

The Grecian Doric-column lighthouse of Madras (1840) and its builder John Thomas Smith, Madras Army Corps of Engineers

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Lighthouses fascinate us. They captivate our minds not only by their imposingly variable structures and engineering nuances, but also by the benefits they offer to sailors. John Thomas Smith of the Madras Army Corps of Engineers was directed to build the stonework lighthouse in Madras in the late 1830s. The present article chronicles the research he did before building the lighthouse and the task he completed in 1838–1839. Today the light apparatus and the lantern seated atop this Doric tower have gone missing. What is immensely striking is that the Doric-column structure, which once provided a beaming light with a wide and long sweep for boats and ships passing along the Madras coast, today stands as a mute testimony of the acumen of a sharp army engineer, burying in it brilliant physical and engineering details of a unique edifice.

*But thou, whose splendour dims each beam,
Whose firm, unmoved position might
declare*

*Thy throne a monarch's – like the north-
star's gleam,*

Reveals each snare.

–Ode to the lighthouse at Malta
El Duque de Rivas (1791–1865)

Lighthouses fascinate us humans for various reasons: as centre stages either in crime-thriller novel plots (e.g. Kathryn Louise Wood's *Sea Snow: The Gentle Haunting of a 19th Century Lighthouse*), or romantic poetry such as the one cited above.

Maritime trade on the Coromandel Coast prospered with Madras emerging as a key commercial hub in the 18th century. One notable cargo that was imported into Madras was ice, cut from the frozen lakes of New England, America. Shipped by Frederick Tudor of the Tudor Ice Company, Boston, the *Young Mechanic* (1375 tonnes) brought ice as 2 sq ft blocks to Madras in 1865 (ref. 1), which were stocked in the 'Ice House' (Figure 1; note 1) on the Marina². Ice-carrying boats left Madras carrying saltpetre, animal hides, jute fibres and finished materials, cotton cloth, shellac, indigo and linseed to Europe (note 2). Boats approaching the Madras coastline, after sunset, generally risked running aground along the shoals of Kovalam (12°47'N; 80°15'E) and into the sandbanks of Sadurangapatanam (Sadras; 12°31'N; 80°9'E) in the south and Pazhavérkādu (Pulicat, Paleācattā; 13°33'N; 80°10'E) in the north, necessitating lighthouses. Historically, three lighthouses have functioned in Madras city. The pre-

sently functional fourth lighthouse built in 1977, located along the southern end of Marina is credited with a few 'special' features not found in others in the rest of India.

In the 18th century, an unstructured, open, sandy 'port' functioned in the Madras coast, somewhere opposite to Fort St. George, which was established as 'armagaon' in the 1640s (note 3). Mahābalipuram (Māmallapuram; c. 50 km south of Madras) was a popular port during the reign of the Pallava-s (6th–9th centuries)³ and Pulicat during Dutch rule in the 17th century⁴. In the 1850s, a pier was built in Madras, slightly north of Fort St. George, in response to a request from the Madras Chamber of Commerce and Industry. The Madras coastline is so shallow that ships had to be parked at

least a mile (1–1.5 km) away, and the cargo had to be moved to and from the shore in native boats (note 4), which resulted in damage and loss of cargo, and even attracted pilferage. With the construction of the south pier in 1881, the Madras 'port' began to handle ships. An artificial harbour was dug, which has resulted in various negative environmental consequences, due to alterations made to the mouth of River Cooum⁵. Periodical dredging operations were necessary for port functioning from early days⁶. Organized operations commenced with a new pier built in 1885. The Madras (now, Chennai) Port Trust considers 1881, the year of rebuilding, as the formal start year of the Madras Port.

A lighthouse was proposed in 1795 to enable vessels to enter the open-anchorage



Figure 1. The Madras Ice House (1880s) on the Marina; photograph probably by John Nicholas, who ran the business 'Nicholas Brothers in Madras' in 1861–1905. (Source: British Library, <http://www.bl.uk/onlinegallery/onlineex/apac/photocoll/s/019pho0000472-s1u00011000.html>). The façade has changed over time. This segment of shoreline of Madras, known as the Marina today, was developed and named by Mountstuart Elphinstone Grant-Duff (Governor of Madras, 1881–1886) in 1884.

area anytime of the day. Initially the steeple of St Mary's Church, Fort St George precinct, was identified as the site for the light, which was opposed to by the Church Chaplain. Therefore, the terrace of Officers' Mess & Exchange (note 5) was named as the next best site, and the first lighthouse of Madras came up here in 1796. A 'large' lantern consisting of 12 oil-wick lamps, fixed at 99' (c. 30 m) height, and fed by coconut oil functioned. Locally made mirrors were used as reflectors. It is claimed that the beam from the lamp swept the sea as far as 25 miles. This lighthouse operated until 1841 (ref. 7).

A petition made by Vice-Admiral John Gore in 1834 reiterated the need of a technologically advanced facility. Consequently, the Court of Directors of the English East-India Company (EEIC) in Madras directed Captain John Thomas Smith, Madras Army Corps of Engineers, to develop a proposal, who, at that point of time, was on furlough in the UK. EEIC considered that the new lighthouse should occur further north of the Officer's Mess Building. The Esplanade – the Madras High Court precinct today – was identified as the site for the new lighthouse.

John Thomas Smith, Royal Engineers (1805–1882)

John Smith (note 6) was born at Foëllalt (Cardiganshire (Ceredigion), Wales). After studying mathematics, he won a commission with the Royal Engineers and left for India in 1825. He was appointed as the Executive Engineer in the Northern Districts of Madras Presidency (Ganjam, Rajamundry and Vizagapatnam). He passionately explored the use of limes and country mortars as building material. He translated Louis-Joseph Vicat's *Résumé des Connaissances Positives Actuelles sur les Qualités, le Choix et la Convenance Réciproque des Matériaux Propres à la Fabrication des Mortiers et Ciments Calcaires* (1828, l'Imprimerie de Firmin Didot, Paris, 149 pages) into English. This translated edition also included notes of several of his own trials. As the second book of this kind in English, this edition received a grand response. Smith was passionate of Vicat and the French civil-engineering theory and practice. He was an enthusiastic practical chemist and an experimenter⁸.

Smith served on a committee delegated to report on the possibility of developing the Red-Hills Railroad and Canal in the neighbourhood of Madras city. The Red-Hills Rail Road is the earliest rail road constructed to transport goods in India⁹. He surveyed the Ennore and Pulicat lakes to ascertain the practicality and cost of keeping open the sandbar of the Kuam (read as Cooum) River by artificially closing that of the Ennore River. Thus the waters collected in the Pulicat Lake would be directed to the Kuam, a measure, which he considered would afford use to residents of a then existing suburb 'Black Town' (note 7), besides improving the water communication between Madras and Sulerpet (Sulurpetta; 13.70°N; 80.02°E). The Government requested him to design and develop a system of lights for the Madras coastline. He designed and constructed what is popularly known today as the Doric-column lighthouse.

Smith was elected to the fellowship of the Royal Society in 1836. Earlier he was the President of the Philosophical Society of Edinburgh. He established and, for the first few years, edited the journal *Reports (Correspondence and Original Papers) on Various Professional Subjects Connected with the Duties of the Corps of Engineers, Madras Presidency* printed at the Vepery Mission Press, Madras (Figure 2). He wrote articles on varied engineering themes in this journal. After several years of stay as the Madras Mint Master, Smith was appointed as the Calcutta Mint Master, from where he

retired as 'Colonel'. An innovation he introduced, while in Madras Mint, was adjusting weights of coins using diameters of coin pieces, instead of their thicknesses, which resulted in the design of a novel machine. This machine was capable of weighing 20 or 100 blanks to the accuracy of half 'grain' (note 8). This Smith machine won an award at the London International Exhibition in 1851.

On return to England, Smith was employed as a consulting engineer by a few Indian irrigation companies. He later became a Director, and eventually Chairperson of the Madras Railway Company – a post which he held until his death in 1882. Smith also wrote on aspects of metallurgy and on political economy.

While serving the Madras army as Captain, in 1839, Smith published 'An investigation of the nature and optical efficiency of the combination of mirrors used to augment the illuminating power of the Madras light'¹⁰. In the preamble, he indicates that the text published in 1839 was actually written in 1833. He emphasizes the need to illuminate the Coromandel Coast using correct scientific theory. In 1839, he published a 55-page long paper in *Reports on Various Professional Subjects Connected with the Duties of the Corps of Engineers, Madras Presidency*, which was reproduced in *Papers on Subjects Connected with the Duties of Corps of Royal Engineers Contributed by the Officers of Royal Engineers* published from Woolwich, England. In this paper, consisting of four parts, he describes the physical details of the Doric-column lighthouse¹¹.

Evolution of lighthouses

Despite various lighthouse and lookout towers facilitating better coastal and harbour navigation since 300 BC, only 250 lighthouses – fitting with their present definition – existed in the world in the 1820s. However, lighthouse building occurred at many places through the world between 1840 and World War I, coinciding with intensified maritime trade, steam-power shipping and colonization of Africa and Asia by West-European nations, underpinning navigation safety¹². Ancient Roman lookout towers possibly used oil to generate light. John Smeaton built a cylindrical tower seated on a bell-cast base using interlocking rock blocks

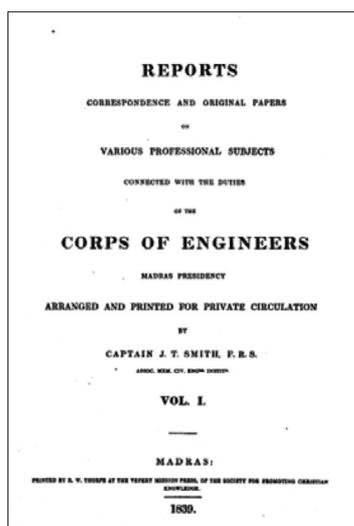


Figure 2. Cover page of the professional journal edited by John Smith.

at Plymouth (Devon) in 1759. Smeaton was inspired by the sturdiness of the English Oak tree (*Quercus robur*, Fagaceae) in withstanding intense winds and rough sea. Smeaton mimicked the shape of the trunk of *Q. robur* to build the Plymouth lighthouse. He built the tower joining blocks of granite with dovetail joints and reinforced with marble dowels. He plastered with hydrologic lime, which set well under water. The shape of the lighthouse, popularly known as ‘wave swept’ model, evolved as a universal model and inspired many lighthouse builders¹³. In the last 400 years a 51-m tall lighthouse built at the mouth of Gironde in France is a scientific marvel, which includes a Fresnel (read as frey-nel) lens that flashes light over 20 miles (32 km)¹⁴.

In the mid and later decades of 18th century, several improvements came into effect in lighthouse optics. Building on the principles of optics developed by Georges-Louis Leclerc (Comte de Buffon) and Marie-Jean Antoine Nicolas de Caritat (Marquis de Condorcet) Augustin-Jean Fresnel (1788–1827) created a bullseye lens panel made with polyzonal glass in early 1821 (Figure 3)¹⁵.

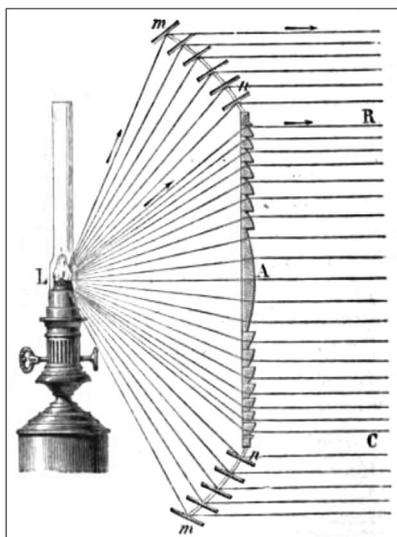


Figure 3. Sectional view illustrating how a Fresnel lens (A) in a lighthouse works to amplify light from an Argand (oil) lamp (L) into a parallel beam. Fresnel lens (1822) enhanced light projecting power of lighthouses greatly without the big load of a conventional lens of its magnitude and power. Mirror strips (*m, n*) are mounted above and below the lens that most lighthouses have to accentuate more of the lamp’s light. Source: Ganot and Atkinson¹⁵.

In 1822, Fresnel completed his flashing lens using eight circular bullseye panels. Each of the bullseye panels refracted light in both horizontal and vertical directions forming beams of light. Exploiting this scientific breakthrough, Chance Brothers of England branched out as opticians from glass-gadget manufacturing. They produced and marketed lighthouse optics that were nearly ready to be placed on towers.

One problem with oil-fed lamps used in lighthouses in the 18th century was smoke, which diminished the efficiency of light because of soot. Ami Argand (1750–1803), a Swiss inventor, designed



Figure 4. A fixed catadioptric light of first order (source: Stevenson¹⁶; note 9). Legends as in Stevenson Plate XVII are: A, B, C: Catadioptric zones, DEF: Compound dioptric belt with diagonal joints, A’, B’, C’: lower catadioptric zones (one division left out for access to the lamp), F: focus with the flame of the lamp, XXX: diagonal supports for the upper catadioptric zones, HH: service table on which the lamp rests, RR: frame carrying the apparatus. (In high possibility, an identical fixed light apparatus functioned in the Doric-column lighthouse, Madras.)

a ‘smokeless’ oil lamp (Figure 3), using a sleeved wick, enabling free air combustion. In the next couple of decades, Benjamin Thompson (1753–1814), an American–British physicist and inventor, devised a multiple-wick lamp, which changed the complexion of lighthouse lights.

Until the early decades of the 19th century, lights fitted in lighthouses used parabolic reflectors built on catoptric principle. In 1823, Fresnel introduced the dioptric apparatus, which he used in the new lighthouse at the mouth of the Gironde River. The dioptric principle involved refraction of light using lenses and prisms on a preferred focal plane. Improved Fresnel concept involved a single-light source in the light apparatus, which was an advantage.

Coupled with increased power and efficiency was the development that enabled a flashing light to be fitted with varying characteristics, such as timing, pauses and the number of flashes. The ability to differentiate the timing and the number of flashes was one major technological breakthrough in the later decades of the 18th century. Such a capacity enabled mariners to identify the lighthouse they looked for. Electric lamps were first used in the South Foreland lighthouse (Dover, England) in 1872, after a series of trials made from 1860. However, use of electric lamps across the world did not take-off immediately. Compressed kerosene-vapour and incandescent-mantle lamps were used until the 1940s. The strength of a light beam, concentrated via a catadioptric lens, was as powerful as the light emanating from three million candles (Figure 4; note 9)¹⁶.

The Doric-column lighthouse of Madras

Work on this lighthouse commenced in 1838. The Government of Madras announced on 13 December 1843 (ref. 17):

‘The light is of the flashing description and the duration of the flashes to that of the eclipses or dark periods is in the ratio of 2 to 3, – but as the nature of the motion is reciprocating instead of rotator, the above ratio mere expresses the average proportion of the light and dark intervals, which are themselves variable, according to the position of the spectator. The rapidity

of movement is adjusted, that the duration of the flashes will vary from 0 sec. to 48 sec., and that of the eclipses from 0 sec. to 72 sec., the sums of the duration of light and darkness bearing however, in every position, the constant ratio of 2 to 3.⁷

The column for the lighthouse was 125' (38.1 m) tall. Popularly referred as the Doric column (Figure 5; note 10), this structure matches precisely with Grecian pillars in bearing a fluted exterior and a slightly wider base than the top with no carving or ornamentation. Many 19th century buildings featured Doric columns, as part of the then popular neo-classical architecture¹⁸. Charnockite (= the Pallavaram gneiss) used to build the Madras column was extracted from Pallavaram (12.98°N; 80.18°E). In 1840, work was completed at a cost of Rs. 60,000 (£ 7500). The corners of the pedestal were covered by four supporting structures, which enabled inclusion of tightly compressed staff quarters within the pedestal¹⁹. Smith superintended the lighthouse until a trained team (one superintendent, one assistant superintendent, one headman, and six assistants) took over its day-to-day management from October 1845.

The light apparatus to sit atop the column was designed and built by Smith using local materials. Since its delivery was delayed, the oil-wick lantern of the first lighthouse was temporarily shifted. With the new lantern ready in 1843, this lighthouse became fully operational from 1 January 1844. This lighthouse endowed with a first class, fixed flashing light serviced vessels sailing in the Bay of Bengal up to a distance of 15 miles (24.14 km) until 1894 (ref. 20; also see Figure 4).

John Smith designing the Doric column and its light

Before launching on the construction of the lighthouse, Smith did his homework thoroughly. He impresses by the clarity he had with regard to the context of his project and by his adeptness in matching his task with local soilscape and other relevant factors, such as climate¹¹. With regard to the light apparatus, he explains the modifications he thought of earlier and made later in the construction of the lamp by substituting plated reflectors for

brass reflectors and by increasing the size of each reflector used to reduce their numbers and thus weight. He elaborately explains the design of the lantern (referred as 'frame') to achieve a superior compactness and strength, and to enable easy access to various parts situated within it for service and maintenance. He had thoroughly examined and weighed advantages and benefits against disadvantages and weaknesses on using a French dioptric apparatus and oil.

Stone-tower design was the most popular for lighthouses in the 19th century, although a few around the world were constructed using timber and iron. They did not bear the tower design²¹. Therefore, a stone-tower design chosen by an experienced civil engineer such as Smith does not surprise. Due to strong winds and

periodical cyclonic rains along the coast of Madras, Smith decided to use the best, locally available rock material, charnockite. In other parts of the world, lighthouses were mostly built using materials such as limestone. I could not access any of drawings and notes made by Smith, when he built the column. I guess that he must have followed the design used by John Smeaton, who built the Plymouth lighthouse involving interweaving rock blocks, reinforced with dovetail joints and marble dowels. Moreover, the then contemporary civil-engineering practice recommended using rock materials in

such edifices rather than bricks, since the bricks were less amenable in achieving a circular shape.

The next need then was to fix the light with the same degree of brilliance of a revolving light as proposed by Fresnel. According to Fresnel's concept, each of its concentrated pencils of rays of a revolving light would fall successively on the eyes of the viewer, principally with no gap from wherever it was viewed. Two key practical problems that needed to be resolved were: Whether or not the degree of velocity required to generate an apparently continuous light could be obtained by the revolution of lenses? Whether such a velocity was practical with no loss of light, because the rapid rotation which would eventuate, would render fixed lights worthless. The following text reproduced from Smith¹¹ explains his rationale on rejecting French lenses:

'The principal objection to the French lenses I found in the great uncertainty and apprehension entertained regarding the security of the focal light, which is generated by a large and complicated lamp governed by clockwork and which at the time I made my inquiries had never been tried in England, was considered liable to serious objection. Nor did the advantage gained by increased power of the French lens, (being derived



Figure 5. The Doric-column sans light compartment (unfilled arrow) in the High Court complex of Madras of Indo-Saracenic architecture built in 1892. The tallest dome (minaret) houses the lantern of the third lighthouse (filled arrow), which succeeded the Doric-column lighthouse. (Photo 1960s?, source: <http://indianquarterly.com/keepers-of-the-light/>, date unknown.)

from the contraction of the duration of the flash,) appear to me to be of so much importance in a climate that of India, as it might reasonably be supposed to be in situations where it is so frequently required to penetrate dense fogs; ... a more useful effect would be produced by giving the greatest possible *duration* to the flash or interval of light, than by sacrificing this important desideratum to obtain a superfluous degree of brilliancy. The experience which has since been gained regarding the use of these instruments has justified the above conclusions, much complaint being made of the shortness and suddenness of the flash exhibited by them; for, although the ray of light cast by the lens is three times more vivid than that of the apparatus designed for the present work, it is only visible during 5 seconds; while the latter will have a mean duration of less than 24", which will occasionally extend to 48". I ought not to omit to add also, that the French lens apparatus would have been more expensive, both in first cost and in annual outlay. Mr Fresnel's beautiful dioptric zonal arrangement was liable to the same objection as that above and as it exhibits merely a *fixed* light would be, I considered, unsuited to the exigencies of the present work, which it seems to be indispensable that some marked distinguishing character should be given'.

Smith¹¹ favoured using gas – oxy-hydrogen – flame instead of an Argand lamp; the latter being popular in such uses. He argues that the use of Argand lamps is challenging and liable to serious risks; moreover, its use demands complicated management. Nevertheless, he also indicates that they are less hazardous in application. He does not explain the rationale behind his latter remark, which appears to be a contradiction to what he said formerly.

Burning oxy-hydrogen gas as a light-generating source (also known as the 'koniophostic light', 'Drummond light', 'lime light'; note 11) was then popular as a useful energy source for use in lighthouses²². The new lantern (interior diameter of 9' (2.74 m), height 4'6" (1.35 m), with a pyramid roof, surmounted by a cowl) – meant for placing atop the Madras lighthouse – was a 12-sided gun-

metal object, of which nine sides were transparent and the rest blinded with copper sheets. An exterior balcony enabled cleaning of the light apparatus. The skeleton of the lantern was made of iron and the rest of the fittings with wood. The upper curb of the lantern frame included an iron cross, which carried a plate and friction rollers supporting the spindle of the frame. The lantern also included eight small and eight large air vents that could be either closed or opened from within the lantern.

The reflector frame consisted of a wrought-iron spindle that carried the 8 + 7 (15 in all) reflectors arranged in two tiers. The reflectors were so arranged to point to the direction of five faces of the dodecagon, with three on each, enabling a flash, when the apparatus was lit and viewed. The light emitted would establish a conical beam inclined at 18°. As the different sets of reflectors cast their light in the perpendicular direction of this beam, inclined to one another by 45°, at any time, there were 18° of the horizon out of the 45° covered by light. Consequently, with the rotation of the lantern driven by clockwork, the duration of flashes in relation to eclipses was in the proportion of 2 : 3. All of the reflectors were identical paraboloids of 3" (7.62 cm) focus, breadth 21" (53.34 cm), and depth 9" (22.86 cm). The reflectors were flat, polished copper – silver discs. The reflector discs were fixed in such a way that each reflected the fixed flame, with the burner adjusted to the focus of the parabola. The parabolic reflector produced a feeble light initially, which intensified gradually and remained maximal for the next few seconds of brightest effulgence that diminished gradually. The illuminating power was equal to 130.43 times that of an unassisted Argand flame.

The novelty of this apparatus was the reciprocating motion to the lamp, making it glide and re-glide over 90° (ref. 11). The faces of illumination inclined to one another at 45°; supply of light in effect along the horizon included rays of light from two extreme faces. The clockwork mechanism (technical drawings available in Smith¹¹) included a train of wheels managed by weights and fans. The fans could be adjusted for their speeds. These weights and fans enabled the reverse movement (thus, reciprocating). Comparing the strengths of a fixed light against a revolving light, Smith argues that in the

fixed light, the effect produced is precisely proportioned so that none of the light is lost, since none of the reflectors is directed inland; in a revolving light, on the contrary, provided the revolution is completed, a part of the light is expended with no purpose. The revolving light, however, has been found useful in many instances, since it is only by a series of flashes and eclipses succeeding in a determined order, that the particular lights on a thickly studded coast can be recognized from each other. Therefore, Smith²³ proposed that in places where lighthouses are not numerous, to stop the revolution of the apparatus after a certain portion of the circumference has been traversed and then to reverse the motion so as to cause the light to reciprocate. The action of the reflectors is thus confined to the seaside only. By this means, a light may be obtained at five-eighths of the expense usually incurred, which was effected in Madras by him in 1838–1839. Notable that this design of clockwork and the reciprocating light was used in improving the existing South Stack lighthouse at Holy Island, Anglesey, Wales.

Conclusion

This is the story of a fascinating scientific adventure made by John Smith in Madras. In 1894, the Government saw the need for a taller lighthouse than the Doric-column lighthouse and favoured creating a new one. The third lighthouse with the lantern placed atop the Madras High Court's tallest dome came up. What is striking is the lantern (or the frame, as described by Smith) does not exist at the top of the Doric-column lighthouse; only a top-vacant column remains today as a 'protected monument' with the Department of Archaeology, Government of India. The reciprocating-motion lantern designed by Smith was moved to the new (third) lighthouse in 1894? Or was it dismantled? I have not found the answers.

Notes

1. Today, Vivekananda House. Several 'ice houses' existed in various parts of the world, including Calcutta, because of Tudor's ice trade. Only the Madras Ice House stands as a memorial for 19th century ice trade.
2. In 1825, Nathaniel Wyeth developed the 'ice plough' – a heavy metal blade

pulled by horses – which made cutting ice efficient and easy. Tight packing of ice blocks with generous insulation rendered with pinewood shavings, sawdust and rice chaff enabled these blocks to reach their destinations. For instance, out of 180 tonnes of ice shipped, close to 100 tonnes arrived in Madras after travelling a distance of 25,000 km.

3. The supposed founder of Madras, Francis Day, a member of Masulipatnam Council and Masulipatnam armagaon landed in Madras travelling in a boat from Masulipatnam in 1637. The etymology of ‘armagaon’ is difficult to explain; varied interpretations occur. In essence it refers to a small, fortified storehouse for ammunition and weapons.
4. Surf (masula) boats and catamarans. For enchanting oil paintings of the 19th century in order to visualize the boisterous sea along Madras coastline, see http://www.surfresearch.com.au/1800_Gold_Catamaran_Masula_Madras.html
5. Today, the Fort Museum.
6. Summarized from *Grace’s Guide to British Industrial History*²⁴ and Lee²⁵.
7. Today, George Town.
8. Grain, a unit of mass equal to 0.065 g or $\frac{1}{7000}$ pound. An early unit of common measure and the smallest, it is a uniform unit in the avoirdupois, apothecaries and troy systems.
9. I found reading Alan Stevenson’s *Account of the Skerryvore Lighthouse, and Notes on the Illumination of Lighthouses* (1848) fascinating for the wealth of details it provides.
10. In my article ‘Photography and photomicrography in 19th century Madras’²⁶, I have used a Frederick Fiebig photograph, made in (1851), of the Doric-column lighthouse showing the light apparatus.
11. Lieutenant Thomas Drummond (1797–1840), Royal Engineers, performed the trigonometric survey of Great Britain in early 1820s. During winters he attended lectures by William Brande and Michael Faraday at the Royal Institution, London. On one occasion, he heard how lime became brilliantly luminous when heated to high temperature. Drummond believed that such a light source could

make distant surveying stations visible, especially at nights and in murky weather. After some experimentation he was able to build a working model that used an alcohol flame and a stream of oxygen directed at a ball of lime, which became useful in lighthouses.

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