Architectus

2020
1(61)

DOI: 10.37190/arc200102

**Marie Grima***

# *The Tod Head lighthouse lantern. The conservation-restoration of a technical object that has been continuously modified over the years*

# *Latarnia morska Tod Head. Konserwacja i restauracja obiektu techniki przez lata poddawanego modernizacji*

## *Introduction*

In March 2019 the National Museums Scotland started the conservation and reassembly of the Tod Head lighthouse lantern. The museum wished to add a lighthouse lantern to its collection, which already has two lighthouses on its premises (the Sule Skerry lighthouse and the Inchkeith lighthouse) and one on loan to the Science Museum in London (the Eilean Glas lighthouse).

The interest in these objects comes firstly from their complexity as technical objects. These are complex lighting devices whose technology has been gradually developed since ancient times (an ancient example being the Lighthouse of Alexandria) [1]. An acceleration happened in the middle of the 18th century, with the abandonment of various fuels (wood, coal, oils) in favour of groups of candles, the development of reflectors, and the introduction of eclipse fires.

Lighthouse lanterns are the products of an entire organization: the rotation of the keepers and their constant presence; their supply of water, food and fuel; the boats providing the link; the building tax allowing the maintenance of the lighthouses and the organization attached to their management.

After being electrified and then automated, some of these objects were gradually deactivated. Electronic means of geolocation – by which we mean satellite positioning systems – are very efficient and make some light towers redundant. It was not always viable to recover the lens and mechanisms from remote areas, as is the case with the Sule Skerry lighthouse mechanism where only the lens was repatriated to land from its isolated rock. The rest would have been too complex and costly to collect. The Tod Head lighthouse was fortunate enough to find refuge in the reserves of the National Museum Scotland.

The project began in March 2019. Its completion is scheduled for Christmas 2019. The four permanent members of the engineering conservation section and their intern participated in the adventure.

## *How does a lighthouse work?*

### *A brief general explanation*

First of all, what is a lighthouse?

A lighthouse is first and foremost a signalling system. Depending on their position and light intensity, lighthouses are divided into four groups: first, second, third and fourth order [2]. The presence of approaching coastlines is the most important information to transmit to navigators, and from as far away as possible. This information is provided by first order lighthouses located at the most prominent

* ORCID: 0000-0002-3328-0497. National Museums Scotland, Scotland. Institut National du Patrimoine, Paris, France.

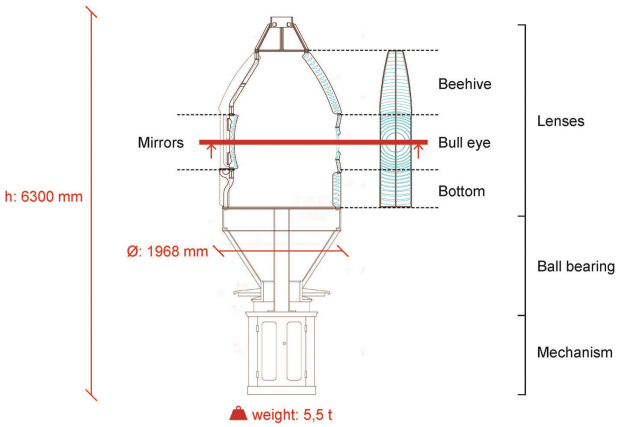


Fig. 1. Technical drawing of the Tod Head lighthouse lantern (author: M. Grima)

Il. 1. Latarnia morska Tod Head – rysunek techniczny (autor: M. Grima)

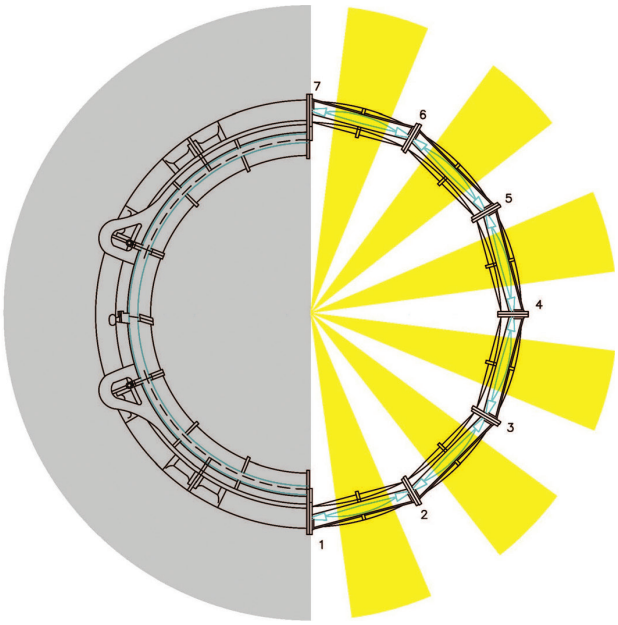


Fig. 2. Top view section and identification signal (author: M. Grima)

Il. 2. Przekrój górnej części z widocznym sygnałem identyfikacyjnym (autor: M. Grima)

points along the coast. They are placed in such a way that it is impossible to approach the coast without seeing one. This is the case for the Tod Head Lighthouse, which was located on the east coast of Scotland some 100 miles north of Edinburgh and which had a signalling range of 21 miles.

Second and third order lighthouses indicate sandbanks, reefs and small islands. Port entrances are signalled by fourth-order lighthouses.

It is necessary for the navigator to differentiate between each of these lights, and especially to be able to identify those of the first order, in order to know their position. The lantern is located at the highest point of the lighthouse building and is both the light source and the signature of the headlight. Each headlight has its own identification signal, obtained through the eclipse system, a complex system explained below.

### *Description of the Tod Head lantern*

The Tod Head lantern is more than 6 m high, its largest diameter is about 2 m and it weighs about 5.5 tonnes (Fig. 1). It is divided into three parts: the lowest part, fixed to the ground, contains the mechanism; the second part contains the mechanical roller bearing and structural elements; the third part consists of the lenses.

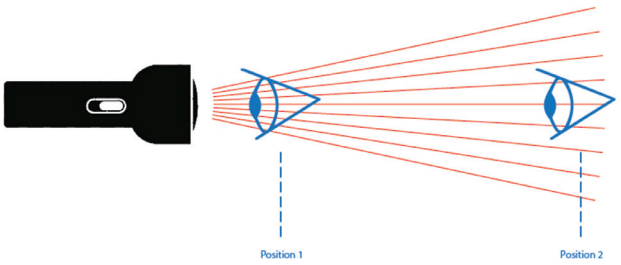


Fig. 3. Light propagation diagram (author: M. Grima)

Il. 3. Schemat propagacji światła (autor: M. Grima)

The clock type mechanism consists of a set of brass wheels and gears, held by steel plates and protected by a box, also made of steel. The movement produced by the mechanism is transmitted to the lenses by the roller bearing, which is also made of steel. The lenses are glass prisms held together by brass frames.

The lenses are divided into two hemispherical parts. The part on the left in Figure 2 corresponds to the part called the “mirrors”. They are actually glass prisms whose particular angle reflects light. The right side of the diagram is composed of six panels as seen in elevation in Figure 1. The upper part is called the “beehive”, the middle part the “bull eye” and the lower part the “bottom”.

These six panels correspond to six flashes. The mirrors correspond to a period of darkness. The lantern makes a revolution in 30 s. This is the identification signal from Tod Head Lighthouse.

### *Explanation of the light device function*

To understand the lenticular system of a headlight, it is first necessary to know that the light intensity does not increase proportionally with the power of the light source. The unit of measurement for light intensity is the candela (cd): 1 cd corresponds to the flame of a candle with a range of 2 km. These values are not proportional. To illuminate at 4 km, it will take 6 cd and to illuminate at 36 km, 100 000 cd will be necessary.

This phenomenon is explained as follows: the light emitted by a light source propagates in a straight line but widens (Fig. 3). In other words, light propagates in the shape of a cone. A receiver close to the source (position 1) will receive many rays while a receiver far from the source (position 2) will receive few rays.

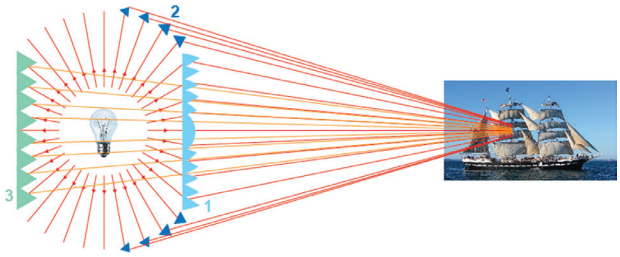


Fig. 4. Diagram of the light displacement in the Tod Head lantern (author: M. Grima)

Il. 4. Schemat rozchodzenia się światła latarni Tod Head (autor: M. Grima)

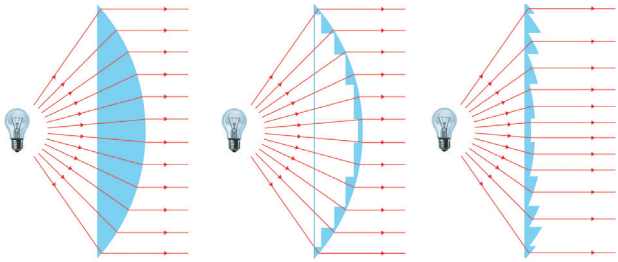

Fig. 5. Explanatory diagram of the stepped lens (author: M. Grima)

Il. 5. Schemat objaśniający działanie soczewki schodkowej (autor: M. Grima)

We call the lantern the light device of the lighthouse. The purpose of the lantern is to collect the lost rays (which go up, back and down) and gather them into a beam of very high intensity (Fig. 4). To do this, the lantern at Tod Head Lighthouse has three types of lenses.

This system was developed after the work of Augustin Fresnel from 1822 [3]. The system used until then was composed of hemispherical or parabolic metal mirrors. It was not very effective because the metal, even polished, absorbs light strongly and tarnishes easily.

Augustin Fresnel's work was to develop a lens shape that could be used for lighthouses [4]. His invention, called a "stepped lens", produces the same result as a conventional lens. It is nevertheless lighter, less expensive and above all feasible in the scales we are interested in, in other words around 1 m high. Fresnel realized that it is not the thickness of the lens that causes the refraction of light but its external curvature. He therefore removed all unnecessary material and then brought the fragments obtained to the same level (Fig. 5).

The three types of lenses used in the Tod Head lantern are as follows: lens no. 1 is the equivalent of the bull eye (Fig. 1); lens no. 2 is the equivalent of the beehive and bottom and lens no. 3 is the equivalent of the mirror. The glass prisms of these three lenses have a different angle in each case. This allows them, although in different areas, to always reflect light in the same direction.

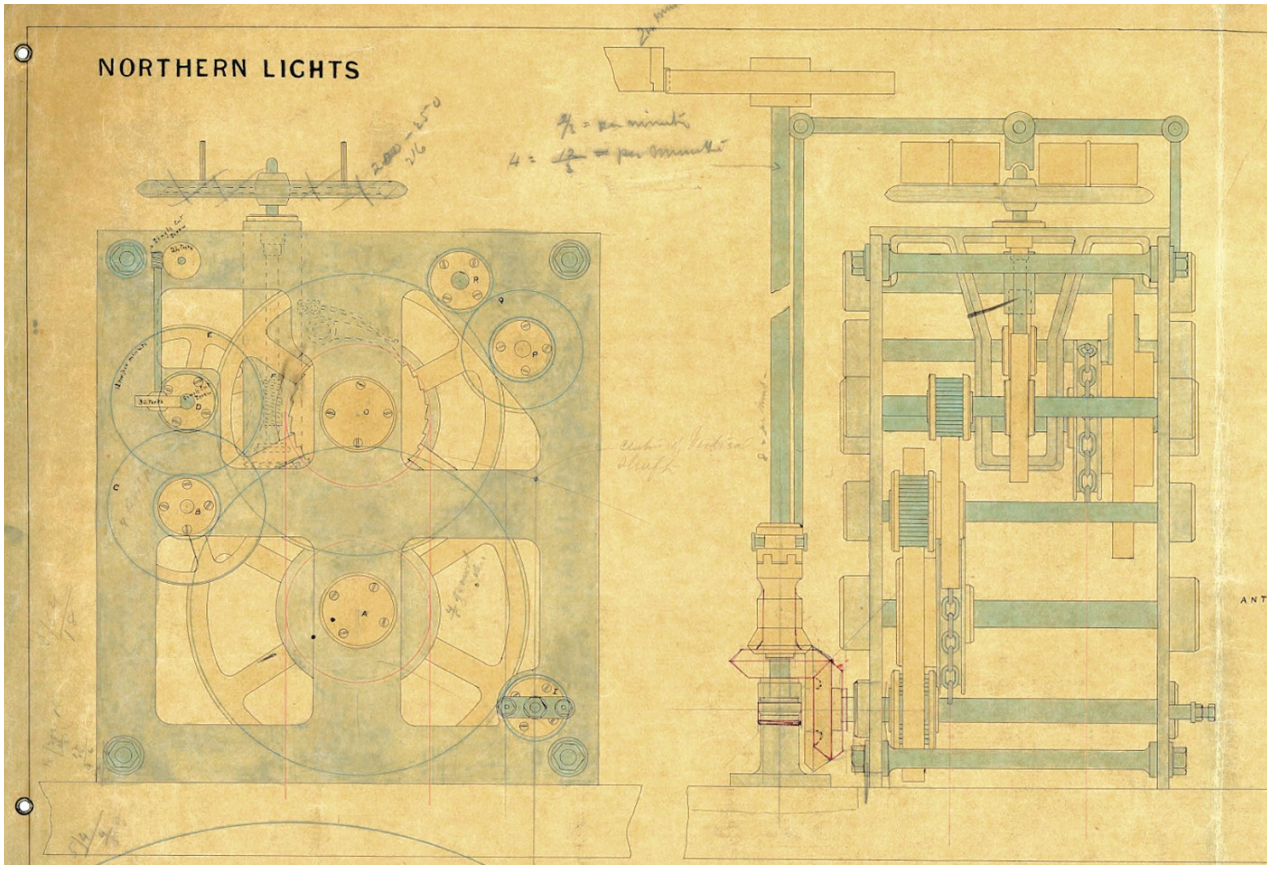


Fig. 6. Detail of the mechanism, technical drawing, 1897 (source: image courtesy of the Northern Lighthouse Board)

Il. 6. Szczegół mechanizmu, rysunek techniczny, 1897 (źródło: zdjęcie dzięki uprzejmości Northern Lighthouse Board)

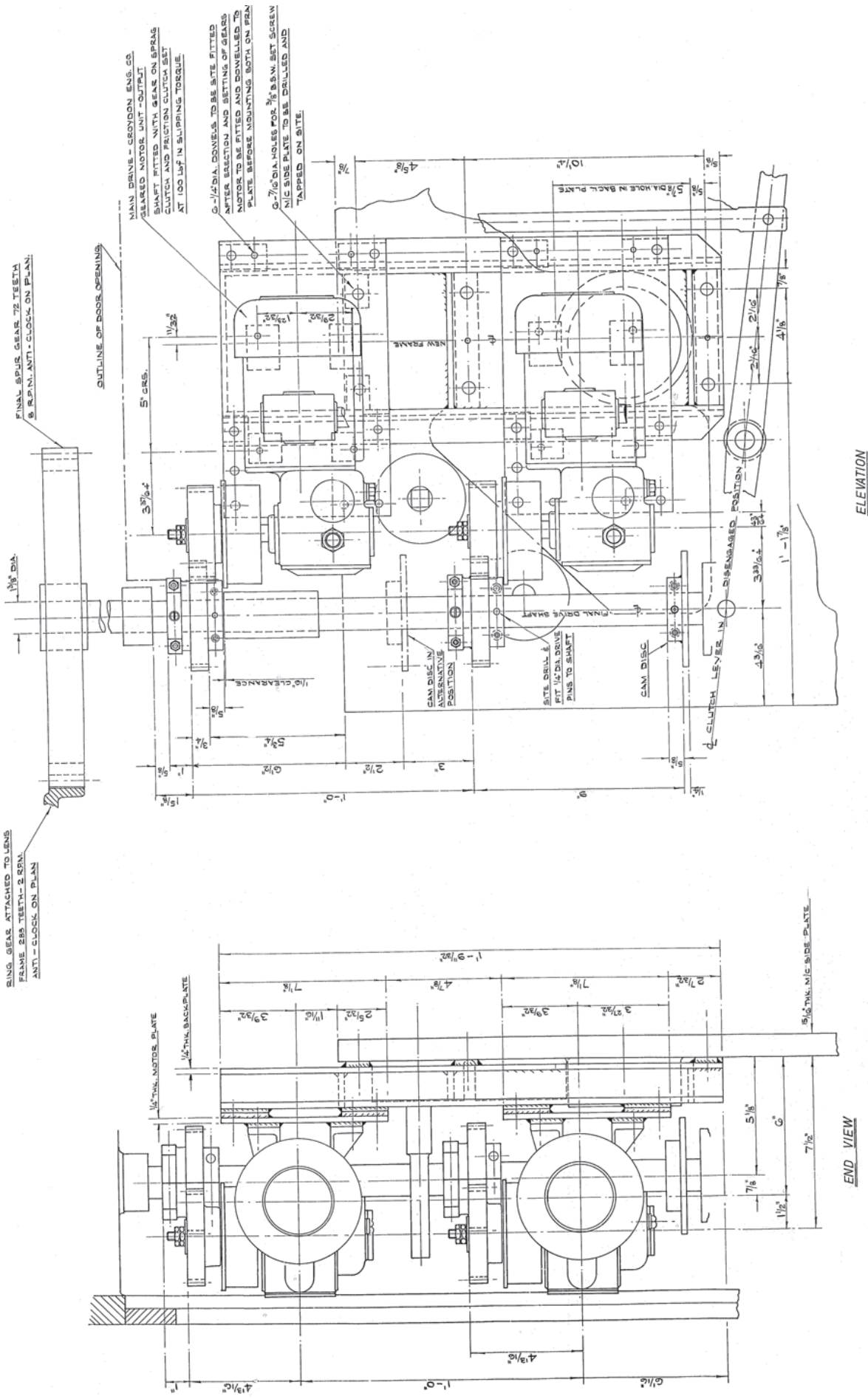


Fig. 7. Details of the mechanism, technical drawing, 1973 (source: image courtesy of the Northern Lighthouse Board)

Il. 7. Szczegóły mechanizmu, rysunek techniczny, 1973 (źródło: zdjęcie dzięki uprzejmości Northern Lighthouse Board)

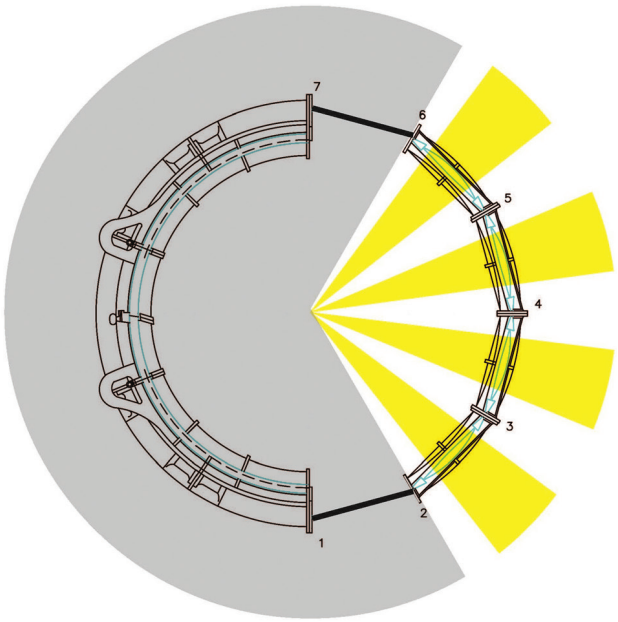


Fig. 8. Tod Head lighthouse identification signal after 1977
(author: M. Grima)

Il. 8. Sygnał identyfikacyjny latarni morskiej Tod Head po 1977 r.
(autor: M. Grima)

Fig. 9. The lantern in spare parts
at the National Museums Collection Centre
(source: image courtesy of National Museums Scotland)

Il. 9. Latarnia w częściach w magazynach National Museums Scotland
(źródło: zdjęcie dzięki uprzejmości National Museums Scotland)

This type of device makes it possible to recover most of the light rays and gather them into a beam with a range greater than 21 miles.

## *Some chronological landmarks*

The Tod Headlight was first switched on in 1897. Its design is the result of a technical collaboration between a Scottish engineer, David Alan Stevenson, and a French watchmaker, Augustin Henry-Lepaute. David Alan Stevenson came from a family of lighthouse engineers, whose work began in 1811 with the construction of the Bell Rock lighthouse by Robert Stevenson [5]. Augustin Henry-Lepaute [6], a student of Gustave Eiffel and a partner from 1823 of Augustin Fresnel, was the watchmaker of Louis Philipe (1830–1848) and Napoleon (1848–1852). He built many lighthouses in Europe (including the one in Valsörarna, Finland).

Around 1950, a major upgrade was completed to replace the rotating lantern system at Tod Head Lighthouse. The original system is known from the construction drawings and its similarity to the Inchkeith Lighthouse. The Inchkeith Lantern is displayed in the large gallery of the National Museum of Scotland: it has circular elements fixed to the central axis and pivots around this axis by means of a rail.

The entire structure of Tod Head, from its rotating rail, was lifted in order to replace the previous system with a mechanical roller bearing. This new device stayed in use throughout the rest of Tod Head's life. This modification is the first in a long series. Only major events are listed here.

In 1964, the paraffin vapour burner was removed and replaced by a light bulb. The central pillar that provided the fuel supply was removed and replaced by an aluminium column. In 1973, the mechanism was motorized (Figs. 6, 7). On this occasion, openings for ventilation and cooling of the motors were added to the doors of the mechanism box.

In 1977, the Northern Lighthouse Board – the administration responsible for managing Scottish lighthouses – requested the removal of two lens panels, to change the identification signal of the lighthouse. Tod Head no longer had six flashes in 15 s followed by 15 s of darkness, but 4 flashes in 10 s followed by 20 s of darkness (Fig. 8).

In 2007, the lighthouse was deactivated and the building was sold as private property. It was dismantled in 2011 by the Northern Lighthouse Board and stored in crates at the National Museums Collection Centre. Around 2015, the clockwork mechanism was cleaned by a former member of the conservation-restoration engineering section specialising in horology.

The cleaning and the reassembly of the Tod Head Lighthouse began in March 2019. The project will be completed by the end of 2019.

## *The reassembly*

### *The objective*

How to reassemble the Tod Head lighthouse lantern? What elements need to be reassembled (Fig. 9)?

The National Museums Scotland already has a lantern on display in the museum's exhibition galleries in Edinburgh. This lantern comes from the Inchkeith Lighthouse and was reassembled to be as it was when it was built in 1804. The addition of the Tod Head lantern to the collection will illustrate the complexity of the modifications made to it over time, and will therefore involve all the elements held by the museum. This will also help prevent loss or dissociation of elements of the lantern from some being on display and others being in storage.

In order to design the conservation project, we relied on the study of the original technical plans, the observa-

Fig. 10. Cleaning product residue
(source: image courtesy of National Museums Scotland)

Il. 10. Pozostałości środków czyszczących
(źródło: zdjęcie dzięki uprzejmości National Museums Scotland)

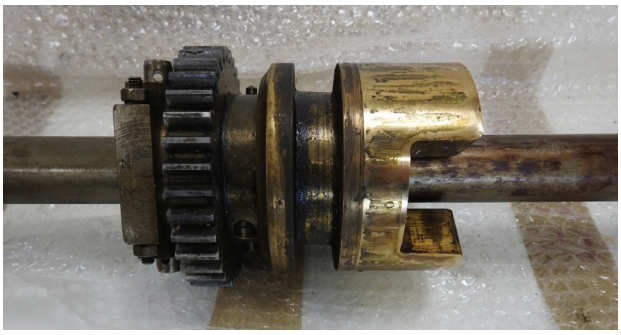

Fig. 11. Element of the mechanism before intervention
(source: image courtesy of National Museums Scotland)

Il. 11. Element mechanizmu przed naprawą
(źródło: zdjęcie dzięki uprzejmości National Museums Scotland)

tion of the photographs of the dismantling and the study of other lanterns.

### *Conservation operations*

From a general point of view, the object is in good condition, particularly the metal which is in very good condition. In hard-to-reach areas (corners, screws), whitish deposits from old cleaning products are present (Fig. 10). In addition to damaging the protective coating, these residues have initiated a corrosion process, as shown by the green colouring of these areas.

There is a strong general fouling accompanied by oily deposits on all the elements (Fig. 11).

Residues of cleaning products, fouling and oily deposits pose a risk to the conservation of the object because they promote corrosion. Fouling was sometimes so severe that it prevented the various components from being reassembled. Cleaning was therefore carried out to remove this fouling.

The cleaning was carried out mechanically (scalpel, steel wool, Garyflex®) and chemically (white spirit and acetone in the case of larger deposits) (Fig. 12).

Fig. 12. Mechanical cleaning of the ball bearing structure
(source: image courtesy of National Museums Scotland)

Il. 12. Mechaniczne czyszczenie konstrukcji łożyska kulkowego
(źródło: zdjęcie dzięki uprzejmości National Museums Scotland)

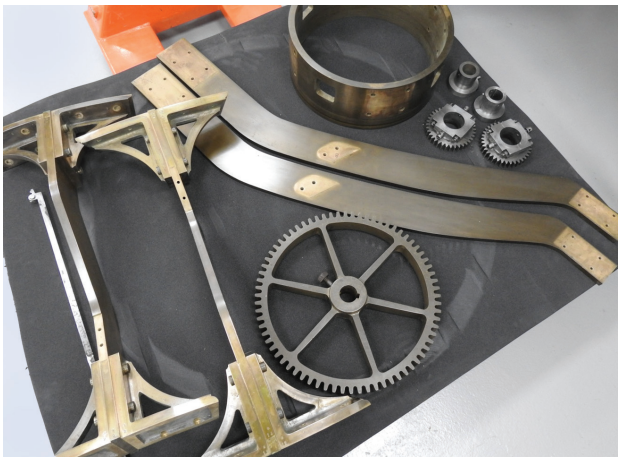

Fig. 13. Parts after cleaning
(source: image courtesy of National Museums Scotland)

Il. 13. Części po czyszczeniu
(źródło: zdjęcie dzięki uprzejmości National Museums Scotland)

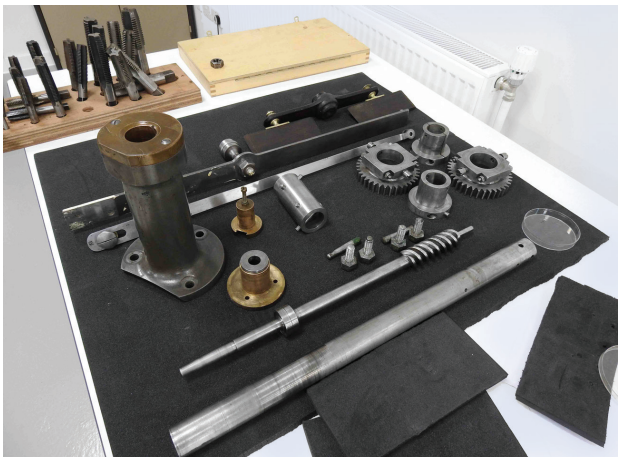

Fig. 14. Parts after cleaning
(source: image courtesy of National Museums Scotland)

Il. 14. Części po czyszczeniu
(źródło: zdjęcie dzięki uprzejmości National Museums Scotland)

The cleaning operations also involved cleaning 35 kilos of screws. We were dealing with an object dating from the end of the 19th century which had been modified throughout the 20th century. The differences in the standardization systems of the different elements testify to this: the original elements are in British Standard Whitworth, the ball bearing is in United National Fine, some elements on the platform are in metric and the lens screws do not belong to any known system.

The two lens panels dismantled in 1977 were separated from the rest of the lantern. Thanks to the collaboration of the Northern Lighthouse Board, we were able to find their location in the reserves of the Lighthouse Museum in Fraserburgh, a town in the Grampian Mountains, north of Aberdeen. Thanks to their collaboration, we were able to recover these panels. Nevertheless, of the 18 lens panels, one is missing. It is the bull eye (middle part) numbered 1/2. After cleaning the parts (Figs. 13, 14), reassembly began.

Once the mechanism was completed, the machine case was closed and the mechanical roller bearing installed. The object then weighed nearly two tonnes. Before being completed, the mechanism had to be moved to its final location because the capacity of the lifting tools did not exceed two tonnes.

For safety reasons, the mechanism was fixed to the ground with 15 cm long dowels. It is important to note that not everything above the ball bearing was fixed since it must be free to rotate. Therefore, the three tonnes of lenses were simply placed on the ball bearing.

The wheel that transmits the movement of the mechanism to the lenses was the first element to be added. Next came the central pillar, as well as the white painted arms supporting the inner platform (fixed) and the green painted arms supporting the lenses (rotating) (Fig. 15). Finally, the "bottom", which is the first level of lenses, was raised; then the structural elements to support the mirrors.

This is how the lighthouse looked in the storage area of the National Museums Scotland (National Museums Collection Centre) at the 1st of September 2019.

Fig. 15. The lantern being reassembled
(source: image courtesy of National Museums Scotland)

Il. 15. Latarnia ponownie zmontowana
(źródło: zdjęcie dzięki uprzejmości National Museums Scotland)

## *Conclusion*

Before continuing this work, the team must face two issues. The first is that while all the lens panels have been found, this is not the case for all the screw elements that supported them. About 60% of the lens screws are missing. In addition, these are screws that do not belong to a standardized threading system. They must therefore be manufactured by an external company specifically for this project.

The second thing that will allow the site to resume will be the installation of a scaffolding for the second and third lens levels.

## *References / Bibliografia*


[1] *Lighthouse of Alexandria*, [in:] *Encyclopaedia Britannica*, https://www.britannica.com/topic/lighthouse-of-Alexandria, [n.d.], [accessed: 26.11.2019].

[2] Figuier L., *Les Merveilles de la Science ou Description populaire des Inventions humaines*, T. 4, Furne, Jouvet et Cie, Paris 1870, 419–470.

[3] Fresnel A., *Mémoire sur un nouveau système d'éclairage des phares lu à l'Académie des Sciences le 29 juillet 1822*, © Ecole nationale des Ponts et Chaussées, 1822.

[4] Brewster D., *On the Construction of Polygonal Lenses, and their Combination with Plain Mirrors, for the purposes of Illumination in Lighthouses*, Transactions of the Royal Society of Edinburgh, Vol. 11, Edinburgh, published by Charles Tait, Bell and Bradpute and T. Cadell, London 1831, 53.

[5] Morrison-Low A.D., *Northern Lights*, National Museums Scotland and the Royal Scottish Society of Arts, Edinburgh 2010, 239.

[6] Beillard A., *Recherches sur l'horlogerie: ses inventions et ses célébrités: notice historique et biographique, d'après les divers documents de la collection de l'école d'horlogerie d'Anet*, E. Bernard, 1895, 168.

## *Abstract*

This paper presents the conservation and reassembly of the Tod Head lighthouse lantern in the storage area of the National Museums Scotland. The Tod Head lighthouse was located on the Scottish east coast, north of Edinburgh. The lantern was dismantled in 2011 and sent to the National Museums Collection Centre. Firstly we look at a technical explanation of a functioning lighthouse. The lighting device – which is called a lantern – uses Fresnel lenses, also called stepped lenses. The design of the lantern was a collaboration between the Scottish engineer David Alan Stevenson and the horologist Augustin Henry-Lepaute, partner of Augustin Fresnel. Secondly, a short history of the object is presented. Throughout the 20$^{th}$ century, the lantern has undergone many changes. The light has been electrified and the mechanism has been motorised. Finally we detail the conservation operations and the reassembly.


**Key words:** lantern, lighthouse, Stevenson, Fresnel


## *Streszczenie*

Tematem artykułu jest proces konserwacji latarni morskiej Tod Head przeprowadzony na terenie magazynu National Museums Scotland. Latarnia Tod Head znajdowała się na wschodnim wybrzeżu Szkocji, na północ od Edynburga. W 2011 r. rozebrano ją i wysłano do National Museums Collection Centre. Na początku sprawdzono dokumentację techniczną funkcjonującej latarni. Urządzenie oświetlające – które nazywa się latarnią – wykorzystuje soczewki Fresnela, zwane również soczewkami schodkowymi. Projekt latarni powstał dzięki współpracy szkockiego inżyniera Dawida Alana Stevensona oraz gnomologa Augustina Henry-Lepaute'a, współpracownika Augustina Fresnela. W pracy przedstawiono krótką historię obiektu. W XX w. latarnia przeszła wiele zmian. Źródło światła (latarni) zostało zelektryfikowane, a mechanizm (obrotowy) zautomatyzowany. W artykule szczegółowo opisano operacje konserwatorskie i ponowne złożenie obiektu.


**Słowa kluczowe:** latarnia morska, Stevenson, Fresnel