A., 2012. "Conservation- restauration d'un redresseur à vapeur de mercure", HE-Arc CR, pp. 62-63. See annexes p. 93

6 Significance

In this investigation of the significance of this object, we will start by presenting the most relevant values, the following ones being presented in order of decreasing intensity.

Currently the value which seems to have the most importance for this object is the historic value: it is a witness of the time before the arrival of mainstream television, which is nowadays present in the vast majority of households. It delivers information on how this technology was perceived at the time and how some people appropriated themselves the nebulous concept of television to add occult and esoteric meaning to it. In this sense, we could consider that if the object was presented with well-chosen additional information to the public, it would have an interesting pedagogic value.

The appearance of the Green Ray Television Wonder was designed to attract people from afar and incite them to place a coin in the slot, therefore its esthetical value is a defining value. The decorative components and lights seen behind glass lenses are present to make more credible the "mind-reading" experience. The colours used for the paint are also saturated and vivid, it was probably chosen to attract the eye of the people passing by.

At the time of this investigation, this object is not in use. As we supposed earlier, the object was used "repeatedly" in 1994, probably was it also used occasionally in the following years but since its acquisition in 2009 by the museum, it has not been used.

In its current state, this object has a noticeable age value, it appears ancient because of its conceptual style and dated electric components, as well as degradations such as the paint layer alterations, the metal corrosion or the yellowing of the paper.

Being created by Granville Bradshaw, a relatively important figure in the world of slot machines, this object has some associative value. It was not created to be an artistic work of art, it has therefore very little to no art value.

This object can deliver information for research papers such as this one: the study of the electrical components and the fabrication of the object will allow us to better determine the most suitable restoration treatment, we can therefore give it a significant research value.

This object is not part of any cult, it has no commemoration value, and the sentimental value is not a defining factor for the conservation of this object.

Another value worth mentioning is its monetary value: a Green Ray Television Wonder is estimated to be worth 6000-8000 $, according to the Sotheby's 1998 auction catalogue in which it is presented[68]. This object was manufactured in series (we didn't find any indication about the numbers), but it is described by collectors as rare[69].

[68] Sotheby's, 1998, lot 6

[69] Braithwaite, 1997, p.73

7 Material history

7.1 Ownership and exhibitions

The present object was bought by the Deutsches Technikmuseum of Berlin on the 30th of September 2009 during a Bonhams auction sale (lot 690, The Michael Bennett-Levy Early Technology Sale). It is now part of the museum inventory with the number 1/2009/0861. As we observed previously, the operating circuit of Green Ray was not functional during the auction sale.

Before that, it belonged to Mr. Bennett-Levy, who presented it in a BBC documentary in 1994 called "Tv is KING". The year 1994 was important for this object, because it was also presented at the "Tv is KING" exhibition at the Edinburgh City Art Centre from March 16th to May 7th and at Sotheby's in London from 1st to 11th August of the same year[70]. We deduced that the object was functional at this time because some of the pre-printed cards were found inside the object in the card dispenser, ready to be distributed.

Mr. Bennett-Levy never mentioned when or where he bought this object, but we suppose it was around the late 1960s (after examination of the different dates of the pennies found inside the machine, we saw that the last year was 1967, and there were significantly more coins of this year than any of the preceding years, see *Fig. 125*).

Another assumption we could make from looking at the coins inside the object is that its first life in exterior in arcades or piers could have ended in the late 1940s. This is supported by the fact that we have found a broad variety of pennies ranging from 1896 to 1948 and then from 1961 to 1967 (with a few gap years which are not big enough to be significant), but no pennies found inside the machine are dating from between 1949 to 1960. We have no information about the ownership of the object prior to its acquisition by Mr. Bennett-Levy.

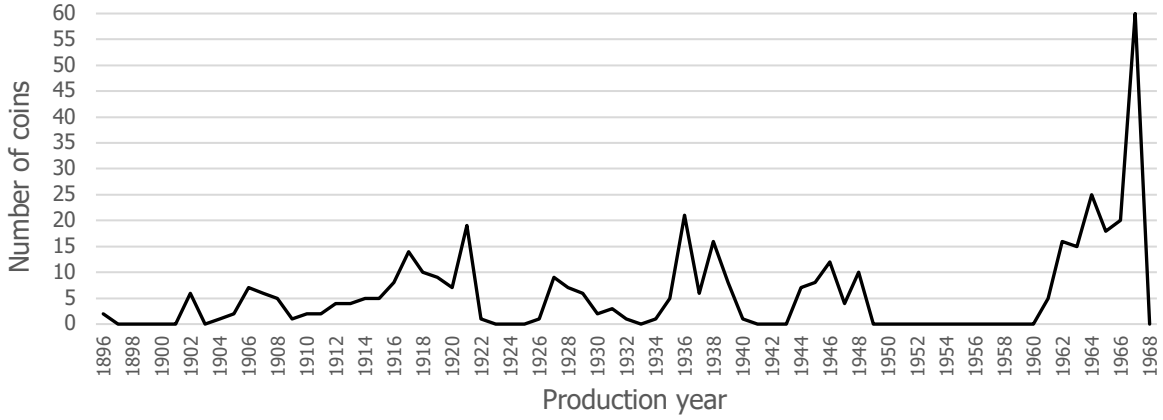

Fig. 125: Graph of the number of pennies found in the Green Ray in function of their production year, there are 407 pennies in total

[70] Bennett-Levy, 1994, p.5

7.2 Modifications throughout the life of the object

This object has undergone many interventions in the past and it seems that many components are not original anymore. We listed in the table below the previous interventions that we discovered. The heaviest repairs were made to make the object functional again, probably for the 1994 exhibition.

Table 3: Description of the previous interventions undergone by the object

Location	Previous interventions discovered
Electric circuit	The electric cables inside the machine are not dating from 1930s, they are insulated with a white plastic sheath, probably in PVC (polyvinyl chloride). Another confirmation that this wiring is not original is the presence of a few centimetres of old wiring hold by a metal strap, and there are many other of these straps in the back of the front panel, but they are now unused.
	The wire nut connectors are modern adjustments to the circuit.
	A modern rectangular battery of 4.5 V is present in the object but not linked to the wiring. We see that there is a slot in which a battery can be inserted, but it seems that it was not made for a modern 4.5 V battery but for an older, larger battery.
	The electrical plug present outside of the machine is a type G, which replaced the previous D model in 1947. It could mean that the replacement of the electric cables and the battery was made after this date.
	Some of the front lamps have been replaced, as we can see when we compare the object to the photograph in the TV is king book by Bennett-Levy (see Annexes p.91). None of the lamps behind the front display panel (4, 5, 6, 7) seem to be original.
Motor	The manufacturer of the motor is Burroughs Adding Machines Ltd (English branch of the Burroughs Adding Machines Co. located in the USA); the factory which produced it is in Strathleven in Scotland. The problem is that this factory was built in the late 1940s and the object is dating from 1931-32. Adding machines built by the Strathleven factory displayed an electric motor inside, it is possible that it was reconverted to be used in the Green Ray.
Upper side panels	We noticed that the paper of the left panel is not original, and the right-side glass panel presents the original inscriptions but behind them a non-original paper with repeated patterns is pasted. This paper is also poorly glued, and we can see that at the borders there are residues of an older blue background. There are missing bits in the original inscriptions, which could be coming from the removal of the paper originally pasted to it.
Roof	There are holes and a circular mark on the black paint layer, where there is significantly more corrosion and lack of paint. There are 10 holes which are present on this circular shape, and three inside of it. This circular shape and holes could be what remains of a now missing element which was fixed on the roof of the Green Ray, which could be similar to elements present on the roof of other existing Green Rays (see Annexes p.92)
	The plywood panel forming the roof seems not be original (there are holes in the metal of the roof, but not in the wood). Since the middle panel supporting the mechanism is the same plywood, we deduced it is not original either.
Paint layer	The object was repainted multiple times, as noticed by looking at some paint drips, scratches and the stratigraphy of cross-sections (see Annexes pp.89-90)
Lower right panel	The lock of the lower right panel has been changed. It looks brand new compared to the other panels, and adaptations were made to make it fit.

It can be noted that the radio components present in this object were also present in other Green Rays, we can therefore deduce that they are original (see Annexes p.92).

The pen does not seem to be original; it looks more as if one took a refillable ink pen and flattened the sides to make it fit onto the support. This argument is backed up by the fact that the end of the pen is threaded similarly to modern ink pens. Many signs support the presence of multiple interventions: replacement of screws and bolts with modern ones, lack of screws to maintain some of the parts, free bolts and other small elements which fell in the lower compartment (see *Fig. 126*), and damage done to the screws.

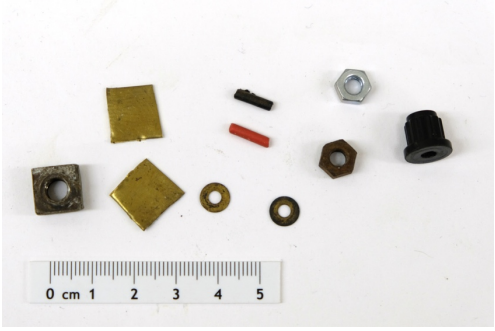

Fig. 126: Elements found inside the Green Ray

After the study of the materiality of the object, we can see that it was heavily modified. It has therefore lost significant historic information, such as the motor originally used, or the original wiring of the circuit and many of the lamps. The past interventions can clearly be considered as repairs, because they were only aimed at making the object functional again and were not evidence-based, they are a new interpretation of the object.

8 Diagnosis and impact on the significance

8.1 Alterations of the materials

Table 4: Diagnosis and prognosis for the alterations of the materials

Alteration	Diagnosis and prognosis	Impact on the significance
Dust and soiling	It can be due to past storage environment, and friction between materials. When present on the metal surfaces it creates areas which capture the moisture in the air and can lead to corrosion.	It impacts the operation of the object as well as the aesthetic aspect. It can also affect the age value, giving it an ancient aspect.
Exogenous deposits and residues	This can be caused by friction of an external material on a surface or the storage context. Some residues come from the presence of now removed adhesive tape or labels. We do not see bad consequences for the object at long term.	The impact of these alterations is principally aesthetic, and it reinforces the age value.
Corrosion of ferrous alloys	This was caused mainly by the exhibition of the object in an exterior environment, and possibly by the past storage environment. If the climate of the storage environment is not regulated properly and the object is exposed to too high humidity, corrosion may resume and become a risk for the future preservation of the object.	Corrosion products have an impact on the aesthetic aspect and age value.
Paint lifts	This can be caused by the ageing of the paint layer and the underlying corrosion of the metal surface, leading to a loss of adhesion to the substrate. If the surfaces are not stabilised, it could lead to paint losses.	Paint lifts have an impact on the aesthetic aspect and age value.
Loss of paint	Theses paint losses can be caused by corrosion of the metallic substrate and ageing of the paint layer, lubrication of the hinges, impact or abrasion of the surface. This leaves the metal surface exposed and can lead to further corrosion growth.	This alteration causes the loss of original material and of historic information.
Paper alterations	The yellowing can be caused by the exposure to UV light, and the stains seem to have been caused by the presence of liquid water. The tears in the paper could have been caused by manipulations. The yellowing of the paper may slightly increase.	These alterations have an impact on the aesthetic aspect and increase the age value.
Broken decorative electromagnet	This alteration seems to have been provoked by manipulation rather than operation. We do not see any evolution of this alteration.	There is a small impact on the aesthetic aspect.

8.2 Alterations of the functional elements

Table 5: Diagnosis and prognosis for the alterations of the functional elements

Alteration	Diagnosis and prognosis	Impact on the significance
Repairs and modifications	The repairs and modifications were done probably by the former owners of the object, in the aim to make it functional again.	Some original materials were removed, some of the historic value has been lost. Some of the repairs have a strong aesthetic impact and diminish the age value.
Wear	The wear of the mechanical components was caused by the operation of the object. If the object is not operated, this alteration will not evolve. If the object is operated, additional wear of the surfaces will occur.	It has an impact on the use value.
Unfixed pen	The pen is not original and not really adapted to the support, it could explain why it is not fixed to it. If the pen is not fixed and the object is operated, mechanical damage could occur.	It has an impact on the use value and the aesthetic value.
Oxidised rubber	The rubber washer has started to degrade due to the presence of impurities in the rubber, high temperature or absorption of light[1]. The degradation will continue with the presence of oxygen. The regular operation of the object could lead to the destruction of this element.	It has a reduced impact on the aesthetic aspect, because it is inside of the object.
Presence of old lubricant	The object was operated in the past, we found the presence of old lubricant on some parts. It could acidify and catalyse corrosion reactions.	It has an impact on the use value.
Dust	There is dust inside the object and on the mechanism, probably due to the storage environment. On the mechanism, it can create three-body abrasion if we run it, leading to additional wear.	It has an impact on the use value, the aesthetic value and the age value.

8.3 Synthesis

As we can see, most of the alterations of the object came either from the past storage-exhibition environment outdoors, or from the modifications to make the object functional again. The corrosion of the ferrous elements which led to the paint losses and paint lifting seems to have occurred mostly during the period where the object was exhibited outside, which could have been a prolonged time. There are water stains on the middle panel in plywood – we saw it is not original – meaning that the object was exposed to liquid water, rain maybe infiltrated inside the object, even after these modifications were done. If the storage environment is not regulated, the corrosion could evolve and create further losses of the paint layer. These alterations are mostly affecting the aesthetic and age value; the historical value is diminished because of the loss of original material. The repairs done to the object were made without much consideration for the original features, many of them were removed, affecting the historical value the most and changing the aesthetic aspect as well as the age value.

[71] Corbin, 2010-2011, p.12

9 Interventions

9.1 Aimed condition and intervention project

The objective of the interventions on the Green Ray is to be able to place the object safely into storage. Some areas in the paint layers are lifting because of the presence of underlying corrosion products. These areas need to be stabilised in order to avoid further paint losses. We also found the presence of asbestos in the rheostat; the fibres need to be fixed by an adhesive to prevent their spread, and the fibres deposited in the rest of the object must be removed. The object will probably take part in an exhibition in the next years, the exterior surfaces will therefore be cleaned from the soiling and dust. The labels for the Bonhams auction will be also be removed.
The ferrous surfaces will be treated to remove partially some of the aesthetically disturbing corrosion products and stabilised to prevent further corrosion. No interventions on paper will be undertaken, due to the lack of specialised personnel at the museum for the supervision of the treatments.

One of our tasks was also to assess the functional condition of the object. After the inspection of the object and the results of our static tests, we determined that the object can be operated without the replacement of electric parts. Indeed, many components were already replaced during earlier repairs to make the object functional again. Many parts of the mechanism are already worn, some of them could be problematic if a regular use was considered, notably the oxidised rubber washer which could be damaged by frequent operation of the object during an exhibition. The policy at the Deutsches Technikmuseum for objects which are operated when exhibited is to place a hidden secondary electric circuit, in order to avoid using the original components. In our case, the most problematic part is not electric but assures a mechanical role, it would have to be replaced if the object was to be regularly operated, we therefore ruled out this way of interpretation because this part is one of the last original features left. Building a replica in our case would be too costly, this possibility was quickly put aside, even if some cases it can be a good possibility for the interpretation of technical objects.
We chose one of the alternatives to using the object during the exhibition, which is to film the object in operation and show the video to the public. This way, the wear on the pieces will be greatly reduced compared to regular operation, and this interpretation gives a good way of understanding the functionality and get a glimpse of the true mind-reading experience. The preservation and maintenance strategy to follow will then be the maintenance in static condition scenario.

9.2 Undergone interventions

9.2.1 Dusting

For the dusting of the exterior of the object, we used a vacuum cleaner class L filtered aspiration and a brush. The soiling on the lower part of the Green Ray was hard to remove, but stiffer brushes allowed an acceptable result.

On the card pocket, we used a plastic bristle brush which helped remove the denser and dry soiling (see *Fig. 127* and *Fig. 128*).

Fig. 127: Card pocket before treatment

Fig. 128: Card pocket after treatment

For the interior of the object, due to the presence of asbestos, we enclosed the object and used a class H filtered aspiration to create an air depression and avoid the spread of the fibres into the work environment[72]. It is important as well to wear the appropriate personal protection equipment, a FFP3 breathing mask, an airtight suit and gloves[73].

9.2.2 Treatment of the rheostat

The rheostat is the source of asbestos, we removed it from the object to treat it separately under a filtered aspiration in an enclosure. The asbestos fibres were soaked with Klucel® E, an hydroxypropyl cellulose[74], diluted at 10% (w/v) in ethanol and applied abundantly with a syringe. This prevents the release of asbestos fibres into the air and lowers the risk of exposure. The use of Klucel® E was preferred to Plexigum® PQ611 because it does not cause a darkening of the fibres while still encapsulating them[75]. The coils were then cleaned with a natural rubber sponge and a natural bristle brush (see *Fig. 129*), and the metallic parts holding the coils was rid of most of the corrosion products with a copper wire brush, to reveal again the nickel plating underneath (see *Fig. 130*).

[72] Information from a workshop with Mr. Wolf Meyer zu Bargholz at the HE-Arc

[73] Hürlimann, 1998, p.21

[74] Kremer, 2020a, [Online]

[75] Discussion with Lars König about the results of their tests at the Deutsches Technikmuseum

Fig. 129: Treatment of the wire coils, before (up) and after (down)

Fig. 130: Treatment of the metallic holders, half-treated (before/after)

Because of the presence of a source of asbestos, the object will have to be labelled with an etiquette found in Annexes p.94.

9.2.3 Cleaning of the mould

We noticed the presence of mould in a dry, powdery form on the surface of the leather collecting bag (see *Fig. 131*) and on the green plastic film around the main lamp. For the leather, we used a soft brush slightly soaked in a water/ethanol mixture which removed the mould (see *Fig. 132*). The best way to remove mould is to use a mixture of distilled wated and ethanol at 70%/30%, the water acts as a trojan horse and the ethanol kills the mould once it has been absorbed by it[76]. The white filaments inside the buzzer and the spots on the green plastic film were removed with the same method (*Fig. 133* and *Fig. 134*).

Fig. 131: Leather collecting bag before treatment

Fig. 132: Leather collecting bag after treatment

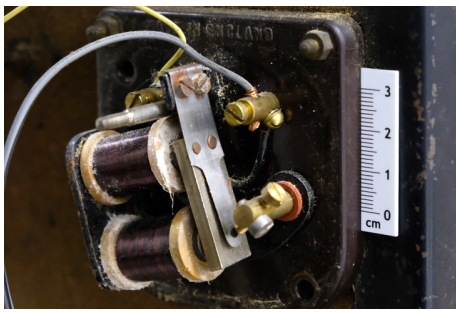

Fig. 133: Interior of the buzzer before treatment

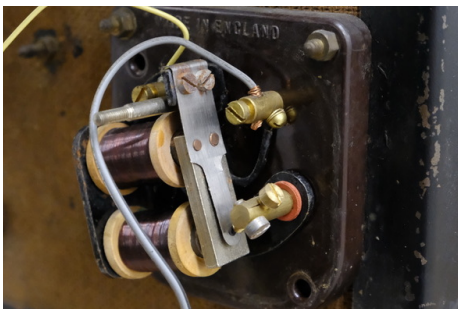

Fig. 134: Interior of the buzzer after treatment

[76] Discussion with Lars König at the Deutsches Technikmuseum

9.2.4 Treatment of the corroded ferrous surfaces

For the removal of the ferrous corrosion products, we chose to use mechanical methods over chemical methods whenever possible, because our action can be more controlled. When our action stops, the cleaning stops, whereas the chemical action can continue after the application and requires a thorough rinsing of the surfaces. On the interior sides of the front display, the ferrous corrosion products were removed with steel wool (see *Fig. 135* and *Fig. 136*), the surface was lubricated slightly with chlorine-free cutting oil for steel. It was rinsed after the application with Shellsol® T, an odourless and aromatic-free hydrocarbon solvent[77].

Fig. 135: Backside of the display panel before treatment

Fig. 136: Backside of the display panel after treatment

The metallic box present on the lower compartment and containing the coins was treated in the same manner, but because the corrosion products were slightly more voluminous (see *Fig. 137*), we also used the mechanical action of a polished scalpel blade which allowed to have a more satisfying and flatter look; lubricating oil should also be used to avoid leaving traces on the metal surface.

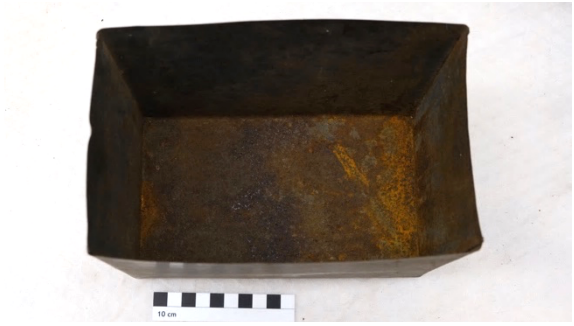

Fig. 137: Box before treatment

Fig. 138: Box after mechanical treatment and application of tannic acid

For the protection of the metallic surfaces, we chose to apply tannic acid which gives a darker appearance to the treated surfaces (see *Fig. 138*). It stabilises the corroded ferrous metal surfaces by forming iron tannate complexes which form a protective adherent layer on the metal surface and inhibit the corrosion reactions[78].

[77] Kremer, 2020b, [Online]
[78] Logan, 2014, [Online]

Before the application the surfaces were degreased with Shellsol® T. We used a 10% (w/v) tannic acid solution in distilled water, the pH of the solution was then dropped to 2.4 with phosphoric acid H_3PO_4.[79] We then applied two layers of the prepared solution mixed 1:1 with distilled water to get a 5% solution. An additional protective coating on all these surfaces does not seem necessary because of the regulated storage conditions in which the object will be placed[80].

9.2.5 Refixing of the paint layer

To fix the lifting flakes of the paint layer (see *Fig. 139*), we used Plexigum® PQ611, an iso-butyl methacrylate[81] diluted at 7% (w/v) in 100/140 benzine. Depending on the size of the flakes and the way they behaved during the refixing, we used a dilution of up to 15% which made the adhesion easier. The choice of this adhesive was made because the paint layers on the entirety of the object are dissolved by ethanol, acetone or ethyl acetate, but not in non-polar solvents. This adhesive has a relatively low glass transition temperature (Tg= 33°C), meaning that it will stay flexible and should not lose adhesion or crack in case of the dilatation of the metallic substrate due to temperature variations. To give back the flat form of the lifted paint flakes on the surface, we used a heated spatula; the heat allowed us to partly flatten them (see *Fig. 140*). The spatula was applied on the surface to flatten with a silicone-coated plastic film interface which prevented the adhesion of the flakes to the spatula.

Fig. 139: Lifting of the paint layer on the upper right panel before treatment

Fig. 140: Lifting of the paint layer on the upper right panel after treatment

We noticed that on the exterior of the Green Ray and on the inner side of the panels, the flakes were not flattening on the surface as much as we expected, because of the presence of the underlying corrosion products. We were not able to remove the underlying corrosion products due to a reduced access. What was surprising was that next to the lifted paint, the metal surface where there are paint losses did not present voluminous corrosion products such as the ones present under the paint flakes. It could mean that the accessible metal surfaces were already treated in the past to remove part of the corrosion products.

[79] Logan, 2014, [Online]
[80] Logan, 2014, [Online]
[81] Kremer, 2020c, [Online]

9.2.6 Cleaning of the paint layer

For the roof, in order to do the cleaning on a more comfortable workspace, we had to disassemble it from the frame. Once it was done, we first used a soft brush with a light aspiration to remove the superficial dust. The soiling on the black paint was partially removed with the use of a smoke sponge made of natural vulcanised rubber[82] (see *Fig. 141*). We then tried the use of different solvents but none of them proved to be really conclusive to remove the rest of the soiling.

We tried to remove the soiling and the rust stains with ethylenediamine tetra acetic acid (EDTA) at 0.1 M, applied in gelled form in Klucel® G at 5%. The paint surface has a slightly acidic pH around 5.5, we therefore used a solution of disodium EDTA at the same pH, where it is still autobuffering (it has autobuffering ranges between 5.1 to 7.1 and 9.4 to 11.4)[83]. We left it on the surface for a duration of 10 min, which allowed us to get a relatively satisfying result (see *Fig. 142*); the surface was then rinsed multiple times with Shellsol® T. We can see the roof before and after treatment in *Fig. 143* and *Fig. 144*.

Fig. 141: Zone of the roof after the smoke sponge cleaning

Fig. 142: The rust stains have been removed on the left with EDTA in gelled form

Fig. 143: The roof before the interventions

Fig. 144: The roof after the interventions

For the rest of the object, we used natural rubber sponges and natural bristle brushes which were really efficient and 100/140 benzine applied with cotton swabs helped remove the greasy soiling (see *Fig. 145* and *Fig. 146*).

[82] Conservation resources, 2020, [Online]
[83] Cremonesi, 2019, *unpublished*

Fig. 145: After/before removal of the soiling on the inner side of the upper front panel

Fig. 146: Before/after removal of the soiling on the back panel

9.2.7 Refixing of the pen on its support

The old repair of the pen seems to be mechanically resistant, we decided to leave it as-is. We did not remove any of the other repairs that occurred on the object, leaving the repair of the pen seemed a coherent choice. What we did was rotating the pen – the front now facing the back – this way the repair is still visible but less noticeable (see *Fig. 147* and *Fig. 148*). We then fixed the pen on its support by using Paraloid® B-72, an ethyl methacrylate (70%) and methyl acrylate (30%) copolymer[84] that we diluted at 40% (w/v) in acetone/ethanol (1:1). We chose this adhesive because its compatibility with the materials, mechanical strength, and because its use in conservation has been shown very stable[85].

Fig. 147: Pen before the interventions

Fig. 148: Pen after the interventions

9.2.8 Consolidation of the oxidised rubber

For the consolidation of the oxidised rubber washer next to the hook of the horizontal pen movement system, we used Lascaux 498 HV, a wated-based emulsion of a thermoplastic resin composed of butyl acrylate thickened with methacrylic acid[86]. It was chosen because it forms an elastic hard film which stays slightly tacky due to its Tg of 26°C[87] and is highly flexible, with an elongation at break of 400%[88]. This way even if the degradation evolves, the rubber will not fall apart and will stay in place in the film.

[84] CAMEO, 2020a, [Online]
[85] CAMEO, 2020a, [Online]
[86] CAMEO, 2020b, [Online]
[87] CAMEO, 2020b, [Online]
[88] Talas, 2020, [Online]

9.2.9 Cleaning, lubricating and protecting the mechanism

To clean the mechanism, we decided to dismantle it. This operation allowed a better way of assessing the degradations on the functional surfaces and allowed the isolation of the different pieces for their treatment. We first used isopropanol with a cotton swab and cotton tissues to remove the majority of the old lubricant residues. We then used the same method with Shellsol® T to ensure that the surfaces were rid of residual oil or grease. Once it was cleaned, the functional surfaces were covered with Vaseline®, a petroleum jelly composed of a mixture of aliphatic hydrocarbons ranging from about C15 to C20[89] which will protect and lubricate the functional surfaces. The non-functional surfaces were coated with Cosmoloid H80[90] wax diluted in Shellsol® T at 20% (w/v). The wiring of the circuit was also cleaned with 100/140 benzine to remove the soiling present. We can see the mechanism before and after in *Fig. 149* and *Fig. 150*.

On the motor, we first used a soft brush followed by the application of Shellsol® T to remove the dust and part of the lubricant residues (see *Fig. 151* and *Fig. 152*). We opened the side cover of the motor and cleaned the inside with Shellsol® T applied with cotton swabs. The interior of the motor compartment was then greased again with Vaseline®.

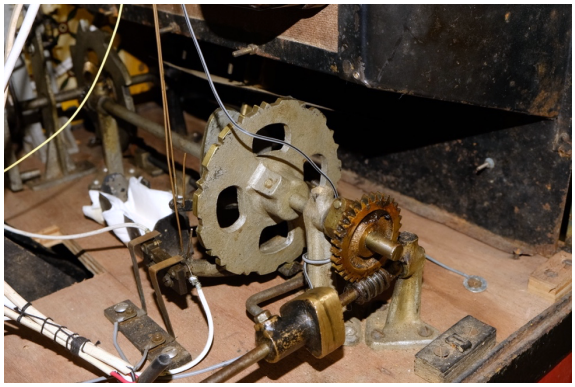

Fig. 149: Mechanism before treatment

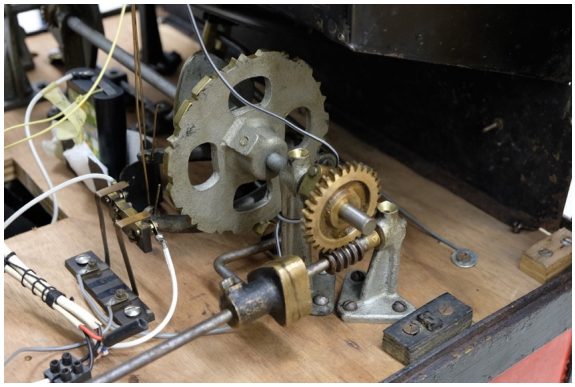

Fig. 150: Mechanism after treatment

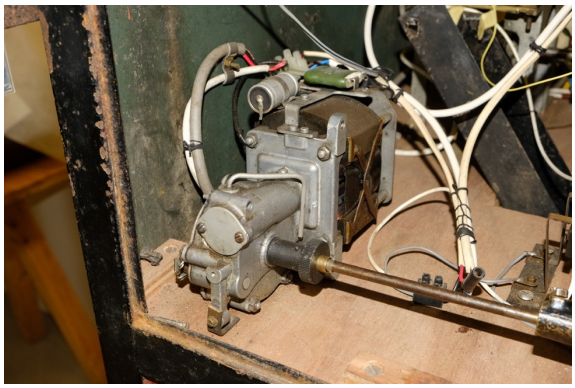

Fig. 151: Motor before treatment

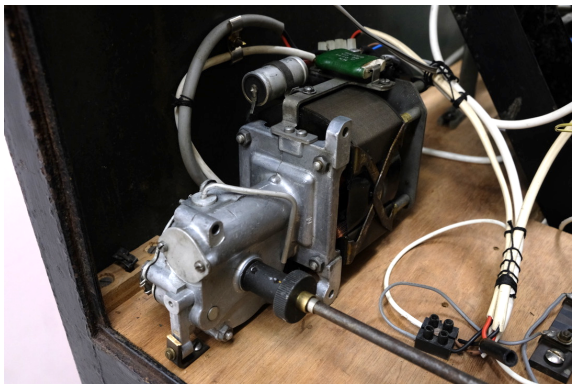

Fig. 152: Motor after treatment

[89] CAMEO, 2020c, [Online]
[90] Kremer, 2020d, [Online]

9.2.10 Making it work

All the components had already been tested individually in the test under static constraint. For the dynamic test, we used a calibrator (see *Fig. 153*) to start with lower voltage in order to prevent damage to the electric components[91]. Because we did not have a type G plug adapter, we connected the calibrator directly to the circuit in the place of the wiring linked to the plug (see *Fig. 154*).

Fig. 153: Calibrator used for the regulated operation of the object

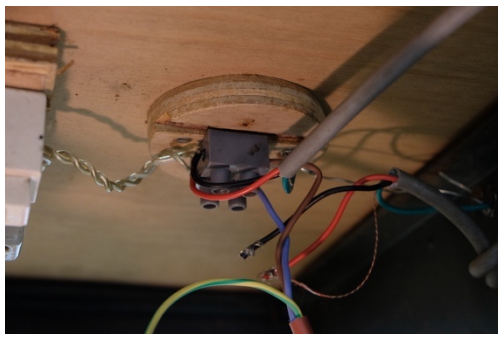

Fig. 154: Connection of the cables coming from the calibrator directly onto the circuit

We then observed the operation of the object (see *Fig. 155* and *Fig. 156*). The components are all working but the mechanism has probably undergone previous adjustments in the past, because at the end of the first operating cycle the mechanical switch was stopped in the closed position, which kept the buzzer going when instead it should have stopped. We adjusted the relative position of the axes in order for the mechanical switch to stay opened in the default rest position (see *Fig. 157*), but then the

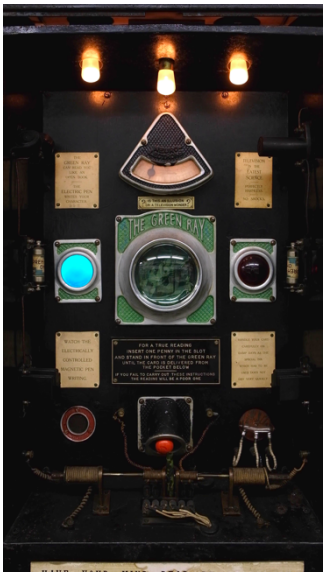

Fig. 155: The operating circuit is activated, and the mechanical switch is opened

Fig. 156: The operating circuit is activated, and the mechanical switch is closed

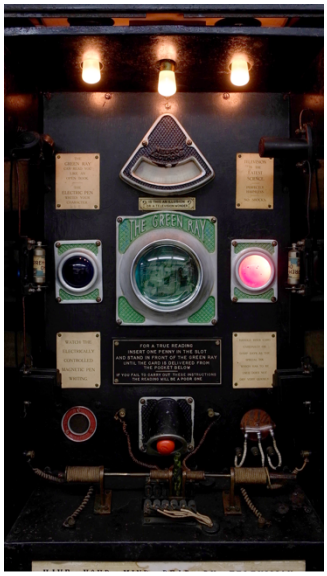

Fig. 157: The operating circuit is unpowered, but the pen is not in its standard position on the left

[91] Brenni, 1999, p.22

pen is stopped on the right and does not return to its rest position on the left. We were careful to reassemble the mechanism in the exact same way it was when we started the interventions, it could mean that the object was previously adjusted poorly. Some fine tuning is still required to get it running as it did originally in a video presented to the public, but all the sub-functions are operational.

9.3 Photographs of the object after treatment

Fig. 158: Interior of the object, viewed from the left

Fig. 159: The upper front part of the object, without the cover panel[92]

Fig. 160: Interior of the object, viewed from the right

Fig. 161: Lower right panel (disassembled)

Fig. 162: Front bottom half of the object

Fig. 163: Lower compartment

[92] The removable panels are not reassembled for the moment, because we had to lockpick them to open them due to the lack of keys. The personnel who opened it was not present at the museum at the time we did the pictures because of the short-time work imposed by the covid-19 regulations at the museum. Pictures of the object completely reassembled will be available for the corrected version of this report.

Discussion - Evaluation of the interventions

Due to the epidemy of covid-19, the conditions in which this work was undertaken were particular. We were not able to work on the object as much as planned due to the closing of the frontiers and of the museum itself. The practical time for the intervention was reduced, we therefore adapted the objectives according to the time available and put priority on the documentation of the object, the stabilisation interventions and the assessment of the functional restoration of the object.

We had additional issues due to the relocation of the restoration workshop, which meant that many products were not available, and due to the lack of time for the practical part, we sometimes had to use alternatives to our first choices. We also did not have the access and opportunity to do composition analyses of the materials and the paint layer. Nevertheless, we managed to obtain acceptable results and reach the objectives that were set by the museum.

If we consider the criteria of reversibility, the treatment of the corrosion products with tannic acid transformed them to inhibit the future corrosion reactions, it is therefore not a reversible intervention. However, a certain level of irreversibility can be accepted if it can help the preservation of the object, and tannic acid has been proven to be an efficient protection of metal surfaces in indoor environments[93].

The undertaken interventions were quite simple and standard for objects of technical heritage, we hope nonetheless to have illustrated with this report the process of decision-making which led to our choices to achieve the restoration goals set for this object.

[93] Logan, 2014, [Online]

Conclusion

When it arrived in the collections of the Deutsches Technikmuseum in 2009, there was no other documentation than a small description of the exterior of the object. Our study of its historical context, materiality and functionality allowed to get a better understanding of this mysterious mind-reader. In reality, there is no direct relation between the Green Ray and the technology of the television other than the inscriptions it bears. There is not even the presence of an electro-magnet controlling the pen, and this one is not really writing: the mechanism mimics the movement of the pen and the electric components such as the lamps and buzzer are activated during the operation to fool the person who put one penny inside the machine, who does not know that nearly all the components he sees are only decorative. One of the twenty-five different already-written card placed inside the object is simply dispensed to the operator at the end of the show.

The Green Ray has undergone many repairs in its past in order to make it functional again, which have led to the loss of valuable historic traces. What results of these interventions is that the original electric wiring circuit is nearly completely gone, replaced by a more modern one in order to make the object work again, and it was not the only part to suffer a similar fate.

We saw that the functionality of objects should be preserved, but the choices for its preservation should be taken with a thorough understanding of the object in mind and with regards to ethical standards to avoid losing important historic information forever.

By studying this object in depth, we were able to retrace some of the life of the object and better understand its significance. This helped choosing the most suitable options for the conservation of the object for the role that was intended by the museum. We saw that there cannot be a unique approach when it comes to treating technical heritage, but that the choices taken for the restoration must be made in function of the significance of the object and the museographical discourse. In our case, the assessment of the functionality showed that some mechanical elements cannot sustain repeated operation over a long period of time, and because these elements are some of the last remaining original features of the object, it was decided that these pieces would not be replaced and an alternative to regular operation would be used. The object will be presented in a video showing it in operation, which will still allow to grasp the mind-reading experience, while the object will be exhibited and preserved in static condition.

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List of Figures

List of tables

List of abbreviations and symbols

°C: Degree Celsius
Ω: Ohm
Co.: Company
Ltd.: Limited
M: Molar concentration
pH: Potential of hydrogen
PVC: Polyvinyl chloride
Tg: Glass transition temperature
V: Volt
w/v: Weight volume rate

Glossary of terms

"**Conservation** means all the processes of looking after an object so as to retain its cultural significance.
Maintenance means the continuous protective care of the fabric and setting of an object, and is to be distinguished from repair. **Repair** involves restoration or reconstruction.
Preservation means maintaining the fabric of an object in its existing state and retarding deterioration.
Restoration means returning the existing fabric of an object to a known earlier state by removing accretions or by reassembling existing components without the introduction of new material.
Reconstruction means returning an object to a known earlier state and is distinguished from restoration by the introduction of new material into the fabric.
Adaptation means modifying an object to suit the existing use or a proposed use.
Interpretation means all the ways of presenting the cultural significance of an object."

Definitions taken from the Burra charter[94], where the term "place" has been replaced by the term "object". The Burra charter was originally developed for architectural heritage, but it can be adapted to technical heritage.

A more complete definition of restoration is the following:
"**Restoration** - all actions directly applied to a single and stable item aimed at facilitating its appreciation, understanding and use. These actions are only carried out when the item has lost part of its significance or function through past alteration or deterioration. They are based on respect for the original material. Most often such actions modify the appearance of the item". [95]

[94] *Australia ICOMOS Charter for Places of Cultural Significance, The Burra Charter, 2013 (Burra Charter)*
[95] *Terminology for conservation* [Online]. ICOM-CC, 2008 [Last consulted on 06.09.2020]. URL: http://www.icom-cc.org/242/about/terminology-for-conservation/

Annexes

Dimensions of the object

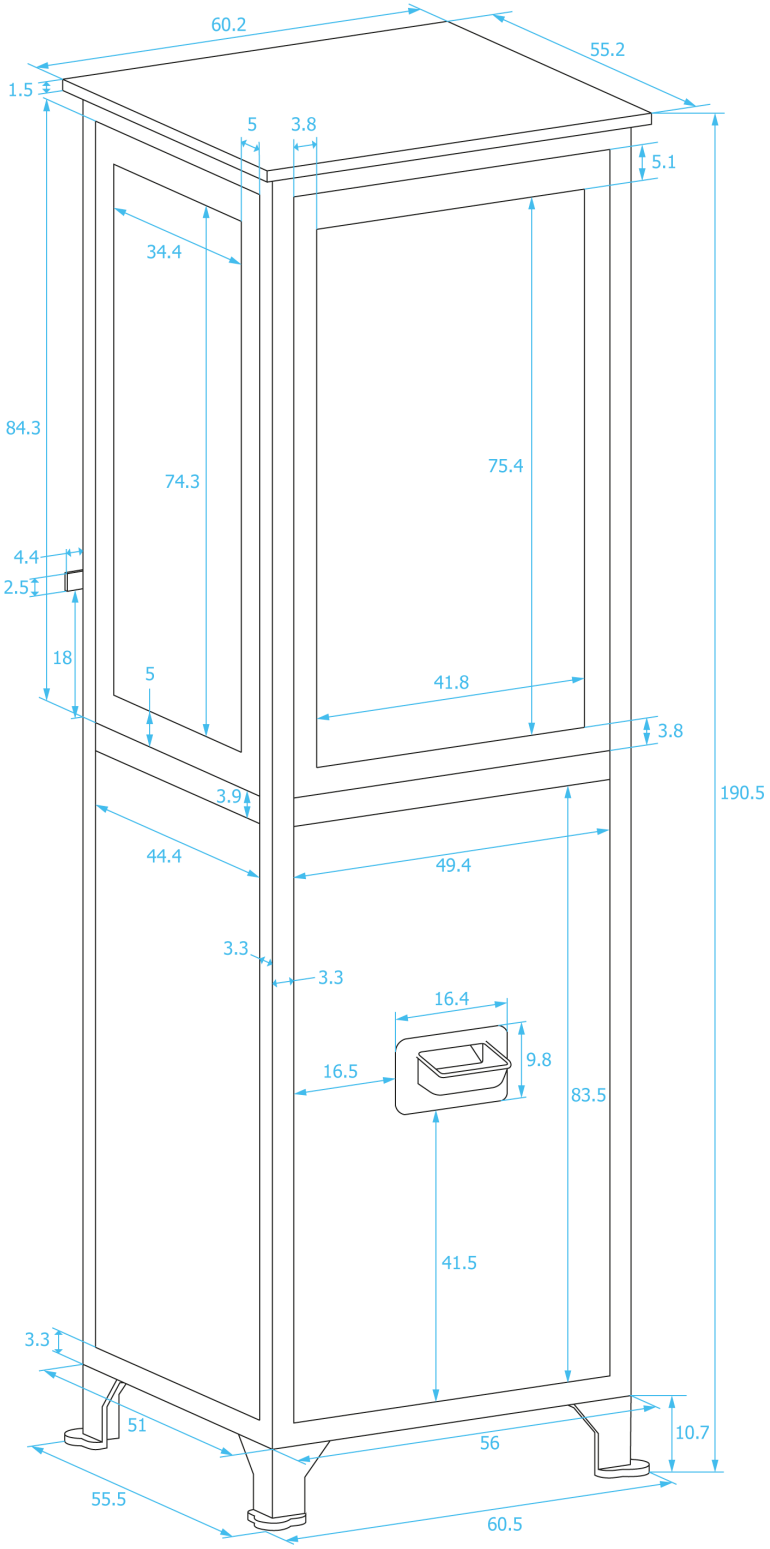


Fig. 164: Dimensions of the object (in cm)

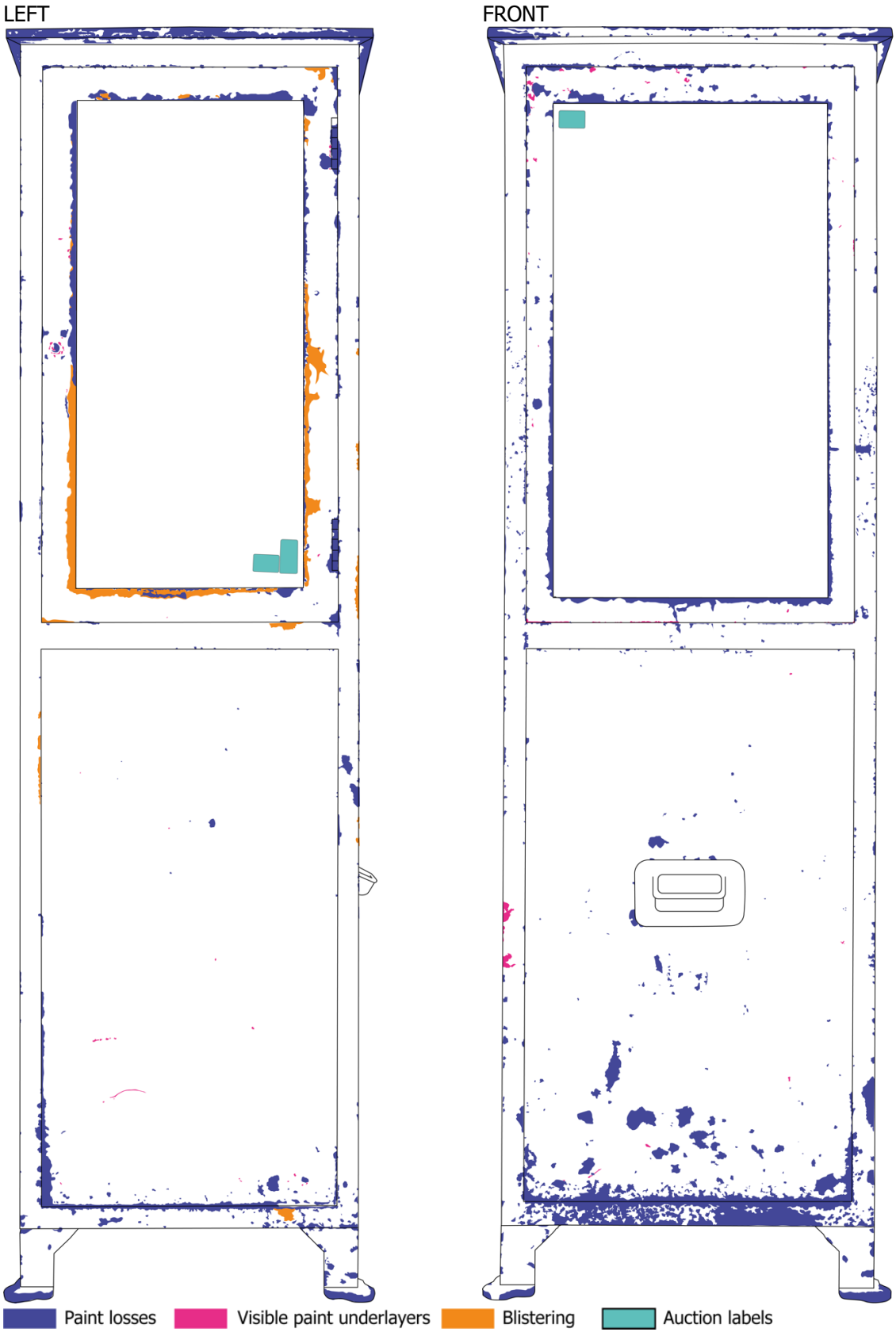
Inscriptions on the cards

Table 6: Inscriptions written on the cards

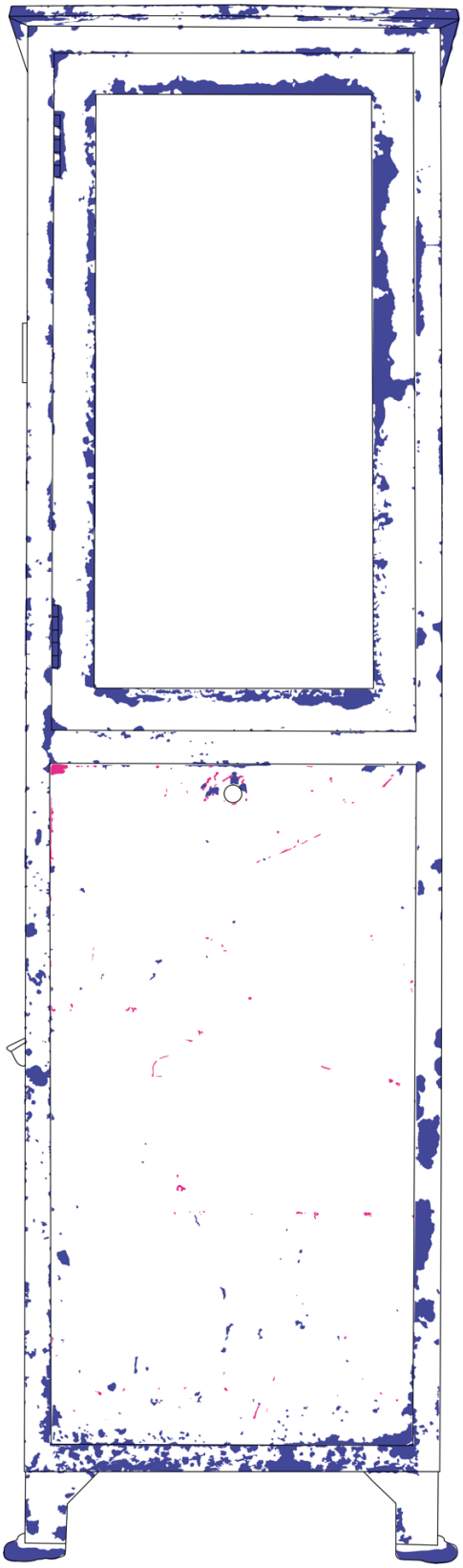
Text written on the recto of the cards	Number of original cards	Number of printed cards
Control your thoughts more…. they wander far too much …. curb your scepticism …. if you'll but concentrare the Green Ray will help you - but at the present minute your thoughts are miles away …. now try again and get some practical advice.	5	3
Cultivate your mind and body … inhale fresh mental ideas from good books … inhale more fresh air by deep breathing … practice both daily … believe in yourself more and you'll be more successful in life.	5	2
Cultivate your optimism - it's precious …. you'll win through believing more and more in your capabilities …. study detail …. you've a happy nature - cultivate it …. give your heart more rein. Don't get ruffled …. Stop worrying over little things … think bigger.	3	2
Don't be so sensitive. Think of others - forget your feelings … Take more open air exercise … Think high … you've great talents … develop them and you'll succeed beyond your expectations	4	1
Don't worry so much …. belive in yourself more. Acquire greater strength of character by cultivating your mind …. practice deep breathing for your body and deep thinking for your mind …. the results will be marvellous.	3	1
Emotional and Sad at times - Industrious - want everybody to be happy - sex appeal constant - very truthful - you hate deceit - travel would help you - a good friend - firmness needed - artistic	4	3
Forget the past and build for the future …. others willl love you and will help you if you will let them. Aim high …. work hard …. study detail more …. you're going to win through …. realise it quickly and get busy.	2	3
"Full of beans" and popular … have few enemies … perhaps too trusting … never lend money … truthful and reticent regarding the great gifts you have … too independent … fond of the other sex …. sensible.	5	3
Full of energy and purpose … temper quick when roused … affections lasting … sex appeal magnetic …. emotional … a good subject possessing psychic powers …. kind- hearted and generous …. conceited.	3	3
Keen as mustard and a great trier … are bound to keep going … you overcame all obstacles yourself … a powerful personality …. ingenious … very sympathetic in times of need … peace loving where the opportunity permits …. artistic.	5	2
Keep on being "Bull dog" in tenacity …. it will pay you. Base your ambitions on sound common-sense …. believe a bit more in yourself …. aim high …. success is coming to you in big capitals.	5	5
Keep your courage high … life has great gifts in store for you shortly …. study detail more - keep pegging away …. much is on its way to you, if you will only believe in your own capabilities	3	2
Look at life in perspective … forget the past …. tackle the present - and your future is assured … your personality attracts affection from all round you - but beware … let your head rule your heart a bit more often. You're born for big things …. get busy.	6	3
Not easily roused, but can be bitter … never really defeated … sex appeal very selective … will stand no bunkum … artistic temperament … strong will power …. sincere …. personal vanity.	6	2
Not easy to read … must be worrying … you have a genuine heart and a fellow feeling …. books will do you good … rather pessimistic … as honest as the day. You should have good luck in the end … overcautious …. loyal.	6	3
Often misunderstood … you bear no malice … fluent and accurate … highly strung and temperamental … emotional … instincts are good and genuine … well balanced … vain … hopeful	2	3

Quick in temper which keeps you backward … dynamic energy that needs restraint … fond of life … your thoughts have strayed and spoiled the reading … fond of friends and company …. to be trusted.	6	0
Sarcastically inclined and argumentative …. temper quick when roused but soon over …. tons of talent …. energetic and hardworking …. careless in some things … faithful to those you love …. strong will.	6	3
The difficulties you endetector are moulding your character ….. use your own obstacles as mounting steps to greater achievements …. keep a tight upper lip …. fight bravely …. success is within your grasp.	4	2
Try and cultivate the humorous side of life more …. loook for the sunny and funny side of difficulties …. it gives such a zest to life …. it's a tonic …. develop optimism …. believe more in yourself	3	2
Why don't you concentrate more on what you are doing? Your wandering thoughts and sceptical attitude towards the Green Ray obviate a true reading …. try again and concentrate properly next time	5	3
Why not cultivate the BETTER SIDE of life …. good books - good music - intellectual friends? …. you could develop your brain far more …. try it out …. you'll thank the Green Ray afterwards.	4	4
You are fond of life and good companionship …. look wide and oppportunities will offer wonders …. success will be yours but you must concentrate more upon the job in hand …. never give up …. consult the Green Ray again …. it will help you.	4	2
You do everything thoroughly - perhaps too enthusiastically. Use your reason more in matters of business … strive for better individuality in ideas …. you have dormant qualities that need development …. actually you are artistic in nature … cultivate this more.	2	4
You doubt the ability of the Green Ray …. your lack of concentration implies your unbelief in its ability to help you …. try again - concentrate much harder. You'll not be disappointed in the result.	5	1
You have intense personal magnetism …. cultivate the serious side of life more and you will draw many friends. The opposite sex secretly admires you …. be careful that you don't uncounsciously break hearts.	3	1
You trust others when they have proved their worth …. you hate deceit ... fond of children … artistic temperament …. temper volcanic when really roused …. a loyal person …. blood is thicker than water with you …. try to be calm.	4	1
Your friends admire you - cultivate their friendship - it will help …. develop the many refinements in your character and aim high …. you are on the high road to success if you keep pegging away.	4	1
Your thoughts are wandering …. your mind isn't concentrating. How can the Green Ray help you if you don't co-operate? Now try again …. concentrate very hard and note the difference.	4	1
Why so disappointed with life? You have latent powers to make your own future …. study and work …. success is coming to you …. you have fine qualities which your friends can see better than you can …. you are very attractive to the opposing sex without realising it.	3	0
Total number of cards	124	66

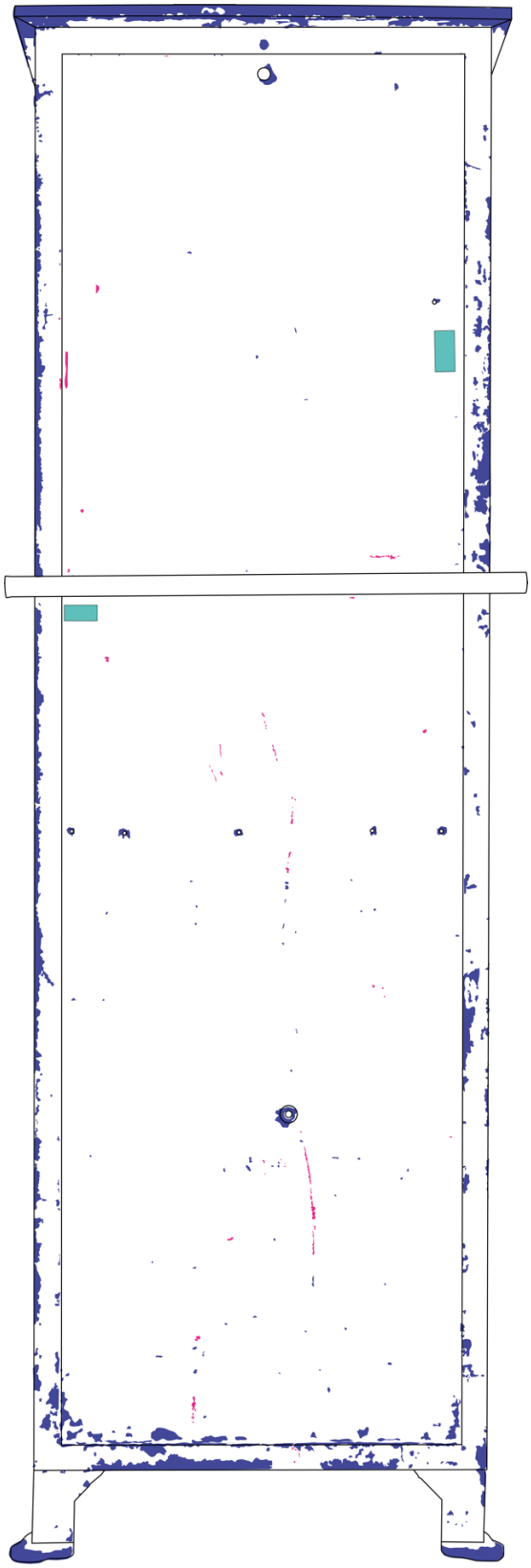
Mapping of the alterations of the paint layer



RIGHT



BACK



Paint losses Visible paint underlayers Auction labels

Union lock reference from the manufacturer

Cabinet Locks

4143

Cylinder Cupboard Lock

UNION
ASSA ABLOY

Application:

- For wooden doors hinged on the left or right
- To suit doors up to 12.5mm material thickness
- Suitable for cupboard doors

Specification:

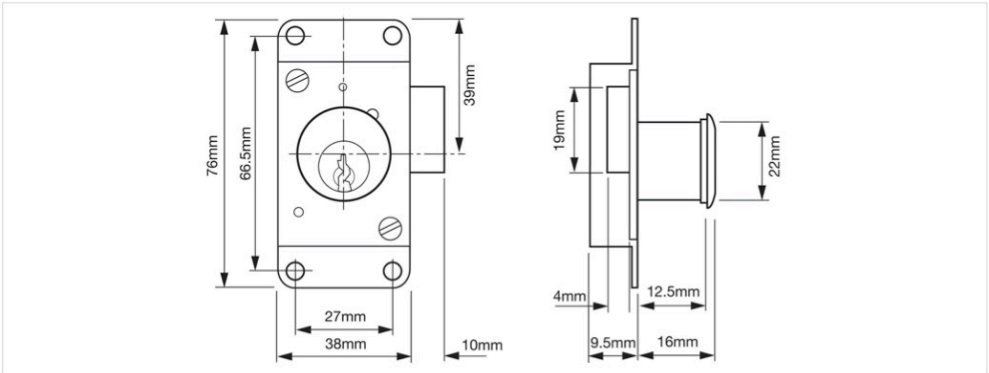
- The bolt is locked and unlocked by key
- Case Size: 76mm (3")
- Cylinder Projection: 16mm
- Case: Zinc, gold enamel
- Cap: Brass
- Striking Plate: Supplied separately, See separate page
- Deadbolt: Brass
- Cylinder Type: Brass, 4-pin tumbler mechanism
- Keying Groups: May be supplied standard differ, keyed alike, keyed to pass or masterkeyed
- Supplied with 2 nickel silver keys
- May be keyed alike with other utility locks of the same key blank number
- Key Blank Number: KB11-534-55
- Also supplied with extra length cylinder projections:
  - 22mm - 414302 (PL finish only)
  - 25mm - 414303

3 YEAR

Finish:

- PL - Polished Brass
- SC - Satin Chrome

Technical Design:



SCHEMATEC Visual methodology

The object we are focusing on during this work is a relatively complex technical object. It is constituted of multiple mechanical or electric components which interact with each other to create a working object. It can therefore be complex to find ways to create a good documentation of the object because the tools for the visual description of technical objects are mainly those of the engineer and manufacturer, with their norms and coded language which are adapted for a certain context but were not made to be understood by all the different people involved in a conservation project or to the future readers of this report.

A tool for the visual description of complex scientific, technical and horology artefacts called *SCHEMATEC* was developed by the HE-Arc conservation-restoration from Neuchâtel in Switzerland[96]. Its aim is to help the conservator-restorer all along the conservation process, with accessible tools for the description of the different levels of visualisation, for the documentation and diagnosis of the conservation conditions of these objects. By using different levels of visualisation, we are able to better document such an object, going from the global view of the object to the more detailed components. The aim here is not to do a step by step explanation on how to use this tool, but rather using the visualisation possibilities it presents which are relevant for a better comprehension of the Green Ray.

Draft of the electric wiring diagram

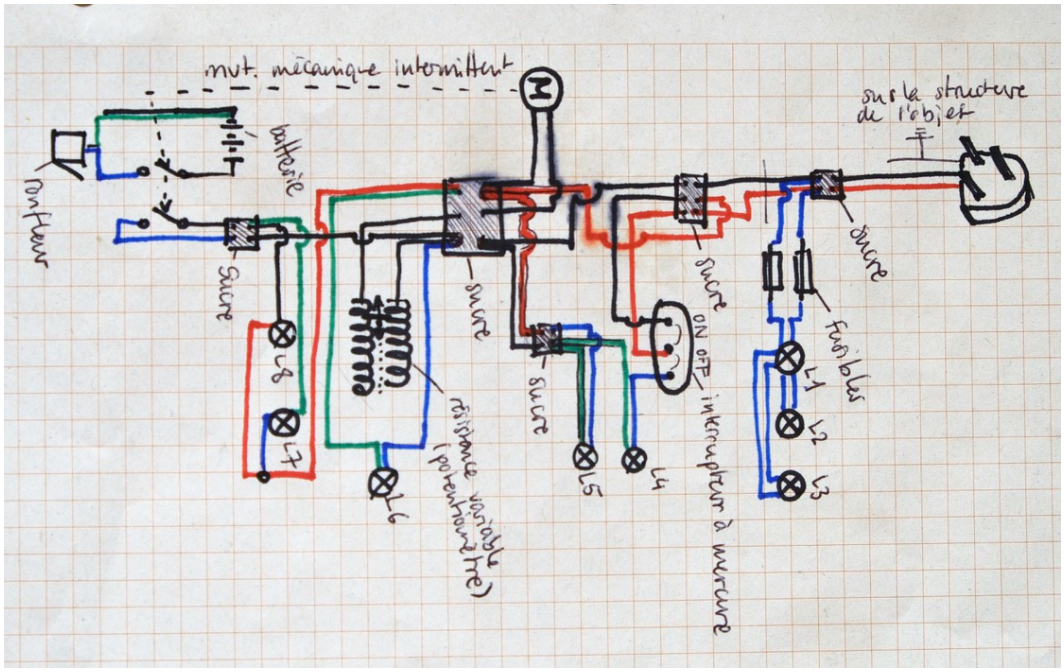
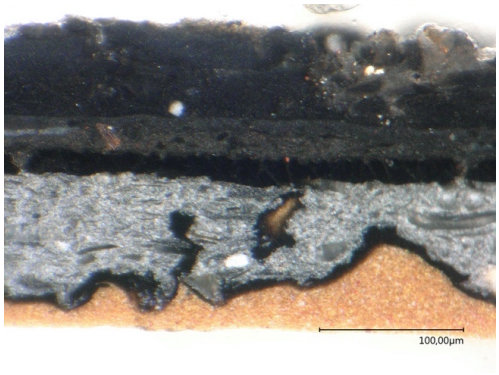


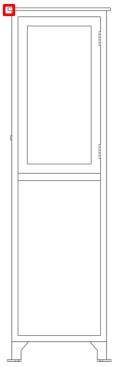
Fig. 165: First draft of the electric wiring inside the object

[96] Tool developped by Christian Degrigny and Romain Jeanneret, http://schematec.he-arc.ch/

Stratigraphy of the paint layer

Sample 1: Roof



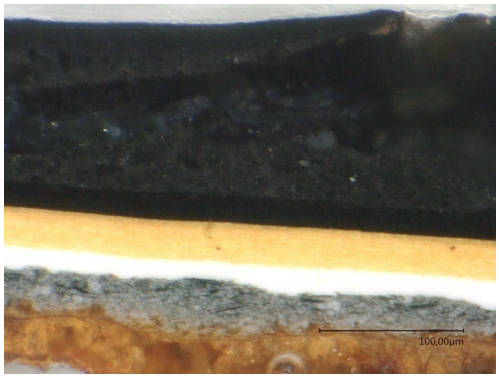


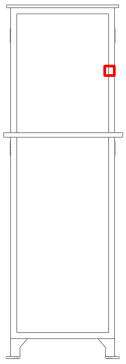
>5 layers

There is a brown underlayer covered with a metallic paint, covered by at least 3 layers of black paint

Figure 166: Cross-section 1

Sample 2: Frame of the object (backside)



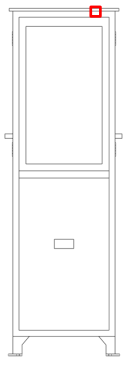


>5 layers

There is no brown underlayer, but the metallic paint layer is present. There is a white layer on top and then a yellow layer. There are mutliple black paint layers forming a thick coat.

Figure 167: Cross-section 2

Sample 3: Frame of the object (frontside)

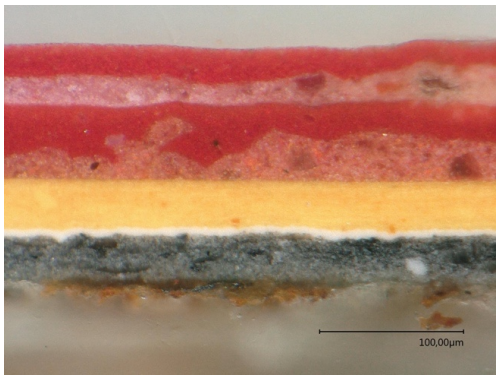


6 layers

Like in sample 2, there is a metallic paint underlayer, covered by 5 different dark layers

Figure 168: Cross-section 3

Sample 4: Exterior of the side panels



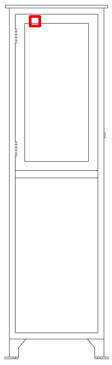


Figure 169: Cross-section 4

7 layers

There is a metallic paint underlayer, covered by the same white/yellow layers as sample 2, and then there are four red layers in alterned light/dark nuances. It seems that the combination of the two red bottom layers has been applied once again on top of them.

Sample 5: Interior of the side panels

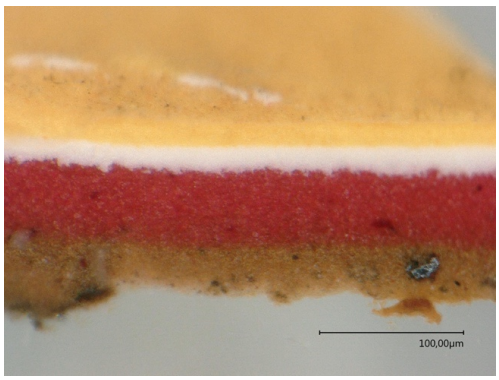


Figure 170: Cross-section 5

4 layers

1 brown underlayer

The red paint could have been the original colour of the inside, it was repainted with a thin yellow layer (the white layer is always present under it, probably that it was to lighten the colour).

Photographs of the Green Ray before its acquisition by the museum

Fig. 171: Photograph taken from the book "Tv is King", written in 1994 by Michael Bennett-Levy, the former owner of the Green Ray

Fig. 172: Photograph from the Bonhams auction sale in 2009 ©Bonhams

We can observe that on the picture from "Tv is King" book from 1994 that at the top of the display panel, there is a red central lamp (*Fig. 171*) which has now been replaced. On the photograph from the auction sale (*Fig. 172*), the mercury switch is tilted in the ON position, which activates the operation circuit. It was because a series of coins was found in the coin slot, probably coming from repeated attempts at making the object operate while it was not responding. We can see that the lamps 7 and 8 (central lamp behind the main lens and red lamp behind the pen) are activated, it means that the mercury switch is in the closed position and the current can pass through the operating circuit. The buzzer is supposed to make sound in this position, if could be the reason why the battery powering it was disconnected from it. In the default rest position of the object, the mechanical switch is not supposed to be closed at all, which could indicate previous modifications or adjustments the mechanism.

Other Green Rays

Fig. 173: Green Ray present at Watermouth Castle ©Arrgee/ ©pennymachines.co.uk

Fig. 174: Green Ray present at Wookey Hole ©Arrgee/ ©pennymachines.co.uk

Fig. 175: Unlocalised Green Ray ©Ted Perkins ©icollector.com

Fig. 176: Unlocalised Green Ray ©pennymachines.co.uk

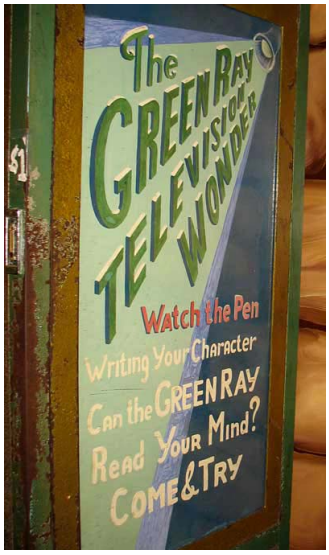


Fig. 177: Green Ray from the Luna Park at Coney Island, Sydney, in 2007, ©Timothy Nohe

Fig. 178: Green Ray from the Luna Park at Coney Island, Sydney, in 2007 ©Timothy Nohe

Fig. 179: Green Ray from the Luna Park at Coney Island, Sydney, after a "restoration" in 2016 ©olivia's penny arcade

Test under static constraint

When testing the conductors, the two electrodes of the ohmmeter were placed on both ends of the wiring segment we wanted to test. The resistance value shown should be around RΩ=0. If it is not the case, it could mean two things: if the resistance value reaches infinity (or the maximum value that the ohmmeter can display) RΩ=∞, the connector is interrupted and the current cannot pass; if there is a resistance RΩ≠0, the current can still pass but the connector is damaged.
To test the individual electric components, we isolated each one of them by removing them from the electric circuit. If the component displays a resistance value (RΩ≠0), it means that the current can pass; the resistance value should be checked to match coherent values for the type of component tested. If it does not correspond it means that the connector might be altered. It the resistance value is near zero (RΩ≈0), the current passes through the component but does not follow the planned path, it means that the component in is a state of short-circuit and there are heavy risks for health if the object were plugged to an electric current source. The last case which could be detected is if the resistance value reaches infinite (RΩ=∞), meaning that the current cannot pass through the component.
This methodology was taken from Michel, Aline. *Conservation-restauration d'un redresseur à vapeur de mercure* (Annexe 8). HE-Arc CR, unpublished, pp. 62-63.

Table 7: Measures of the resistance during the static test

Component	Resistance measured	Component	Resistance measured
Motor	340 Ω	Lamp 4	105 Ω
Rheostat	± 150-750 Ω	Lamp 5	107 Ω
Buzzer	0,4 Ω	Lamp 6	73 Ω
Lamp 1	368 Ω	Lamp 7	68 Ω
Lamp 2	380 Ω	Lamp 8	353 Ω
Lamp 3	359 Ω		

Label indicating the presence of asbestos

Fig. 180: Label which has to be put on the object in the presence of asbestos