e-maritime

NOVEMBER 2021

Eddystone Lighthouse, UK

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Front Cover: Eddystone Lighthouse, Plymouth, UK

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International, online magazine about ports, docks, vessels and maritime equipment. Peer-reviewed.

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November 2021

Dear Readers

In this Issue, you can read ***A Brief Review of Lighthouse Construction around the British Isles*** *which was prepared by Timothy Douglass. This article is intended to provide the reader with an outline of the history of how lighthouses construction evolved in the British Isles, particularly lighthouses built on wave-swept rocks out to sea, much of which was adopted abroad.*

It is followed by an ***Overview of already published articles in e-maritime*** *from its first Issue about Specialized Vessels in March 2019 to today.*

We regret to inform you that this Issue is the last one we plan to publish. The main reason is that we are going to focus mainly on our magazine e-mosty about bridge design, construction, operation and maintenance, and in 2022 we will start a new bridge-related magazine, e-BrIM, which will focus on Bridge Information Modelling.

All already released e-maritime editions will stay available online, with open access. If you are interested in vessels and equipment used in bridge construction, you may consider subscribing to e-mosty magazine or following us on LinkedIn.

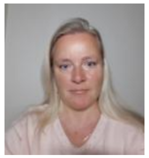
I would like to thank all people and companies who have been helping us, supporting us, and also all authors and other people who have contributed to our magazine.

We would like to wish you many successfully implemented projects, satisfied customers and clients, and a lot of achievements and satisfaction in your careers and lives.

Thank you all.

Magdaléna Sobotková

Chief Editor



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The magazine **e-maritime** is an international peer-reviewed online magazine about ports, docks, vessels, maritime equipment and construction at sea.

It was regularly published at www.e-maritime.cz three times a year, from March 2019 to November 2021:

30 March, 30 June and 30 November.

September Issue was shared with the magazine e-mosty ("e-bridges"): "Vessels and Equipment for Bridge Construction" which is published on 20 September at www.e-mosty.cz.

It can be read free of charge (open access). The magazines stay **available online** on our website as pdf.

The magazine brought **original articles about design, construction, operation and maintenance of ports, docks, vessels, maritime equipment and construction at sea** from around the world.

Its electronic form enabled publishing of high-quality photos, videos, drawings, links, etc.

We aimed to include **all important and technical information** and show the grace and beauty of the structures and vessels as well.

As of 2022, the magazine will be released on an irregular basis – when there is content, we will publish it.

ISSN 2571-3914

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e-mosty

The magazine **e-mosty** (“e-bridges”) is an international, interactive, peer-reviewed magazine about bridges.

It is published at www.e-mosty.cz and can be read free of charge (open access) with possibility to subscribe.

It is published quarterly: 20 March, 20 June, 20 September and 20 December. The magazines stay **available online** on our website as pdf.

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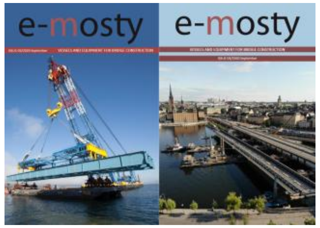
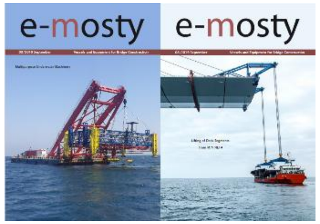
We aim to include **all important and technical information** and show the grace and beauty of the structures.

We are happy to provide media support for important bridge conferences, educational activities, charitable projects, books, etc.

Our Editorial Board comprises bridge engineers and experts mainly from the UK, US and Australia.

The readers are mainly bridge engineers, designers, constructors and managers of construction companies, university lecturers and students, or people who just love bridges.





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e-BrIM

The magazine **e-BrIM** is an international, interactive, peer-reviewed magazine about bridge information modelling.

It is published at www.e-brim.com and can be read free of charge (open access) with possibility to subscribe.

It is typically published three times a year: 20 February, 20 May and 20 October.
The magazines stay **available online** on our website as pdf.

The magazine brings **original articles** about **bridge digital technology** from early planning till operation and maintenance**, theoretical and practical innovations, Case Studies** and much more from around the world.

Its electronic form enables publishing of high-quality photos, videos, drawings, 3D models, links, etc.

We aim to include **all important and technical information, to share theory and practice, knowledge and experience** and at the same time, to show the grace and beauty of the structures.

We are happy to provide media support for important BIM and bridge conferences, educational activities, charitable projects, books, etc.

Our Editorial Board comprises BIM and bridge experts and engineers from academic, research and business environments and the bridge industry.

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RÚBRICA® BRIDGES

A BRIEF REVIEW OF LIGHTHOUSE CONSTRUCTION AROUND THE BRITISH ISLES

By Timothy Douglass

By the end of the seventeenth century, there were approximately thirty lighthouses located around the British Isles, all on land.

Over the next two hundred years, a major effort was made to make the seas safe for shipping by adding nearly 250 more, excluding harbour lights.

These were mainly put in place by the three-lighthouse authorities; Trinity House for England, Wales, Channel Islands; (less Jersey) and Gibraltar, The Northern Lighthouse Board for Scotland and the Isle of Man; and the Commissioners of Irish Lights, (formerly the Dublin Ballast Board), for Ireland.

Three family dynasties played a major role in design and construction.

Four generations of the Stevensons in Scotland who designed and built lighthouses for the NLB, which included Robert Stevenson's stepfather, John Smith; two generations of Halpins in Ireland who designed lighthouses for the Dublin Ballast Board; and three generations of Douglasses who designed and built lighthouses in England a Wales for Trinity House and in Ireland for the Commissioners of Irish Lights.

Another major player was James Walker who designed many of Trinity House's lighthouses. Some of the earlier ones were built under leases granted to private individuals together with the authority to collect dues from passing shipping.

These were later bought out by the lighthouse authorities. Lighthouses can be considered as falling into two categories.

Hartland Point Lighthouse. Becks CC by 2.0

SHORE LIGHTHOUSES

The first covers lighthouses located on land, on islands, and in shallow or sheltered waters, out of reach of any heavy wave impact, where before automation the lighthouse keepers, normally two, lived with their families.

Most took one or two years to build, and usually construction could follow normal architectural practices allowing a lot of latitude in design, with many being built by regular building contractors.

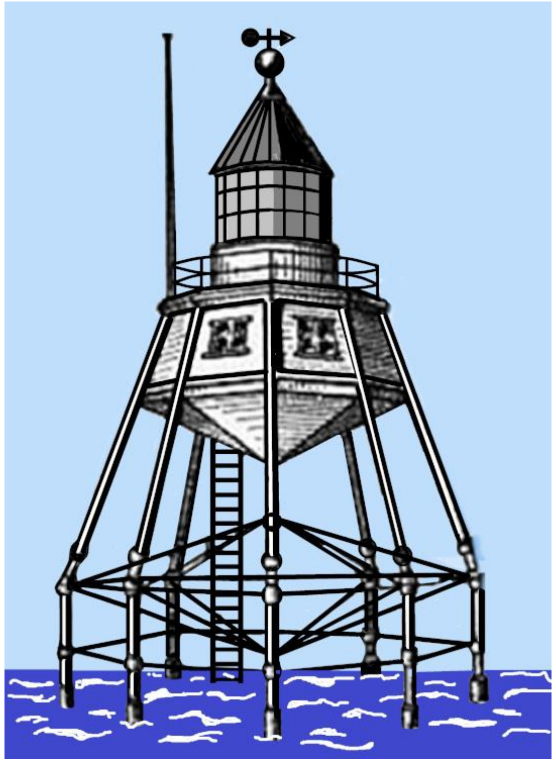
If there was no suitable housing close by, accommodation for the keepers and their families was built as well as workshops and storage facilities, sometimes within the tower itself.

The Hartland point lighthouse on the north Devon coast in the picture is an example of a shore lighthouse. Another is the Bidston Lighthouse shown in: *'A Short History of Bidston Lighthouse and Associated Facilities'* by David Stork in the March 2021 issue of e-maritime.

Most of the lighthouses situated in shallow water had the keeper's accommodation and storage space on a single level with the lantern above. This was usually of an octagonal shape and supported by an open metal structure.

Where the bottom was soft, such as sand or mud, steel piles could be driven or screwed into the seabed to support it.

The first screw pile lighthouse was built by a blind Irish engineer, Alexander Mitchelon, between 1838 and 1841 on the Maplin Sands near the mouth of the River Thames.



Maplin Sands Screw Pile Lighthouse Completed in 1841

ROCK LIGHTHOUSES

The second category covers those lighthouses located out to sea on wave-swept rocks, with the keepers having no means to leave the rock except when a relief boat came and sea conditions were favourable, and only seeing their families during shore leave.

They needed to be very sturdily built to withstand the severest storms. Most were constructed with stone and took from four to eight years to complete.

The next page shows approximately to scale the twenty-three rock lighthouses built around the British Isles and the two built by Trinity House off the coast of Sri Lanka, including those that have been replaced.

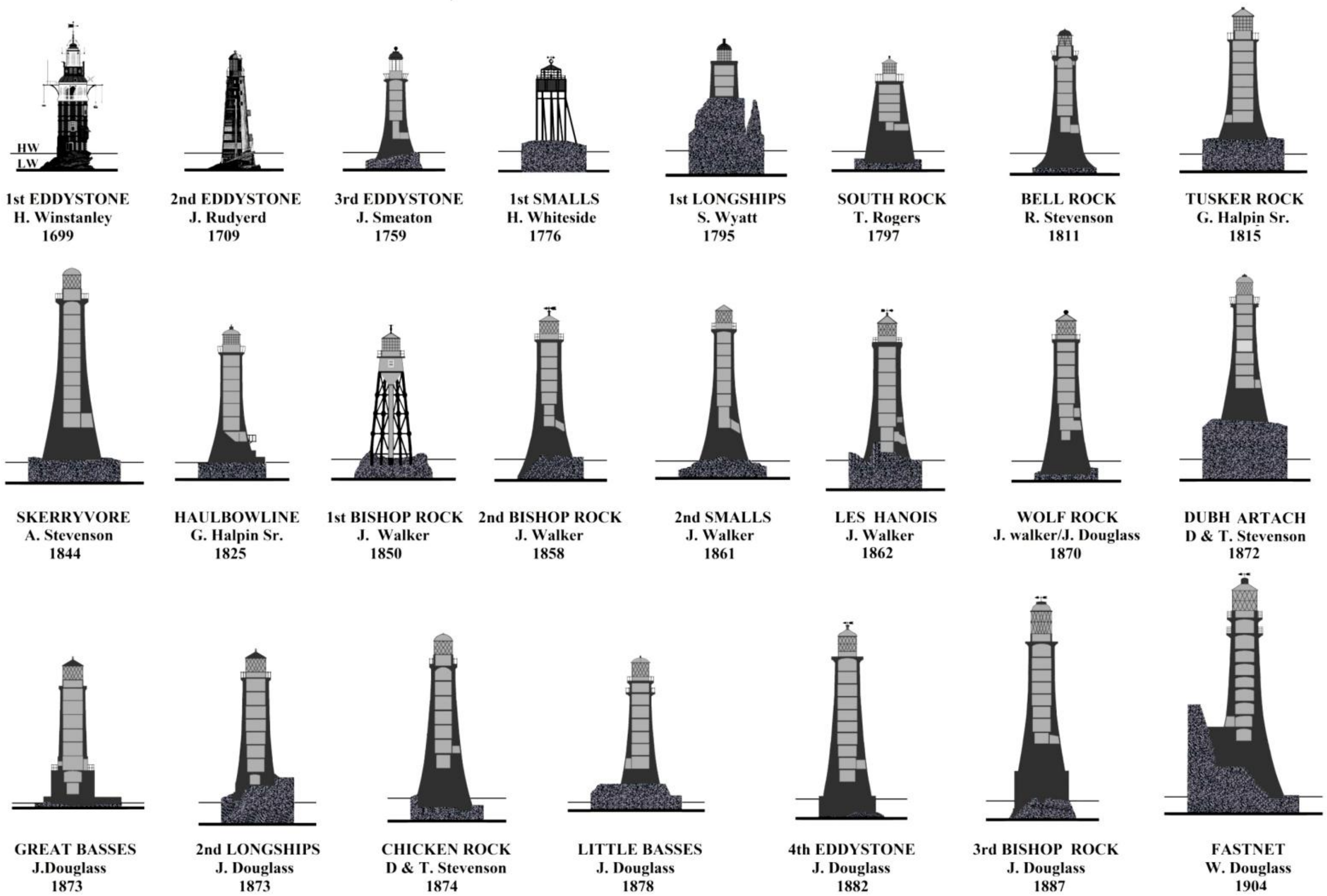
The dates are initial lighting with the exception of the first lighthouse on the Bishop Rock which was washed away in a winter storm before the lantern was fitted.

Fifteen are in operation today and like their shore counterparts are now unmanned. Many have been fitted with helicopter pads and some are solar powered.

The first five were built privately under leases granted by the crown, and later bought out by the lighthouse authorities. In each case, the owner had to find someone to design and build their lighthouse at a time when there was little knowledge of what was involved.

The other seventeen were owned from the start by the lighthouse authorities and designed by their engineers.

↑ *Location of Rock Lighthouses*



↗ *The twenty-three Rock Lighthouses, shown approximately to scale, built around the British Isle and the two built by Trinity House off the Coast of Sri Lanka, including replacements, with the designers & completion dates.*

Note: The First Bishop Rock Lighthouse was washed away before the lantern was installed.

DEVELOPMENT OF LIGHTS

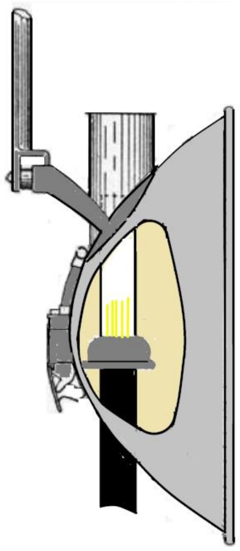
Up until the mid eighteenth-century, the lights were simple with the light going in all directions, being provided by wood or coal fires, candles, and in some cases primitive oil lamps. Many were placed on towers or cliff tops.

The first three rock lighthouses were located on the Eddystone Reef, fitted with candle lights. More and more powerful lights were developed over the next 200 years, initially to improve visibility and later penetration in fog.

The electric light installed on the Isle of May in Scotland in 1886 had an intensity at full power of 6 million candles and the last rock lighthouse built in the British Isles, the Fastnet, equipped with vaporized oil lamps, when completed in 1904 had rotating beams with a maximum intensity of 730,000 candles.

In 1763 flat wick oil lamps fitted with reflectors were installed in Liverpool lighthouses; refer to *'A Short History of Bidston Lighthouse'* in e-maritime March 2021. Lights became brighter and cleaner with the introduction of Argand circular wick oil lamps in 1782 and improved reflectors.

A full or partial circle of light was created by installing several so that the cones of light overlapped, sometimes in more than one tier.



An Oil Lamp Fitted with a Parabolic Reflector

Rotating beams of light were created by installing these on the sides of a frame rotated by a hand wound weight driven clockwork mechanism, with the light increasing and decreasing in intensity as each beam passed an observer.

A major improvement came in France in 1827 when Augustin Fresnel developed lens panels to concentrate rays of light. These consisted of concentric full or partial rings of glass lenses surrounding a central large bull's eye lens.

Any number of these revolving around a single fixed large central burner created rotating beams of light.

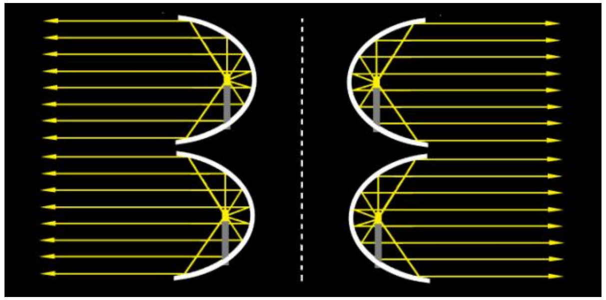
Fresnel also introduced horizontal belt lenses for fixed lights, which, when stacked around a central light source, directed the rays onto the sea, providing a uniform light all-round.

To utilize the light which would otherwise escape above and below, he added reflectors, later replacing these with reflecting prisms.

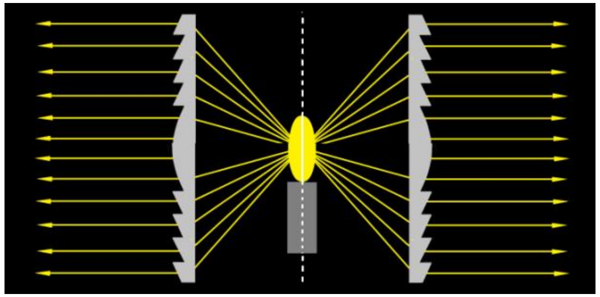
This resulted in lights having the intensity up to four times as great as equivalent systems using multiple small oil lamps fitted with reflectors.

Argand lamps burning animal and vegetable oils were used until a modified one burning much cheaper and more efficient mineral oil was introduced in Scotland in 1868.

A greatly improved version, the Douglass Burner, with three to ten concentric wicks was the most powerful oil burner until Arthur Kitson developed the mantle burner in 1901 using vaporized mineral oil, resulting in lights up to five times more powerful.



Reflected Rays of Light form Multiple Oil Burners



Multiple Rings of Lenses Bending Rays of Light from a Large Central Oil Burner

Michael Faraday played a major role in developing the electric light for shore lighthouses. He was Trinity Houses' Scientific Adviser for thirty years, 1836-66, devoting a considerable amount of time to upgrading the lights in their lighthouses.

This was in addition to his many other interests. He is known for the discovery of the principles of electromagnetic induction, and is credited with having invented the electric motor.

Under his guidance the first electric light, an experimental light, was installed in the South Foreland Lighthouse on the south coast of Kent in 1858.

Trinity House went on to install electric lights on major headlands. Ireland preferred gas, installing powerful Wigham gas lights at several locations.

The use of electricity and gas greatly increased the complexity and cost of operation, because of the need to have on-site electric generators driven by steam or caloric engines or equipment to produce gas from coal.

The number of keepers and mechanics needed to operate a lighthouse went up from two to as many as eight.

Space limitations prevented electric lights from being considered for rock lighthouses until suitable diesel generators became available in the second half of the twentieth century.

DEVELOPMENT OF FOG SIGNALS

Up until the middle of the 19th century only a few lighthouses were equipped with fog signals, mainly bells, gongs and guns, none very effective.

The American-developed reed fog trumpet was introduced in Great Britain, with the installation of one at Dungeness in 1862.

An improved version by Professor Holmes in the UK was first installed at the Souter Point Lighthouse in 1872, using steam from the steam engines there for its electric light.

The first trial of a disc siren, one obtained from New York, took place at the South Foreland Lighthouse in 1873, using air from compressors driven by the steam engines there.

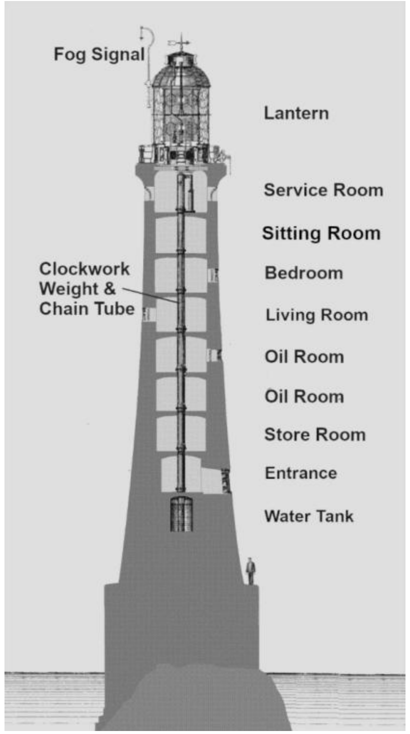
Trinity House developed the more efficient cylinder siren which was first installed at the Lizard Point in Cornwall in 1878, using air from compressors driven by the caloric engines driving the generators for the electric lights in the two lighthouses.

As space prevented the use of reed trumpets and sirens at rock stations, bells were used, some weighing two tons, until James Douglass came up with a system to fire gun-cotton explosive charges from a swing arm raised above the top of lighthouses.

The introduction of reed trumpets and sirens again added to the complexity and cost of operation.

DESCRIPTION OF THE BISHOP ROCK LIGHTHOUSE

The lighthouse on the Bishop Rock is the first landmark encountered when crossing the Atlantic Ocean from New York following the Blue Riband route, and is typical of the later lighthouses built on wave-swept rocks.



The Bishop Rock Lighthouse in the Mid Twentieth Century

Completed in 1887, it is the third lighthouse built on the rock and the second to last rock lighthouse built in the British Isles.

The following describes it as it essentially was in the middle of the twentieth century, before diesel generators and a helipad were installed, followed by automation. Like other rock lighthouses, it had four keepers assigned to it, all men, with one on shore leave at any time.

The Bishop Rock is situated in the Atlantic Ocean on the western edge of thirty-five square miles (90 sq km) of dangerous rocks surrounding the Scilly Isles, twenty-eight miles (45km) west of Land's End, Cornwall, with nothing between it and America but open ocean.

The rock, which is just covered by the highest tides, is subjected to extremely severe Atlantic gales with hurricane force winds and tumultuous seas.

The tower, the height of a sixteen-story building, displays a light 45 meters above high water. Except for a freshwater tank below the entrance floor, the tower is solid up to the entry door 12m above the rock.

This door, weighing about a ton, was strongly constructed to take the impact of heavy seas. The two halves, made of gunmetal, open inward, and are bolted and braced on the inside when closed.

A passage through the 2-meter thick outside wall leads to a central lobby. A manhole in the floor provides access for filling and cleaning the water tank.

Above seven more rooms are arranged vertically and connected by a steep spiral staircase following the outside wall. All windows have a large gap between the inner and outer panes of glass.

There was also a small tank just inside the entry door in which oil from drums hoisted from the supply vessel were emptied, and from there pumped by hand up to storage tanks in the oil rooms.

An iron tube passing through the centre of all rooms housed the weight and chain of the clockwork mechanism rotating the light.

The things needed to operate the light and maintain the establishment were kept in the store room above. Seventeen tanks in the two oil rooms had a combined capacity of 7,700 litres.

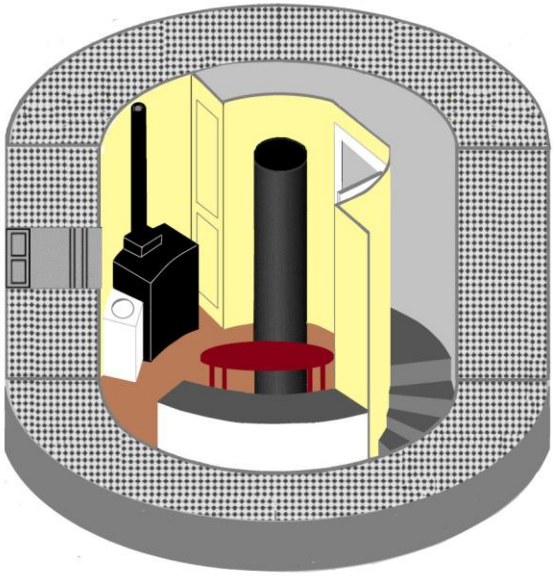
The oil was pumped up to the service room four floors above as needed. The living room and bedroom were not fully round because of the staircase, the maximum dimension being 4m.

There was a sink, and a coke stove for cooking and heating in the living room, with a boiler on the stove providing a constant supply of hot water. A table by the central tube with a bench against the wall sat four, leaving just enough space for a small chair.

The bedroom had five built-in curved bunks behind curtains in two tiers against the outside wall for the three keepers and two visitors. The upper oil room, kitchen and bedroom were separated from the staircase by a wall.

The room above the bedroom was used as a sitting room and for communications. The service room immediately below the lantern was used by the duty keeper and contained everything needed to operate the light through the night.

It was separated from the stairs by two fireproof doors, like an airlock, as a safeguard against fire spreading. It contained two small tanks pressurized with air by a hand pump to feed oil up to the burners.

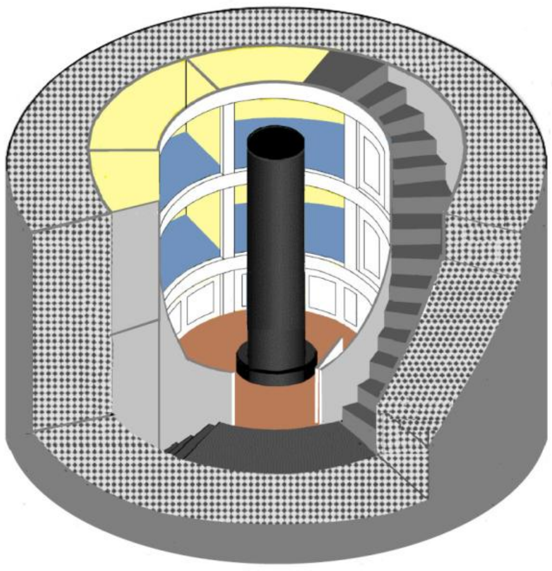


Layout of the Living Room

Around the top of the wall was inscribed from Psalm CXXVII, a practice Smeaton introduced referred to in a later section.

"Except the Lord build the house they labour in vain that build it."

The lantern contained two superimposed optical assemblies rotating together to produce a flashing light, which is described later; one being lit on clear nights.



Layout of the Bedroom

An explosive sound was created every five minutes from equipment located on the outside of the lantern during fog; see the section on fog signals.

A toilet bucket was kept in the lantern, the contents of which were disposed of over the balcony into the sea.

Bishop Rock Lighthouse Today Fitted with a Helipad
Richard Knights CC by 2.0

THE CONSTRUCTION OF LIGHTHOUSES ON WAVE-SWEPT ROCKS

Building lighthouses on small rocks located in very heavy seas presented significant challenges, with successive ones benefiting from the lessons learnt from building their predecessors.

The work could be extremely demanding, putting workers at risk, but the effort was essential to reducing the large number of shipwrecks.

Wave impact forces of up to 15 tons per square meter on the North Sea side of Scotland and 29 tons per square meter on the Atlantic side were measured by Thomas Stevenson in 1883/4.

In addition to conditions on the rocks, frequently getting to and from the rocks and landing men and materials was dangerous. Up until 1830 sailing vessels and rowing boats were the only means available, often taking many hours to get there, if at all.

Work could not take place during winter months and only then when the weather and tides were favourable, on many occasions on reaching a rock it was impossible to land.

Unless there was sufficient space on the rock for a temporary barrack, the workman could not live there until the building was sufficiently complete to provide accommodation.

The first two rock lighthouses were mainly constructed of wood. Although there were some who believed that wood was more resilient in withstanding the impact of waves than stone, stone soon became the preferred material.

All stone towers built around the British Isles had a circular cross-section and were tapered from top to bottom, either straight or convex.

A convex profile afforded the least resistance to winds and waves. For the same reason, the external surface was made as smooth as possible and kept free from unnecessary projections.

The aim was to keep the centre of gravity low for stability, while at the same time ensuring that the weight above any point was great enough to prevent movement or toppling without relying on adhesion of the joints. There were a couple of attempts to support the keepers' quarters and lantern on an open structure.

Apart from providing visibility from a distance, lights needed to be placed sufficiently high to minimise any eclipsing or distortion from water and spray thrown up during storms.

PIONEERING WORK IN BUILDING ROCK LIGHTHOUSES 1696-1759

This took place on the Eddystone Reef in the English Channel, where three lighthouses were built on the same rock in just over sixty years. This treacherous reef, which is located 22.5km south of Plymouth and 9km from the nearest land, is almost completely hidden at high tide.

It was so feared that some mariners took their ships well south, only to be wrecked on the coasts of France or the Channel Islands. The sea, which rises and falls up to 4.9m, almost covers the rock at high water.

It was not until the mid 1690's that there was somebody willing to undertake the task, this was Mr. Henry Winstanley, Clerk of Works at Audely End House in Suffolk and owner of the Mathematical Water Theatre in Hyde Park.

He was stepping into the unknown and would almost certainly have heard about the reputation of the reef and the tides around it.

Lighthouse	Year Completed	Designer	Builder	Height of Building meters	Focal Plane Above High Water	Years to Complete	Approx. Tons of Stone Used
1st Eddystone	1699	Henry Winstanley	Henry Winstanley	33	25	4	Wood
2nd Eddystone	1709	John Rudyerd	John Rudyerd	28	22	4	Wood
3rd Eddystone	1759	John Smeaton	John Smeaton	28	22	4	955
1st Smalls	1776	Henry Whiteside	Henry Whiteside	20	19	2	Wood
1st Longships	1795	Samuel Wyatt	Unknown	16	25	5	550
South Rock	1797	Thomas Rogers	Thomas Rogers	23	19	4	1400
Bell Rock	1811	John Rennie & Robert Stevenson	Robert Stevenson	36	28	4	2040
Tusker Rock	1815	George Halpin Sr.	DBB	34	33	4	1400
Haulbowline	1825	George Halpin Sr.	DBB	34	32		1900
Skerryvore	1844	Alan Stevenson	Alan & Thomas Stevenson	48	46	7	4308
1st Bishop Rock	1850	James Walker	Nicolas Douglass	32	27	3	Wrought Iron
2nd Bishop Rock	1858	James Walker	Nicolas, James &William Douglass	40	34	8	2650
2nd Smalls	1861	James Walker	James Douglass	41	36	5	3250
Les Hanois	1862	James Walker	William Douglass	36	33	4	2500
Wolf Rock	1879	James Walker & James Douglass	James & William Douglass	41	34	8	3300
Dubh Artach	1872	David & Thomas Stevenson	Alan Brebner	38	44	6	3115
Great Basses	1873	James Douglass	William Douglass	37	34	4	3540
2nd Longships	1873	James Douglass	Michael. Beazeley	35	35	4	3526
Chicken Rock	1874	David & Thomas Stevenson	Unknown	44	39	7	3557
Little Basses	1878	James Douglass	William Douglass	37	34	4	3540
4th Eddystone	1882	James Douglass	Thomas Edmond & William Tregarthen Douglass	45	41	4	4668
3rd Bishop Rock	1887	James Douglass	William Tregarthen Douglass	54	45	5	5880
Fastnet	1904	William Douglass	Mr. Foot	54	49	8	4300

The site he chose was on a sloping rock where the stub of Smeaton's tower stands today. His design was to come under much criticism.

Although he saw the need to make the base solid to take the impact of waves, appearing to contain stone, his mainly wooden structure had many protrusions, an open gallery, and cranes and ornamental ironwork attached to the outside.

Finding it difficult to penetrate the very hard rock, during the first summer, in 1696, he managed to embed twelve iron stanchions in it with molten lead.

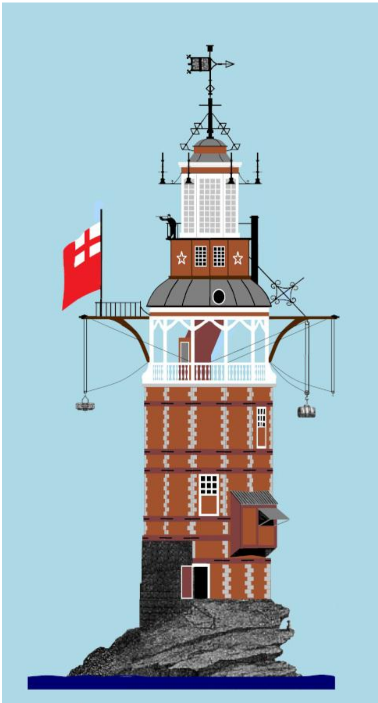
The following summer he built a solid 4.3-meter diameter pillar reaching 3.6m above the rock, increasing the diameter to 4.9m at the start of the third summer. He completed the lighthouse as he originally planned over three summers.

He wrote on an engraving that "*this was not because of the magnitude of the work involved, but due to the difficulty and danger in getting to and from the rock."* Light from candles was shown on for the first time in November 1698.

As a result of damage during the winter, he made the lighthouse much larger the following summer. He increased the diameter of the base to 7.3m and its height to 6.1m above the rock, keeping it solid except for space for a staircase.

He replaced the upper part with a larger structure, increasing the size of every part in proportion. The final building was completed in 1699, equipped with candles.

However, the sea enveloped it during storms, which at times appeared to fly 30m above the wind vane. In neither case, when he increased the diameter, does it appear that he added further stanchions to secure the building to the rock.



The First Eddystone Lighthouse built by Henry Winstanley, completed in 1699

In November 1703, before leaving for the rock to make some much-needed repairs, it is said that *"his friends taunted him with their belief that one day or other the lighthouse would certainly be overset.*

He replied: he was so very well assured of the strength of his building, he should wish to be there in the greatest storm that ever blew under the face of the heavens, that he might see what effect it would have upon the structure."

It happened that he was amply gratified in this wish, for after reaching the lighthouse a dreadful storm raged most violently during the night.

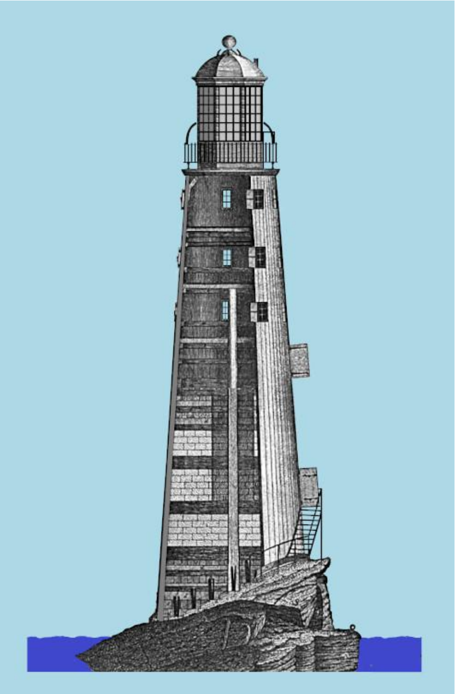
The next morning nothing was left save for some iron stanchions, and a bit of chain attached to a shackle jammed in a crack so forcibly that it could not be removed. None of the occupants or anything of the building were found.

The storm caused extensive damage in southern England, destroying 2,000 chimney stacks. 15,000 lives were lost, including some 1,500 seamen. Soon after, a ship was wrecked on the rock where the lighthouse had stood, drowning most of her crew.

Two years later Captain Lovett was granted a 99-year lease by the Crown to replace it. He engaged John Rudyerd, a silk merchant from London; his lack of experience being compensated by two shipwrights assisting him.

He built a smooth tapering round tower which offered considerably less resistance to the sea, again mainly made of wood. It rested on rough steps in the rock, and was much more firmly anchored.

The total height above high water was 25m. It had four rooms in the main column, a store room, a state room, a bed chamber and a kitchen. The lantern was six sided, with a big ground glass window in each.



The Second Eddystone Lighthouse Built by John Rudyerd Completed in 1709

Whereas Winstanley's lighthouse had towering ornamental ironwork supporting a wind vane 6.4m above the cupola, Rudyerd installed a 60cm diameter gilded ball. A tackle hooked to the balcony rail replaced Winstanley's cranes.

Using shipbuilding techniques, with the outside planking running vertically instead of horizontally, Rudyerd constructed a building that could have lasted almost indefinitely.

He secured the base to the rock with thirty-four metal stanchions projecting one meter above the rock. Each was made up of a dovetail followed by a key placed in a tapered hole increasing in width from top to bottom.

These were run in with molten lead and after setting could not be pulled out. An oak column positioned at the centre and reaching to the floor of the first room provided a datum for the rest of the structure.

The solid part of the tower comprised a combination of courses of wood and stone. Seventy-one uprights, made up of wood boards joined end to end formed the outer skin, and like ships at the time, the seams were caulked with oakum and covered with pitch.

A simple cornice at the top reduced the impact of the upward wash of the sea on the lantern.

The window shutters, which were flush when closed, were double planked.

By the end of the fourth summer in 1709 the lighthouse was ready, showing light from 24 candles mounted in a chandelier, 2m lower than Winstanley's.

With maintenance it stood up to winter storms until December 1755, when the keeper on watch found the roof of the lantern on fire.

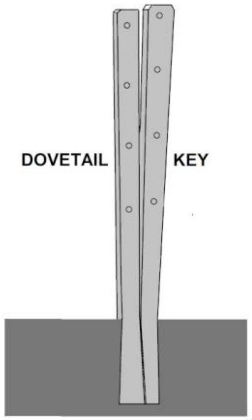
He attempted to extinguish it by throwing water from a tank on the balcony over the roof 3.6m above his head, while his comrades went to fetch more water from the sea 21m below.

He was looking up with his mouth open when a torrent of molten lead landed on his head, burning his neck and shoulder, and creating violent sensation of a quantity going down his throat.

The keepers moved downwards as the fire advanced, eventually taking refuge in a hollow in the rock until they were rescued, when one made off and was never heard of again.

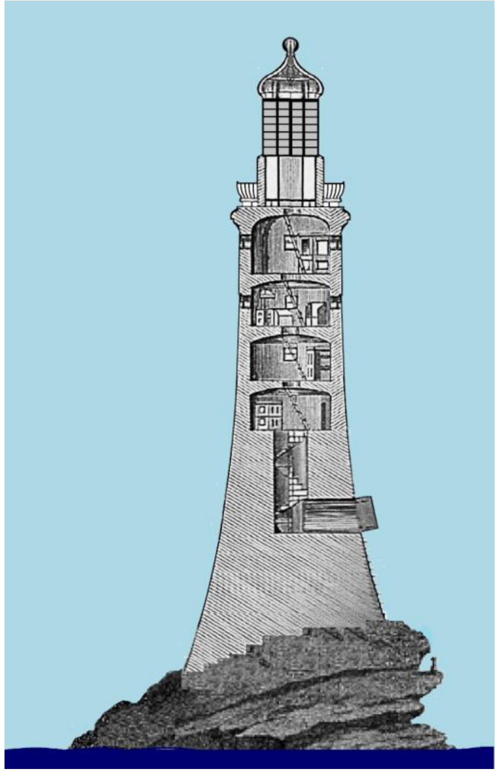
It became one great mass of red-hot matter, and it took six days for the combination of the fire, the wind and the sea to complete the destruction.

The watch keeper died ten days later, when a flat oval piece of lead weighing just over 198grams was found in his stomach.



Rudyerd's Stanchions

Smeaton´s Sketch sowing the joint between a branch of an Oak Tree and the Trunk



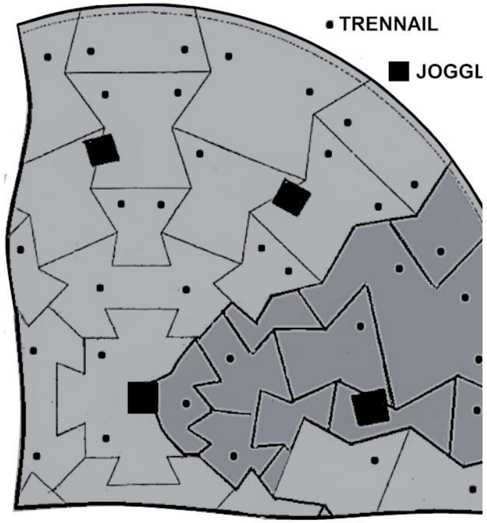
The Third Eddystone Lighthouse built by John Smeaton, completed in 1759

John Smeaton, on the recommendation of the Royal Society, completed the third lighthouse in 1759.

Essentially it was a stone version of Rudyerd's, larger in diameter at the base for stability and resting on steps sunk into the sloping rock, preventing sideways movement of the base.

In considering how to further reduce the resistance to wind and seas, he felt that the shape of a tree branch where it obliquely joined the trunk, representing the sloping rock, provided the strength to resist external forces.

Using stone blocks, he made the lower part of the tower solid, dovetailing the blocks in each course on the sides and to a center block to prevent them from being pulled out radially. Pairs of oak wedges driven into vertical grooves between the blocks position them precisely for setting with cement.



Dovetailing of the Base Courses

Each course was fastened to the one below with oak trenails (woodpegs), while joggles, cubes of marble, recessed in the courses above and below prevented the courses from sliding over one other while the cement set.

As the wall around the rooms was only a single block thick, dovetailing was impractical.

As well as cement, U-clamps were used to join the blocks making up each ring and joggles and trenails connecting courses. Flat stones set in slots between the blocks prevented water from making its way through the vertical joints.

Each floor was supported by ledges in the surrounding courses and made up with circles of stone slabs, arched to prevent them from collapsing.

A continuous chain set with lead in a groove in the top of each supporting course resisted radial pressure from the arched floors. Iron was used for the lantern window framing and other features for fire resistance.

Twenty-four large tallow candles mounted in a chandelier, similar to Rudyerd's, provided light with an intensity of about 67 standard candles. Smeaton considered oil lamps to be too primitive and would soot up the lantern windows.

The building work was carried out by two companies of twelve men alternating between working on the rock and dressing blocks and preparing other items in the shore yard.

A herring boat moored half a mile from the rock provided a barracks for the men while working there.

As with the previous two lighthouses, there were many delays due to weather. All three took four years to build.

Smeaton's design and construction methods provided the basis for later lighthouses located in similar conditions around the British Isles and many abroad, and established him as one of the greatest engineers of all times.

The fixed light was upgraded three times, improving it in both power and concentration.

In 1810, the candles were replaced with twenty-four Argand oil burners fitted with reflectors in three tiers, increasing the intensity to 1,980 candles.

In 1845 these were removed in favour of a system using Fresnel's belt lenses and prisms surrounding a single large central burner in an arrangement resembling a beehive, with an intensity of 3,216 candles.

In 1832 a more powerful lamp increased the intensity to 7,325 candles. Space limitations prevented any further upgrading. Around the top of the wall in the service room were written words from Psalm CXXVII.

"Except the Lord build the house
they labour in vain that build it."

ROCK LIGHTHOUSES BUILT BETWEEN 1775-1797

It was seventeen years before another rock lighthouse was built, with the erection of one on the Smalls Reef twenty-one miles (34km) off the southwest coast of Wales, completed in 1775.

This was over twice the distance from land and on a rock of much larger in area than the Eddystone. Its top was 2.7m above the highest tides, whereas the top of the Eddystone Rock was just submerged.

Model of the First Smalls Lighthouse
in the Science Museum, GFDL CC-BY-SA

Accessing the reef depended on the weather, in much the same or worse conditions. Designed and built by Henry Whiteside, a maker of violins, spinets and harpsichords, it was a complete departure from Smeaton's stone building.

He decided on a single story octagonal structure of wood, 4.6m across, containing the keepers' quarters and storage, with the lantern above. A door opened onto a small balcony for taking in supplies.

The lantern, surrounded by a full balcony, was reached through a hatch in the ceiling. He planned to support this on eight 12-meter-long cast-iron pillars set in the rock, one at each corner.

Understandably, the logic for this approach was that heavy waves would pass underneath with little resistance. A 12-meter rope ladder fastened to the rock and securely fixed beneath the floor of the raised building provided access.

He soon realised that cast iron was not the right material for the pillars because of its poor quality and the difficulty in joining sections together. He abandoned these in favour of eight massive wooden legs, one at each corner.

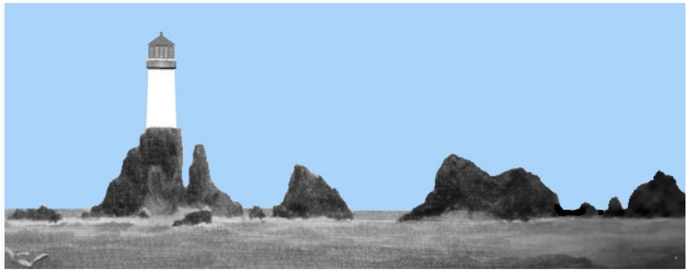
Each was 61cm in diameter and over 13.7m long, and hewn in one piece from good quality English oak.

Having made a trial assembly during the winter, he was able to complete the building the second year.

Although heavily damaged several times in major storms, with repairs and reinforcing, including adding stays and more legs, it stood for eighty years before Trinity House decided to replace it.

It was equipped with fixed oil lamps fitted with reflectors. The light was upgraded several times, increasing it in power, with the annual consumption of oil increasing from less than 200 to 1500 gallons a year during its life.

It was thirty-one years after Smeaton completed his lighthouse, before another stone one was built on a wave-swept rock out to sea.



The First Longships Lighthouse completed in 1795

Completed in 1795, this was on the highest point on the Longships Reef just over a mile (1.6km) out to sea from Land's End, Cornwall.

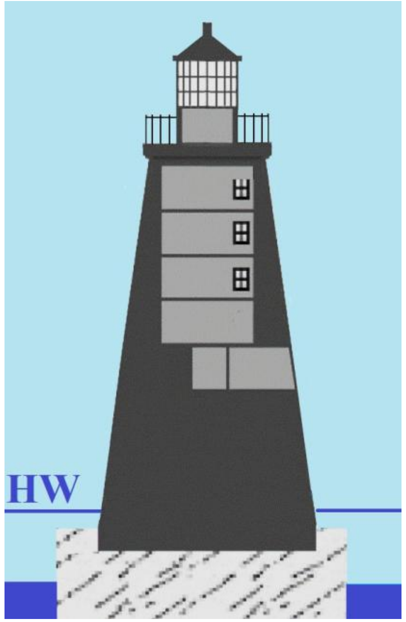
It was not very large as it was set high on a rock. Rough seas made access and construction difficult. The third stone lighthouse was built in the Irish Sea east of Belfast on the South Rock which is covered by two feet of water at high tide.

Thomas Rogers, the designer and builder, sank a pit 1.2m deep into the rock for the foundation because of the rock's poor condition.

The construction of its straight tapered stone tower, using iron bars and cement to tie courses together, was different from Smeaton's Eddystone.

It was the first rock lighthouse to be fitted with a revolving light in the British Isles, consisting of five oil lamps fitted with parabolic reflectors attached to each side of a two-sided rotating frame, increasing and decreasing the light intensity twice on each rotation.

The hand wound weight driven clockwork mechanism also operated two fog bells. It was completed in 1797, and was replaced by a lightship after eighty years. The stone tower still stands minus its lantern.



The South Rock Lighthouse completed in 1877

ROCK LIGHTHOUSES BUILT BETWEEN 1806-1844

The fourth stone lighthouse and one closely resembling Smeaton's Eddystone was Scotland's famous Bell Rock in the North Sea, built on a large reef covered by up to 3.6m of water at high tide, and subjected to North Sea storms.

The Eddystone design formed the basis as it had stood the test of time.

Built by Robert Stevenson, it had a larger base and was taller, containing five rooms.

Its construction improved on Smeaton's dovetailing system and method of construction around the rooms. It was the first time a temporary barrack on the rock housed the workmen, living on a schooner until this was completed.

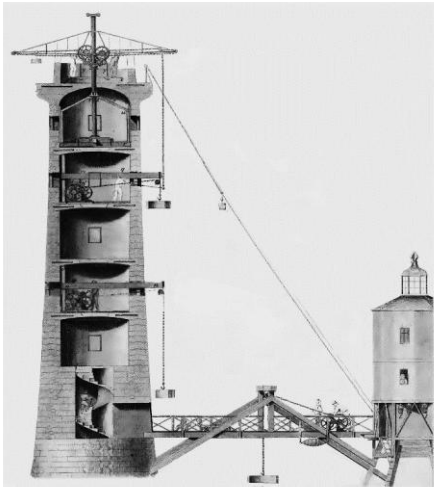
Materials were brought out in sailing vessels from a work yard at Arbroath eleven miles away and transferred to small barges which were rowed to the rock.

2042 tons of stone blocks weighing up to 2 tons each were used in its construction. A railway was built to move the blocks on hand trucks from the landing creeks to the worksite.

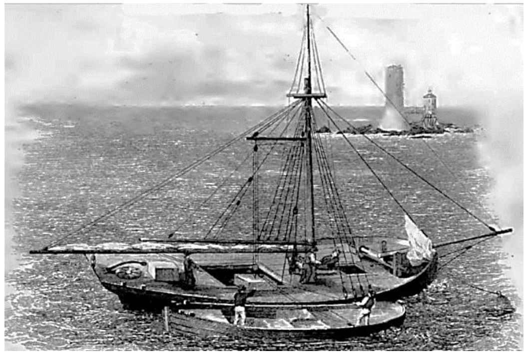
Its revolving light, which was first lit in 1811, was an improvement over the one installed in the South Rock Lighthouse.

The rotating frame had three sides with the lamps on one side having red shades, producing two

The Bell Rock Lighthouse Completed in 1811 Dereck Robertson CC BY-SA 2.0



Construction of the Bell Rock Lighthouse. Temporary Barracks on Right



Transferring Stone Blocks to a Small Barge for Landing on the Bell Rock white and one red flash on each rotation. Like the Eddystone it took four years to build.

Although the work was more demanding, the size of the rock allowed many more men to work there.

Another two rock lighthouses, which were designed by George Halpin Sr. along the lines of the Eddystone, were built off the coast of Ireland.

The first, seven miles from the southeast coast on the treacherous Tusker Rock, was completed in 1815.

The foundation was well above high water and the size of the rock made construction easier. The second, the Haulbowline, was completed in 1825, at the entrance of Carlingford Lough south of Belfast, on a rock surrounded by fast-moving currents.

Like the Bell Rock, its foundation was submerged under 3.6 meters of water at high tide.

It was another twelve years before a start was made on the next rock lighthouse, a magnificent tower located in very turbulent seas on the Skerryvore Reef, eleven miles (18km) south of the Island of Tyree on the west coast of Scotland.

It was designed by Allan Stevenson, the eldest son of Robert, who also supervised its construction with his youngest brother, Thomas, taking over during the final year. Thomas was the father of Robert Louis Stevenson, the author.

It is one of the tallest rock lighthouses in the British Isles.

The height was needed so that its light could be seen from beyond distant rocks.

With its foundation 1.2m above high water and with the rock taking the initial wave impact, construction differed from the Bell Rock Lighthouse.

The blocks in the solid base were not dovetailed to simplify construction. Instead, Allan relied on the mass above and cement to keep them in place.

As no nearby facilities existed, a harbour, work yard, and accommodation for the workmen were set up on the Island of Tyree,12 miles away (19km) as well as a quarry on the Island of Mull.

Much of the time the men at the rock lived in temporary barracks similar to that used at the bell rock, and it was the first time that a steam vessel was used in the construction of a lighthouse, replacing a sailing vessel after the first year.

The Skerryvore Lighthouse Completed in 1844
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ROCK LIGHTHOUSES BUILT BETWEEN 1847-1904

In 1847, a decision was made by Trinity House to establish a lighthouse on the Bishop Rock, the most western of the hazardous rocks surrounding the Scilly Islands, described earlier.

James Walker, Trinity House's consultant engineer, first designed a lighthouse supported by an open iron structure.

This was on the assumption that, like the Smalls with its wood legs, waves would pass harmlessly between the supports. It was constructed by Nicholas Douglass, Trinity Houses' Superintending Engineer, assisted by his eldest son James, only to be washed away in January 1850 in a winter storm before the lantern was installed, having been subjected to much greater seas than anticipated.

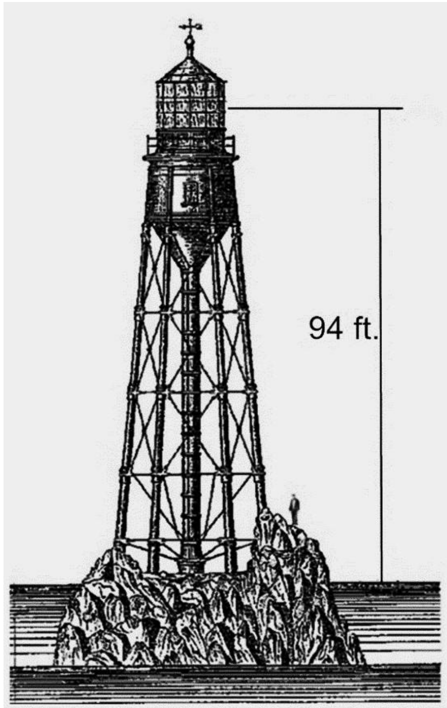
The men working on the rock lodged on Rosevear, a very exposed small rock island two miles away.

Undeterred, Walker designed a stone structure to replace it similar to the Eddystone and Bell Rock Lighthouses, with its foundation extending down the slope of rock to 30cm below low water.

This was also erected by Nicholas Douglass, with James supervising most of the rock work during the first year, before leaving to further his career elsewhere. His place was taken by his younger brother, William.

The granite blocks were supplied in a rough state from quarries in Cornwall, and dressed in a yard on Rat Island at the end of the St. Mary's harbour pier, where passengers now embark and disembark the ferry from Penzance.

The dressed blocks were initially conveyed the seven miles (11 km) to the rock in a sailing tender until a 21-meter paddle steam tug was procured and used to tow barges.



The First Bishop Rock Lighthouse

The men again lodged on Rosevear Island, much of the time under the most appalling conditions, sometimes being cut off completely from the outside world for days, even weeks. It took eight years to build and was completed in 1858.

Another three rock towers designed by James Walker were built by Trinity House along similar lines.

The first, completed in 1861, replaced Whiteside's Smalls lighthouse.

It was constructed by James Douglass who returned to Trinity House in 1855. After finishing the Bishop Rock Lighthouse, William Douglass went on to build the one on the Les Hanois Reef in the Channel Islands, completed in 1862.

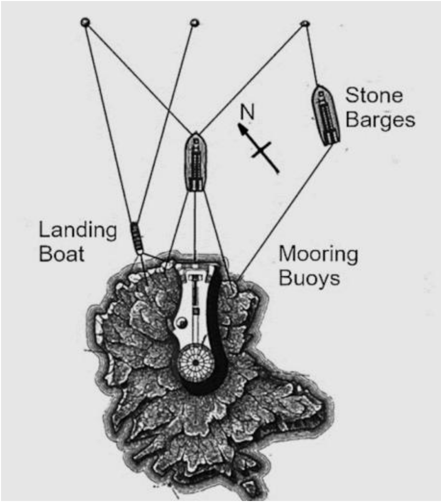
It was the first time that a new method of dovetailing was used, devised by Nicholas Douglass, which locked the outer ring of stone blocks in each course to the ones above and below, details of this system are shown later.

The third was built on the very treacherous Wolf Rock between Land`s End and the Scilly Islands, where even erecting a globe beacon on a pole had proved nearly impossible.

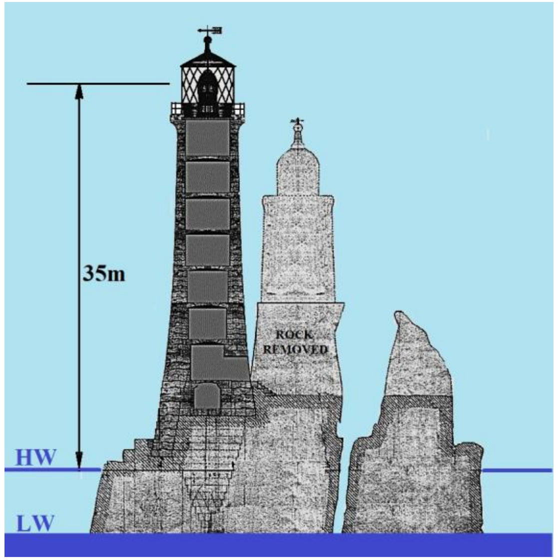
Like the Bishop Rock further west, this rock is exposed to the full force of Atlantic storms, with terrific seas.

Up to 5.2m of the rock is exposed at low tide and the rugged surface made landing difficult.

Nearly forty years earlier Robert Stevenson provided a rough plan for a stone lighthouse, with an estimate that it would take fifteen years to build at a cost of £150,000.



Mooring of Boats at the Wolf Rock



The Second Longships Lighthouse Compared with the First

This was almost four times the length of time he spent on the Bell Rock Lighthouse and almost three times the cost, which was an indication of the difficult nature of the project.

Because of the exposed position, as well as to the ones above and below each course, the outside blocks in each course were dovetailed circumferentially to form a solid ring.

As well as providing strength the dovetails protected the joints from the wash of the sea while the cement set.

The first landing to start work on the foundation-pit, under the supervision of James Douglass, was not possible until March 1862, when a few hours at rare intervals could be spent on the rock.

Only twenty-two landings were possible during the first season during which eighty-three hours of work was accomplished.

With insecure footholds and surf constantly breaking over the rock, great care was taken to ensure the safety of the men.

Towards the end of the year, James Walker died and James was appointed Trinity House's first Engineer in Chief with overall responsibility for all Trinity House's lighthouse construction and modification work.

As a result, his brother, William, took over supervising the building work under his direction. Whereas James Walker designed the masonry, James was now responsible for it and designed the interior and everything above the balcony.

It was the first use of the cylindrical-framed lantern developed by James Douglass, with little loss of light due to framing.

It was the first time that stone blocks and other materials were offloaded from barges moored a safe distance away, rather than alongside, increasing the times stones could be landed.

It was also the first time that steam power was used to raise blocks to the top of the work. The average time taken to raise a block was only two and a half minutes, compared with fifteen using manual labour.

Having taken eight years to construct the light was first lit on 1st January 1870.

Immediately following the completion of the Wolf Rock Lighthouse, work started on replacing the Longships Lighthouse completed in 1795, as the rock underneath was becoming increasingly unstable and heavy seas were obscuring the light.

James Douglass designed a new taller structure located on a sound foundation low down. This required removing a considerable amount of rock.

Michael Beazely, who assisted with the Wolf Rock, supervised the construction work, utilizing the same yard at Penzance, boats and equipment.

Around the same time, Trinity House undertook the construction of two lighthouses on the Basses Reefs off the south-east coast of Sri Lanka. Designed by James Douglass, they were built by his brother, William, who went to Sri Lanka as Executive Engineer.

It was the first time that steam vessels specifically designed for lighthouse work were used to transport and land materials at the rock as well, as providing a barrack for the men.

Two were used as the lighthouses were located 80 and 100 miles from the work yard.

Like the barges at the Wolf Rock, the vessels were moored a safe distance from the rock for unloading.

The Great Basses was completed in 1873 and the Little Basses in 1878.

On returning, William Douglass took up the position of Chief Engineer to the Commissioners of Irish Lights, having spent 25 years building lighthouses on wave-swept rocks.

Based on their experience building the Bell Rock and Skerryvore Lighthouses, the Northern Lighthouse Board erected two more large rock lighthouses designed by Allan Stevenson's brothers, David and Thomas.

The first, on the Dubh Artach Rock located fifteen miles (24 km) south-west of the Ross of Mull off the west coast of Scotland. Being in the same area as the Skerryvore, similar ferocious seas were experienced.

The yard and quarry were on the Island of Iona fourteen miles (22.5km) away. Again a temporary barrack was built, this time made of metal. Situated on the top of the rock 11 meters above high water, the lighthouse was first lit in 1872.

The other was built on the Chicken Rock at the southern tip of the Isle of Man. Although not exposed to rough seas of the same magnitude, being covered at high tide made the rock dangerous to work on.

Although it was very close to the shore yard, it took six years to erect. It was completed in 1874 and was the last of the four rock lighthouses built out to sea by the Stevensons.

ROCK LIGHTHOUSES BUILT BETWEEN 1877-1904

James Douglass designed two of the last three rock lighthouses built around the British Isles.

These were replacements for Smeaton's Eddystone and the second lighthouse on the Bishop Rock which he had participated in building.

He used his experience to create what is generally regarded as two of the greatest lighthouses designed to withstand the impact of very heavy seas.

The Fourth Eddystone Lighthouse & the Stub of Smeaton's Tower, Author's Painting

He made an announcement in Plymouth in 1877 that Smeaton`s tower on the Eddystone Reef would have to be replaced as the rock below was being undermined by the sea.

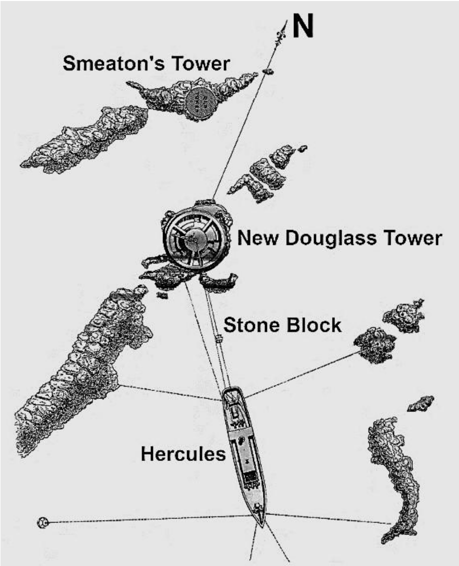
It had been in operation for 118 years, and some years before, the keepers had become alarmed by tremors and shaking of the building. As a result, the tower was strengthened on the inside with iron ties and many joints repointed.

The projection of the cornice was reduced by 13cm to lessen the impact on it from the upward strokes of waves.

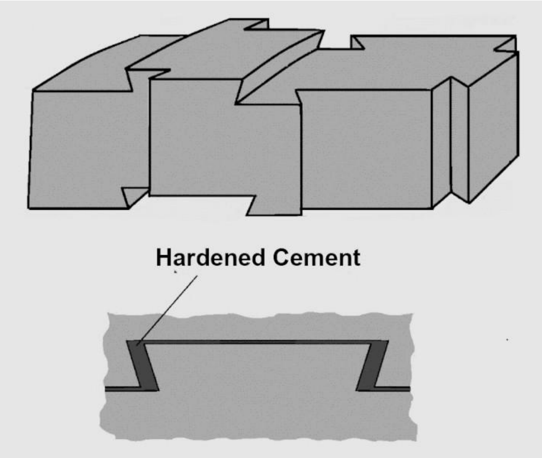
The keepers continued to have fears about the security of the building, and the decision to replace it was made after it was discovered that a large wedge of rock had separated below the lighthouse.

This was at the location of the shallow cave where the keepers of Rudyerd's Lighthouse had taken refuge while the building above burned.

Immediate steps were taken to build a much larger tower on another section of the reef which provided a sound and level foundation. Being just clear of the water at low tide was not considered a problem.



Mooring of the Hercules at the Eddystone Rocks



Example of Dovetailed Stone Block

The question of arresting the forces from large ocean waves on lighthouse structures had long engaged James Douglass' attention. An upward curving shape sends waves sweeping up the tower dissipating much of the energy.

Although this reduces the overall force on the structure, the centre of the force is elevated, imposing more strain on the structure at the base. In addition, the amount of green water and spray reaching the lantern could be considerable, resulting in significant eclipsing of lights in heavy storms.

Stepping the lower courses, rather like the stepped pyramid, was tried at the Wolf Rock, and found to have little effect in reducing the upward wash. He came to the conclusion that the best shape was one with a vertical cylindrical base with a curved profile above.

Although a cylindrical base would be subjected to heavier blows, the waves would divide, sending most of the water around it rather than upwards. This created less leverage on the base where the structure is best able to withstand it.

This arrangement also provided a convenient ledge for landing stores and keeper relief. The new tower had five more rooms, nine in total.

The column was constructed using 4,668 tons of granite blocks weighing up to three tons each, which were dovetailed to the adjacent ones on all adjoining sides, top and bottom, using Nicholas Douglass' system.

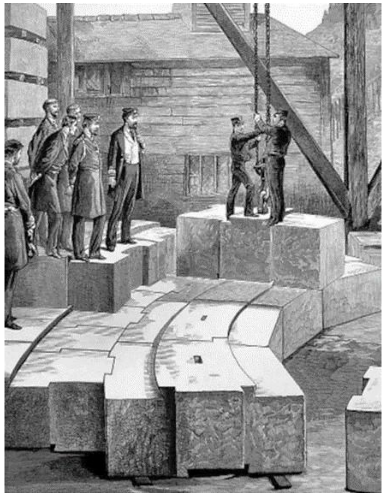
Once the gaps were filled with mortar and set, the blocks could not be pulled apart.

Experiments with blocks put together this way using Portland cement had shown that the assembled blocks were so homogeneous that it was nearly as strong as if one piece of solid granite.

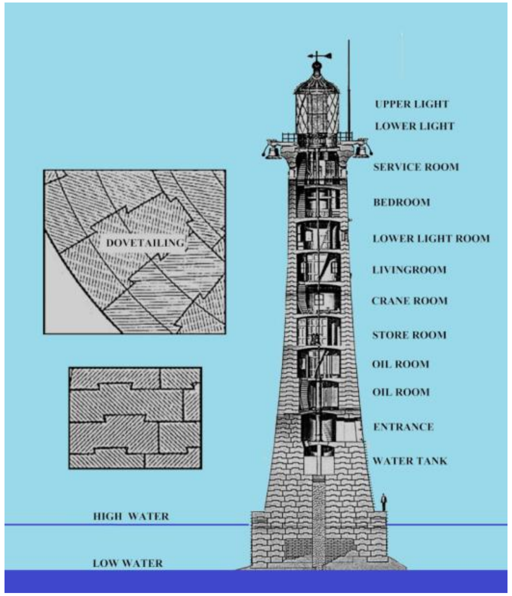
A cofferdam was built, increasing the time that works on the foundation and lower courses could take place each tide. The tender was the Hercules, one of the steam vessels, used in the construction of the Basses lighthouses, which could reach the rock in an hour.

It was equipped with steam-driven pumps for emptying the cofferdam before work could start after each tide, and supplied compressed air for pneumatic drills. It had steam winches for landing and hoisting blocks.

It was the first time that power-driven drills were employed on a rock, rather than depending on manual labour alone. One did the work of at least ten of the brawniest Cornish miners using hand tools.



The Duke of Edinburgh Watching a Trial Assembly



The Fourth Eddystone Lighthouse - Cutaway & Dovetailing

This equipment contributed to the lighthouse being completed in 1882, in just under four years.

James Douglass' son William Tregarthen Douglass was his father's assistant, who supervised construction during the final year, taking over from Thomas Edmonds who left to build a lighthouse designed by James Douglass on Minicoy Island in the Indian Ocean.

Afterwards William Tregarthen took down Smeaton`s tower to the solid base, and re-erected it on Plymouth Hoe, on a new base, as a memorial to Smeaton at the request of the people of Plymouth, where it is a museum today.

The 4.6-meter diameter lantern contained two superimposed optical assemblies 2m in diameter, which rotated together producing five beams of light sweeping over the ocean.

Each tier had a single fixed Douglass oil burner at its centre, with six lens panels in a ring rotating around it, designed and very accurately manufactured by Chance Bros. & Co., the main supplier of the optics installed in Trinity House's lighthouses.

Each panel had a bull's eye lens surrounded by numerous full or partial circles of glass lenses and prisms concentrating the light into a beam.

The panels were divided down the centre with one half slightly canted outwards to split the light so that the beam from each panel was seen as a double flash as it passed.

The assembly weighing over six-tons initially rotated on rollers on the top outside edge of the pedestal. The total height from the floor was 5m.

In operation, it was turned by a weight-driven clockwork mechanism similar to that found in a grandfather clock, but very much larger; which was installed in the pedestal supporting the assembly.

The weight of about a ton was suspended from the end of the drive chain in the weight tube down through the center of the rooms and rose and fell about 4.6m. It was wound up by hand approximately every hour, requiring considerable stamina.

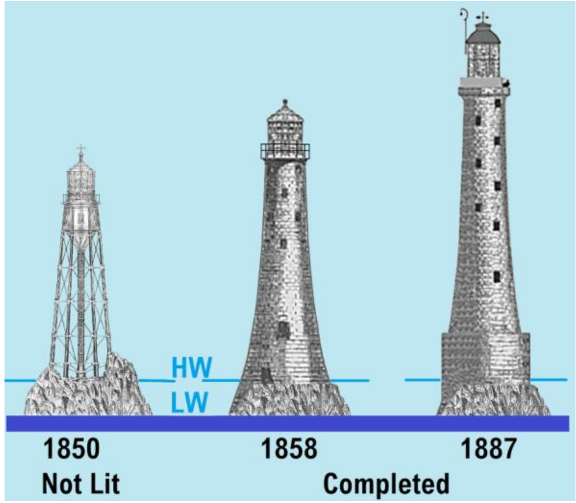
Access to the interior of the optics for lighting and servicing the burners, without the need to stop rotation, was through an opening in the pedestal with ladders inside. Burner changers allowed switching to a spare quickly in the event of failure.

The lantern was ventilated by air entering through open windows in the service room below.

Some of it flowed up through an opening at the centre of the ceiling, supplying air to the burners and dissipating the large amount of the heat generated, before exhausting through chimneys.

The remainder flowed upwards through grates around the edge of the ceiling and up the inside of the lantern windows to prevent fogging before venting through the cupola.

As soon as the new Eddystone was completed, work started on a larger tower on the Bishop Rock, the one described earlier. For many years Trinity House was concerned about the condition of the lighthouse completed in 1858 after some granite blocks just above high water cracked.



The Three Bishop Rock Lighthouses

The seas were so terrific, that during a violent storm the 254kg fog bell, which was firmly secured to the cornice 30m up, was torn away. In 1874, the tower was reinforced from top to bottom by bolting iron ties to the inside of the outer wall.

However, during a violent storm in 1881 pieces of granite weighing over 23kg split away a meter or two above high-water level.

In view of the ever increasing number of vessels using the light and the number of wrecks in foggy weather, Trinity House decided not only to strengthen the tower, but to thoroughly improve the interior, the light and fog-signal, placing it foremost amongst rock lighthouses.

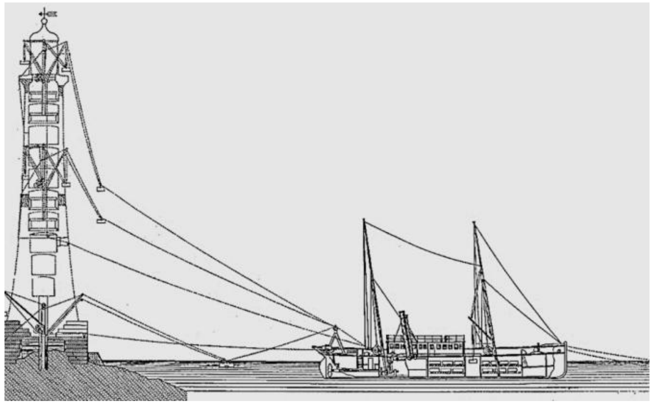
James Douglass advised that this would require a larger building, and made a commitment to maintain a light while it was being built. He embodied most of the masonry of the existing lighthouse by building over it, while greatly increasing the height.

He made the top of the cylindrical base significantly higher than the Eddystone's because of the further west location with heavier seas. Construction was similar, with the added task of cutting dovetails in the outside of the existing masonry.

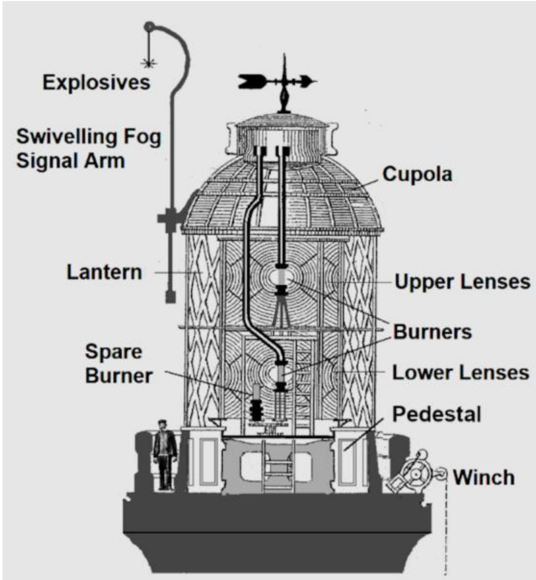
This was a hazardous operation low down close to the water, and time-consuming. Except for an increase in size and power and having five lens panels in each ring in place of six, the new lighthouses had similar superimposed optical assemblies to the Eddystone.

When the building work reached the height of the floor of the top room of the existing lighthouse, the part above was taken down removing the lantern.

It was immediately replaced with a temporary lantern mounted on top of a new crane for raising blocks to the top of the work. James Douglass' son, William Tregarthen, managed the construction using the same yard on Rat Island, as used for the previous lighthouse.



Landing Stone Blocks at the Bishop Rock.
Temporary Lantern Shown



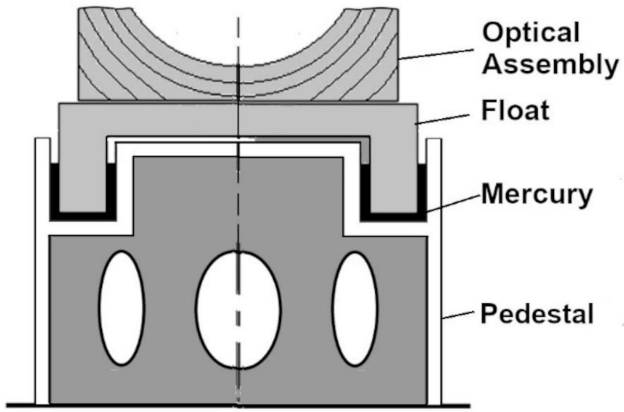
The Bishop Rock Lantern

With the Hercules able to reach the rock quickly there was no need for the men to lodge on Rosevear Island. It was completed in 1887 in five years.

In both the Eddystone and Bishop Rock Lighthouses, the roller ring supporting the optical assembly was later replaced by a mercury float, greatly reducing the friction and hence the power needed, allowing faster rotation.

It was now possible to rotate the assemblies with a slight push of a hand.

The Douglass Burners were also replaced with much more powerful triple-mantle vaporized oil burners without having to change the optics, and the fog bells initially installed with explosive signals.



Section Diagram through a Mercury Float

The final rock lighthouse built in the British Isles was the Fastnet located four and a half miles (7km) southwest of Cape Clear, southwest Ireland.

It replaced a lighthouse located high above the water on the summit where the rock turned out to be to be unstable. Completed in 1853, it was designed by George Halpin, Junior, who took over from his father as Engineer to the Dublin Ballast Board.

The height above the rock was 28m, and its circular cast-iron tower was lined with brick. After being in place for ten years, westerly gales and the condition of the rock caused grave concerns for its safety.

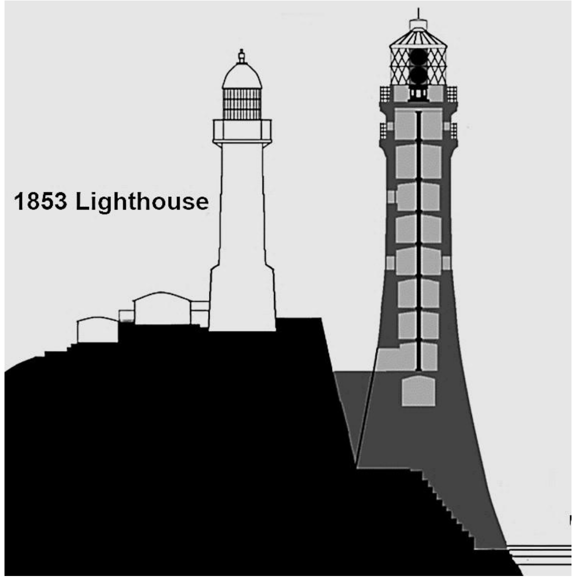
Like the Bishop and Wolf rocks, this rock is exposed to the full fury of the Atlantic gales, and the deep water surrounding it is seldom calm enough to allow stepping directly onto the rock from a boat.

In 1865, the lower part of the tower was made solid and surrounded by a casing of cast iron. Also, a dangerous chasm at the west end of the rock was filled in.

The Fastnet Lighthouse seen from the West Completed in 1904
Richard Webb CC SA 2.0

This work was completed in 1868. There were further concerns when the sea broke some lantern glass in November 1881.

By 1891, it was also evident that a more powerful light, with a focal plane 49m above the high-water mark, was needed at this important location.



The New Fastnet Lighthouse alongside the First

The Dublin Ballast Board, now the Commissioners of Irish Lights, considered that the expenditure required to provide the best light available was justified since the Fastnet was the principal landfall from the southwest.

For this a new tower was needed and William Douglass was instructed to submit a design. He selected a site low down on the west side where the rock was soundest, in spite of being on the side most exposed to severe Atlantic storms.

He settled on an effective base diameter of 15.8m with the lowest stones just below high-water.

A special steam vessel was used, with both men and materials being hoisted onto a landing platform on the other side of the rock from a safe distance away.

Hand trucks running on a level railway were used to convey materials to the building site.

The method of construction was similar to the new Eddystone and Bishop Rock Lighthouses.

Working close to the water on a sloping rock facing thousands of miles of open-ocean made preparing the foundation steps and setting the lower courses difficult.

Days and weeks went by without being able to descend the rock to the worksite. Just over 113 cubic meters of granite filled the space between the tower and the rock up to the entrance door.

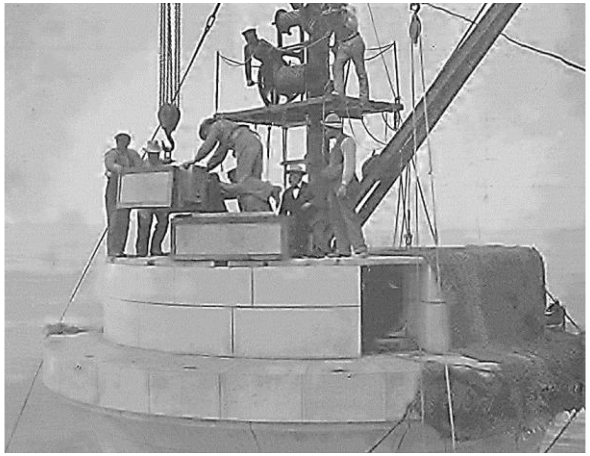
With some of the workmen living on the rock, the lighthouse took eight years to build, and was completed in 1904.

There were many accidents while building rock lighthouses, but remarkably most were completed without a fatality.

However, there were five deaths during the work on the Bell Rock, one caused by equipment failure, one from a fall, and the other three from drowning.

Although not a result of accidents, another two died while building the Skerryvore, one from a heart attack and one from disease. There were another two while building the 2nd Smalls, one due to equipment failure and the other when a man was washed off the rock.

Most notable were two fatal accidents when working on the Tusker Rock Lighthouse. Ten men drowned when the huts they were sleeping in were washed off the rock, and the other when a workman died as the result of a fall.



Constructing the Fastnet Lighthouse

Constructing the Lantern of the Fastnet Lighthouse

The foreman, who had lived almost continuously on the Fastnet Rock while the lighthouse was being built, on reaching shore on completion, died a few days later.

The difficulties encountered by the men working on rocks and landing materials can be summed up by a friend of Sir James Douglass' comment having made several visits to the Eddystone Reef while the fourth lighthouse was being there.

"*He and his companions had envisaged the Hercules (steam tender) lying quietly moored near the rock, but found things very different when they were there. He often had misgivings at the risk the men were taking, as it seemed that every wave was about to overwhelm them*."

Although the Fastnet was the last major rock lighthouse built out to sea around the British Isles, the construction of the Beachy Head Lighthouse about the same time presented a significant challenge because of its location 174m from the base of the 86m high chalk cliff near the low water mark.

It replaced a lighthouse on the cliff top completed in 1834, which was endangered by cliff erosion and had a light that was frequently obscured by mist or fog when lower down it was clearer.

In 1899, Trinity House decided to build a 43-meter granite tower 165m from the base of the cliff at the low water mark with its focal plane 32m above high water.

The chalk below the surface was excavated to a depth of 3m within a coffer-dam, for a concrete base to support the main column comprising 3,660 tons of dovetailed Cornish granite blocks.

A funicular from the top of the cliff was used to lower men and materials down to the building site, which otherwise was inaccessible except for steep steps down the cliff.

It was designed by Sir Thomas Mathews, Sir James Douglass' successor as Engineer-in-Chief at Trinity House. It was completed in three years and first lit in 1902.

A few more lighthouses were built on shore during the first part of the twentieth century, many of them were replacements.

By the end of the twentieth century, most of the lighthouses around the British Isles had been automated and operated remotely by the lighthouse authorities from central locations, a few have been decommissioned.

For most ships' lights are no longer the primary navigation aids, but provide assurance and assist less equipped vessels.

Constructing the Beachy Head Lighthouse completed in 1902

This article is intended to provide the reader with an outline of the history of how lighthouses construction evolved in the British Isles, particularly lighthouses built on wave-swept rocks out to sea, much of which was adopted abroad.

Space has not permitted the work in building them to be addressed in any detail, including the many difficulties and hazards that had to be overcome by the men involved. There are numerous stories associated with the work that can be found in books.

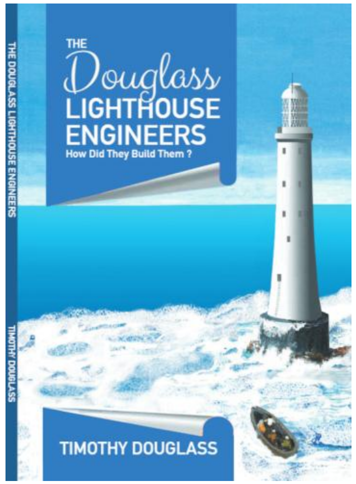
The author is a great grandson of Sir James Douglass who was Trinity House's Engineer in Chief for thirty years, 1862-1892, and received his Knighthood on completion of the Eddystone Lighthouse, the one seen today.

Much of the material was drawn from a recent book published by the author: "*The Douglass Lighthouse Engineers*", available from Amazon.

Although the emphasis of this book is on the work and life of his ancestors, covering three generations, during the second half of the nineteenth century, much of it covers the history of lighthouse construction from the first Eddystone to the Fastnet over a span of 208 years.

The parts played by many of the people who contributed to making the seas safer are described, a few of which have been mentioned, whether by designing and building lighthouses and beacons, or developing and manufacturing the lights and fog signals installed in them.

Many other books can be found for further reading, some covering a single lighthouse while others emphasize different aspects.



OVERVIEW OF SOME OF THE MAJOR PROJECTS FEATURED IN PAST E-MARITIME EDITIONS

Since the beginning, we have tried to share technical and informative articles about

- Vessels;
- Design, construction and operation of ports;
- Equipment used in maritime industry;
- Construction methods of sea-crossing bridges.

On the following pages, let us remind you of some of the projects we have focused on.

By clicking on the cover image, the magazine opens as pdf.

Thank you all for your cooperation.

November 2021

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MONACO LAND EXTENSION

CAISSON BELT AND LANDFILLING - DESIGN AND CONSTRUCTION

VESSELS AND EQUIPMENT

This special issue was dedicated to Monaco Land Extension Projects with a special focus on the project of land creation for Portier Cove.

In the first article, you can find an overview of two Monaco Projects: Port Hercules extension and Portier Cove.

In the next article, Jacques Resplendino, Technical Director at S.A.M. J.B. PASTOR et Fils (until December 2019 Technical Director, Bouygues TP) describes Design and Construction of Land Project for Portier Cove, caissons production, the caisson belt, backfilling and landfilling.

It is followed by drawings of caissons and of the belt.

Last part of this issue brings information about the floating dock ´Marco Polo´ which was used for production of the caissons as well as about major vessels used for the project.

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CRUISE BERTH LEVELLING AND EXTENSION PORTSMOUTH PORT, UNITED KINGDOM

Portsmouth International Port offers a wider range of ferry routes than any other UK port. Millions of passengers travel to France, Spain and also rely on the port to reach destinations closer to home such as the Isle of Wight and Gosport.

The Port is an essential hub for commerce and the travel industry, taking people on journeys and contributing towards the nation's tourism and visitor economy.

In January 2019, approval was given to one of Portsmouth International Port´s most complex engineering projects, the lowering and extending of the existing cruise berth – a berth Number 2.

The completion of this project has since allowed the port to demonstrate the handling of ships up to 270m in length, hosting a number of cruise ships for repatriation, and with a number of calls scheduled for 2021.Read more in an article prepared for our magazine by Anisa Koci, Senior Project Manager, Portsmouth Port.

NEW CONTAINER TERMINAL IN THE PORT OF HAIFA, ISRAEL

EQUIPMENT AND EXECUTION OF A TOTAL OF ALMOST 2,000M OF CAPPING BEAM

The Port of Haifa is the largest, leading port in Israel. It also serves as a regional trans-shipment hub. The port is located in a natural, deep-water and protected bay in the Mediterranean. It lies in the northern part of Haifa and stretches approx. 3km along the coast.

It consists of numerous terminals, enabling handling all kinds of cargoes as well as receiving large passenger ships. The port operates all year round.

Rúbrica Engineering was assigned to provide equipment and execute a total of almost 2,000m of capping beam.

In this article, Inma Gómez provides information on basic characteristics of the projects and design requirements that had to be taken into account is provided together with an overview of the equipment used and its utilisation.

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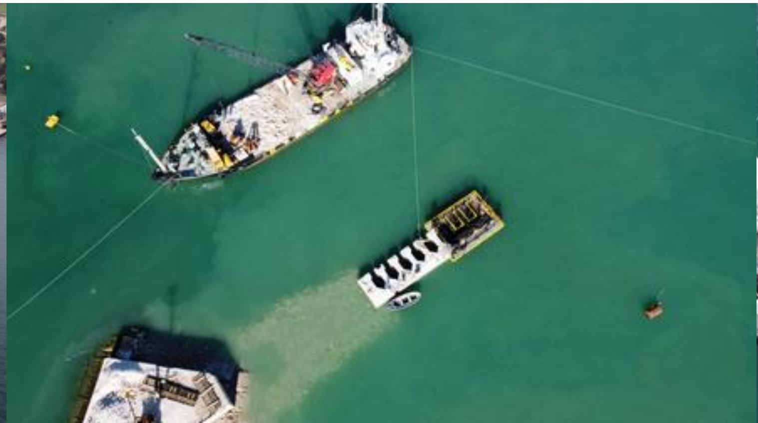
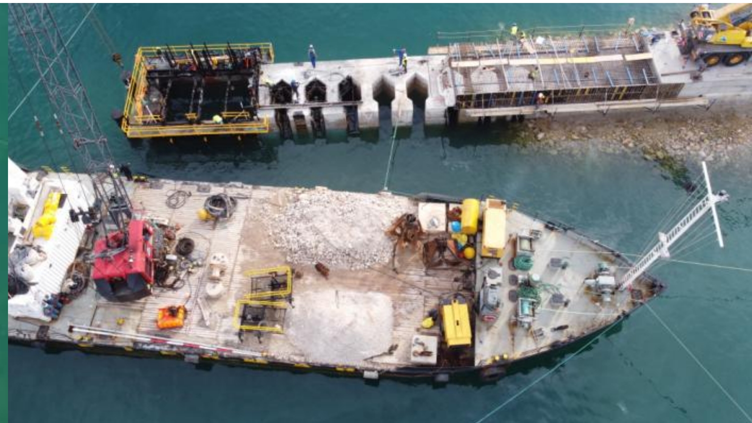
SESIMBRA PORT, PORTUGAL
UNDERWATER CONCRETE FORMWORK

The Port of Sesimbra has important port infrastructure covering the different activity sectors that are established there - fishing, leisure, navigation and maritime-tourism activities. The area dedicated to leisure navigation and maritime-tourism occupies 11.2 hectares of the port infrastructure, of which 1.4 hectares are operated by the Clube Naval de Sesimbra.

The Setúbal Port Authority is investing in the construction of a new dock at Sesimbra Port. The aim of the project is to improve the conditions of shelter and safety of fishing vessels, by protecting the docking areas during adverse weather conditions. It also aims to increase the number and length of berths facing the port and also to protect its parking area from vessels.

In her article, Inma Gómez, Division Manager, Rúbrica Maritime describes underwater concrete movable formwork for the construction of a submerged gravity quay wall and the quay wall above the water level in the fishing port of Sesimbra,Portugal.





SHIPYARDS AND MARITIME INDUSTRY IN TURKEY

In the first article, Mehmet Avcı provides an overview of services offered by Türk Loydu within the framework of internationally recognized accreditations and authorizations. Türk Loydu is an international classification society which was established in Turkey in 1962 by the Turkish Chamber of Naval Architects and Maritime Engineers and is an institution providing classification, inspection and certification services having many valuable shareholders in Turkey.

The next article was written by Kaya Yasar of Gemak. Since 1969, Gemak Group has maintained steady growth, and today is noted in Turkey and around the world for its wide range of skills and technical expertise. With its advanced manufacturing infrastructure, the company is positioned as a leading company in shipbuilding and high quality large steel constructions. In the article, recent activities and achievements are described.

The NB72 SOV vessel for Offshore Wind Farm Maintenance is described in the third article which was prepared by Sinan Kavala and İrem Ünal of Cemre Shipyard where the vessel was built. Conceived by DEME and further designed in close co-operation with Vuyk Engineering Rotterdam and Marin, this innovative vessel significantly improves safety, comfort and workability for wind farm technicians even in the roughest sea conditions.

Marine Construction, Towage, Salvage and Wreck Removal are the core sectors in which Aras Marine provides its services. Naci Hoşcan, Deputy Operations Manager of Aras Marine, has prepared a brief overview of their recent projects.

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SHIPYARDS, MARITIME CONSTRUCTION AND INDUSTRY IN MALTA

In the first article, you can read about the mission and activities of Malta Maritime Forum. Kevin J. Borg, CEO of Malta Maritime Forum, provides an overview of the development, investment strategy and future prospects of the maritime industry in Malta.

The second article of this issue was prepared by Valletta Cruise Port, a major port of call and a thriving homeport with record passenger movements in 2019. You can find information about the port, key facts, current activities and also its development, and how the company is turning the COVID-19 crisis into an opportunity.

This article is followed by an interview with Mr. Stephen Xuereb, CEO of Valletta Cruise Port and COO of Global Ports Holding, which was lead by David Stork. They discussed the details of some port activities, covid-19 related issues and some recent projects.

The next article brings information about The Centre for Maritime Studies (CMS) which forms part of the Institute of Engineering and Transport (IET) of the Malta College for Arts Science and Technology (MCAST). This article was prepared by Eugenio Busuttil, Deputy Director of CMS and Godwin Caruana, Coordinator of Deck Courses.

Design and Construction of St. Elmo Bridge together with a focus on St. Elmo breakwater and Lighthouse is provided in the last article of this issue. This article is also accompanied with drawings, and both historic and recent photos.

PORT OF GÄVLE IN SWEDEN AND ITS EXTENSION

Port of Gävle is a natural east coast hub for import and export, strategically located about two hours north of Stockholm and right next to the industrial Central Sweden region.

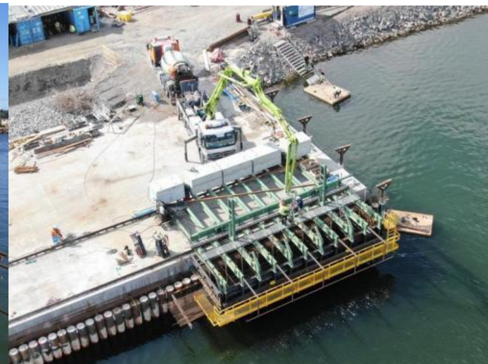
The increasing demand for container transport is the reason for the development of a new terminal that now effectively doubles the port's size.

In the first article we bring an overview of the Port and the Project.

The next article was prepared by Johan Ericsson from the Port of Gävle and describes the Project in further detail, construction works and plans for the future.

Design of the Port extension is described in the third article which was written by Johan Alderborg of WSP Sverige AB. The company was assigned by the Port of Gävle to design the reconstruction and extension of the existing quay and to execute a geotechnical study. The design requirements were to enable the quay to handle bulk goods and containers. The article is accompanied by relevant drawings.

The last article of this issue brings information on equipment which is used in the project. The article was prepared by Inma Gómez of Rúbrica Maritime.



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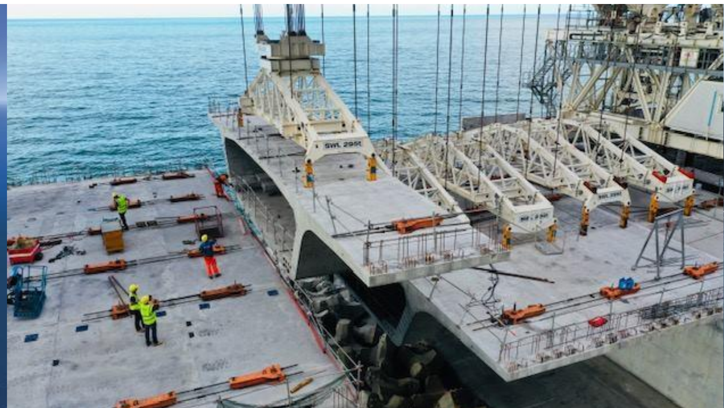
COASTAL ROAD IN RÉUNION

DESIGN, FABRICATION AND ERECTION OF ANTI-SCOURING MATTRESS

In the first article, we provide an overview of a project of New Coastal Road (Nouvelle Route du Littorial) in Réunion. The road has replaced the nearshore existing road RN1 between the two cities of Saint Denis and La Possession. Since the original road frequently underwent extreme natural,geological and marine events, it was decided to build a new one out at sea, further away from the cliff.

We bring information on the project, its history, companies involved, design and construction.

The next article of this issue was prepared by Paula Rinaudo and Jose Vicente Rajadell from Rúbrica Engineering. They describe the spreader beam which was designed for placing the anti-scour protection of the piers of the New Coastal Road in Réunion. They provide technical description of the beam and an overview of its design requirements. They also describe the equipment and its operation. At the time of writing, all half mattresses have been successfully installed and no significant issues were found on the structure or systems during the operations. Rúbrica Engineerings´s team and suppliers took a great part in the achievement of their installation.



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LIGHTHOUSES

The article about Bidston Lighthouse was prepared by David Stork.

The lighthouse is located on the Wirral, across the River Mersey from Liverpool in England. It is known as the world's most inland lighthouse.

This article describes what led to its construction and its subsequent history as a lighthouse. In addition to discussing the lighthouses, their optics and their keepers, the signal station that was located on the site and probably set up prior to the lighthouse being built is discussed. Also briefly described is the development of tide tables in the UK as this was greatly helped by William Hutchinson, a significant character in the story of Bidston and the Port of Liverpool in its formative days. Finally, there is a brief discussion of Bidston Observatory located on the same site.

The article was written by Timothy Douglass and brings a brief review of lighthouse construction around the British Isles.

This article is intended to provide the reader with an outline of the history of how lighthouses construction evolved in the British Isles, particularly lighthouses built on wave-swept rocks out to sea, much of which was adopted abroad.

November 2021

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VESSELS

Our first Edition in March 2019:

Damen Reversed Stern Drive Tug 2513 ´Innovation´

Tugs and their Development through Centuries

Overview of some projects realized by floating sheerlegs ´Matador´, ´Matador 2´and ´Matador 3´ of Bonn & Mees in the years 2016 – 2019

June 2019 Edition: Damen and Amels Expedition Yachts SeaXplorers with focus on The ´La Datcha´ SeaXplorer 77.

Next part of the magazine is dedicated to cruise vessels. Hans Tompot prepared for us an article on cruise vessels featuring:

- *‘Costa Venezia’, ‘Costa Firenze’ and ‘Costa Smeralda’ of Costa Crociere SpA (brand of Carnival Corp.),*
- *‘MSC Bellissima’ of MSC Cruises S.A., and*
- *‘Nieuw Statendam’ of the Holland America Line (brand of Carnival Corp.)*

Samet Cirlak of Cemre Shipyard wrote for us an article about NB57 SOV ´Wind of Change´. SOV is one of the new and unique branches in offshore market. The SOV “Wind of Change” was launched in early October 2018 and delivered in April 2019. Now it is operated by French Operator LDA for Danish ØRSTED on German waters.

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