

Large-scale iron and steel production in the Coromandel: the earliest and longest survived Porto Novo Iron Works (1830–1859)

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Iron production was self-sufficient in 18th century India and the excess was exported. Iron smelting, using modern techniques, commenced with the efforts of Farquhar and Motte in Calcutta, who cooperated in establishing an iron foundry in Panchet in Bengal. But this effort of Farquhar and Motte was short lived. The Tata Iron and Steel Company Limited and Indian Iron and Steel Company Limited (IISCO) were launched in 1907 and 1918 respectively. IISCO merged with the Steel Corporation of Bengal, established in 1939, and operated under a different banner in the late 1940s–early 1950s. In the 1800s, many individual ironsmiths operated in the Madras Presidency producing wrought iron, some of them using cone-shaped furnaces. An association was formed in Madras with an objective of establishing a charcoal-fired iron works in 1830, because the iron ore that occurred naturally in much of the Madras Presidency was then detected. Consequently, one ex-Madras Civil Servant, Josiah Heath, ventured to establish a large-scale iron–steel works in Parangipettai (Porto Novo), 220 km south of Madras, naming it the Porto Novo Iron Works, which went through turbulent phases during its performance. The remarkable aspect is that the Porto Novo Iron Works was the singular large-scale iron and steel factory in the whole of India in the 1830s. Nothing matched with the Porto Novo Iron Works in size and production capacity, which also included state-of-the-art methods of production of that time. The Porto Novo Iron Works serviced the needs of India and Britain for iron and steel for close to 30 years, although after 1849, it changed names to Indian Steel & Iron Company and East India Iron Company. In 1887, its prominent 150' (c. 50 m) tall chimney functioned as a beacon stand for the ships faring along Porto Novo coast. The indiscriminate exploitation of wood for charcoal and other energy requirements was one nasty practice the British Government encouraged to support Heath's enterprise, which resulted in the loss of precious wood in the vast tracts of the Madras Presidency.

Parthasarathi¹ remarks that iron production was self-sufficient in 18th century India and the excess was exported. With the quality of iron produced rated as high, the indicated self-sufficiency remains as a milestone in the pages of the history of Indian science and technology. Jean Baptiste Tavernier, Baron of Aubonne from Morges (Vaud, Switzerland), while travelling in India in the 17th century, remarked that the cannon barrels used by the armies of Abdulla Qutb Shah (r. 1626–1672) and Abul Hasan Qutb Shah (r. 1672–1686) of Golconda (17°38'N, 78°40'E) were stronger than those known in Europe then: the quality of iron was better; it did not crack during firing².

Iron smelting in India, using modern techniques, commenced with the efforts of John Farquhar, a Writer with the English East-India Company (EEIC) in Calcutta and Thomas Motte, a diamond merchant in Calcutta, who cooperated in establishing an iron foundry in Panchet (23°69'N, 86°76'E; Bengal, now in Jharkhand). Farquhar and Motte desired to produce soft iron for civil and military uses of EEIC. They also hoped to build cannons, further to producing cast-iron

pots, frying pans, and other domestic gadgets³. However, their efforts were short-lived⁴. James Erskine established the Bengal Iron Works in 1870. He used raw coal to fire open-top furnaces, with locally available iron ore, which was of poor grade. Iron and steel production began at Kulti (23°73'N, 86°85'E) in 1875, but the project could not compete with the cheaper, imported foreign steel and therefore folded up. The Tata Iron and Steel Company Limited and the Indian Iron and Steel Company Limited (IISCO) were launched in 1907 and 1918 respectively. The Steel Corporation of Bengal (SCB) set up a steel plant in 1939. IISCO and SCB merged and operated under the banner Martin Burn Limited in the late 1940s–early 1950s.

The Madras Government Records⁵ indicate that many small-scale ironsmiths operated in the Madras Presidency producing wrought iron (malleable and of high tensile strength iron alloy of low carbon content, usually obtained by puddling pig iron when molten) using cone-shaped furnaces (4'6" [1.37 m] tall, 13" [33 cm] wide at the bottom, 7" [17.75 cm] wide at the top) in the 1800s. Such fur-

naces bore two holes at the base, one for allowing the air blast provided by a hand-operated bellows and the other for releasing the slag. A 3D reconstruction of the furnace from the Madras Presidency of that time is available⁶. In such iron-smithies, measured volumes of locally available magnetite (Fe₂O₃, Fe₃O₄, Fe₃H₂O₄) and charcoal were introduced at the top of the furnace, first the charcoal, and later – after the charcoal was well fired – the ore. The volume of ore fired in each furnace each day varied from 125 to 210 seers (notes 1, 2). According to Bag⁷, these conical furnaces of Madras were similar to modern blast furnaces used in the manufacture of cast iron (more brittle, non-malleable and of weak tensile strength), whereas according to Biswas⁸ the Madras furnace design bears the semblance of the Austrian Stückofen furnaces, the concept of which was introduced by the Dutch into India. Supposedly an association (note 3) was formed with the sole object of establishing a charcoal-fired iron works in Madras in 1830 (ref. 9, p. 279). This association issued a statement that the magnetic oxide of iron (magnetite) – the

principal source of steel–iron in India – was confined to a part of the peninsula, south of the parallel of Madras. The ore mixed with quartz ‘formed mountain masses’ and was easily removable using a crowbar (note 4).

The remainder of this note sheds light on the establishment and functioning of a charcoal-fired iron works in the Madras Presidency in the early decades of the 19th century, which operated producing quality iron from 1830 till 1859. Pierre de Closets, C.E. (note 5) has written a three-part article¹⁰ on the Porto Novo Iron Works, which provides magnificent details. Hence I have relied on this article¹⁰ while writing this note.

The Porto Novo Iron Works

Josiah Marshall Heath, the founder

René Antoine Ferchault de Réaumur (1683–1757), popularly known in various science disciplines, especially entomology, provided clarity on steel production through his classic *L'Art de Convertir le Fer Forgé en Acier, et l'Art d'adoucir le Fer Fondu, ou de faire des Ouvrages de Fer Fondu aussi Finis que de Fer Forgé (The Art of Converting Iron into Steel, and of Rendering Cast Iron Ductile ...)* (Figure 1)¹¹. Following de Réaumur closely, an English inventor Benjamin Huntsman (1704–1776) perfected the technique of producing cast steel, which is also referred as ‘crucible steel’¹². These developments influenced Josiah Marshall Heath’s to consider steel production in Madras Presidency (note 6).



Figure 1. Cover page of René de Réaumur’s *The Art of Converting Iron into Steel, and of Rendering Cast Iron Ductile...*

Heath came to Madras town as a civil servant of the Government of Fort St George (note 6). When he was the relieving Commercial Resident of Coimbatore–Nilgiris District, Thomas Munro (1761–1827), the Governor of Madras (1820–1827), instructed Heath to trial the cultivation of the bourbon cotton (*Gossypium barbadense*, Malvaceae), then newly introduced from the Americas into Salem (11°65’N, 78°16’E) and Coimbatore (11°2’N, 76°58’E)¹³. Heath resigned his administrative position in 1829 to take up experiments in various scientific efforts towards better technology. He was also an enthusiastic naturalist. He explored southern Indian birds in particular. The biological name of greater Asiatic yellow bat, *Scotophilus heathii* (Chiroptera: Vespertilionidae, named by Thomas Horsfield in 1831) commemorates Heath’s passion in Indian natural history¹⁴.

Heath’s efforts in making steel in India, in the late 1830s, were blazing new trails towards producing cheaper steel, which he claimed would match in quality with the then best Swedish and Russian steel. His trial of adding 1–3% carburet of manganese (note 7) as a deoxidizer led to steel production, which costed lesser by 30–40% in the Sheffield (UK) steel market. This novelty trialled by Heath neither helped him nor his industry, because he failed to patent this procedure¹⁵. The following note appeared in the *Mining Journal* (1857; reproduced in the *Sheffield Daily Telegraph*, 31 March 1857) under ‘Manufacture of Iron and Steel’:

‘In 1839 comes the important invention of Josiah Marshall Heath for the manufacture of iron, and which, as regards steel, was as great a stride in the manufacture as compared with any previous process as the process of Uchatius is at the present time. The duration of this patent was, after much litigation, prolonged, by an application to the Privy Council, for seven years. Although the principle of Heath’s invention had been previously described, and even as early as 1799 William Reynolds patented the employment of oxide of manganese or manganese in the conversion of pig iron into malleable iron or steel, but gave no proportions of details, it appears that until the introduction of Heath’s patent no practical results were arrived at.’

It would be but appropriate at this juncture to recall the Bessemer process developed by Henry Bessemer (1813–1898), who used oxygen to blow through the molten pig iron to slough-off impurities and thus create high-quality steel¹⁶. A sidebar here would be that in spite of the cost of steel production dropping sharply, steel remained as an item of low importance until the mid decades of the 19th century, mostly used in the manufacture of kitchen tools.

Heath applied to the Government at Fort St George, Madras, for permission seeking exclusive rights to build a factory, which he argued would operate on European science. He further argued that he would be able to supply iron and steel at a much cheaper price than what Britain was acquiring from Sweden and Russia. Administrators in Madras approved his request declaring that he would enjoy the exclusive right over the ore material from a vast tract of public land (c. 38,000 mile², 98,500 km²)¹⁷. They also guaranteed Heath substantial loans and purchasing of finished products from his works in 1825. They considered it appropriate to grant him a temporary monopoly for 21 years of iron and steel manufacture, thus enabling and encouraging him to persecute this undertaking and to secure a fair and reasonable remuneration to him for the risk, labour and expenditure. Before Heath became the full Commercial Resident of Coimbatore–Nilgiris District, he was the relieving Commercial Resident in Salem in peninsular India, which naturally includes a rich dose of iron ore (note 8). In this role Heath learnt more about the highly endowed geomorphology of the Salem landscape.

The following from de Closets¹⁰ (p. 368) is relevant to this context:

‘Mr. Heath was a man of great scientific knowledge, and failed to see the advantage of manufacturing Swedish iron and steel. He applied to the Directors of the Honorable E. I. Company, who seeing the benefit to the country of such manufacture, granted to Mr Heath the exclusive privilege of manufacturing iron, by the European process, in the districts of S. and N. Arcot, Trichinapoly, Salem, Coimbatore and Malabar. They granted him the right of cutting in the jungles all the fuel required for the production of iron and also a grant in aid of £9000, showing the

interest they were taking in the industry.’

The factory

The Porto Novo Iron Works (some refer to this as Porto Novo Iron Company) was a large-scale operation, which compared well with those prevailing in Europe then.

Porto Novo (Portuguese; ‘New Port’ in English), also known as *Parangipétai* (corruption of *Férangi-péttā* [note 9]) and *Mahmūd Bandār*¹⁸, has been a Portuguese settlement from the 16th century, probably from the time of Afonso de Albuquerque, the Governor of Portuguese India (1509–1515), which was acquired by the English in 1748. The River Vélār traverses through the residential area here and drains in the Bay of Bengal in Porto Novo. From 1825, the Porto Novo Iron Works functioned here. Garstin¹⁹ refers to it as a ‘large’ factory and as the Porto Novo Iron Company. He indicates that the movement of iron ore from Salem was enabled to Porto Novo for Heath’s company via the sea, especially using the Khan Sahib Brackish Water Canals, which linked the north-lying Vélār and the south-lying Kollidam (a tributary of Kāvéri). The Khan Sahib Canals were made navigable in 1854 by integrating three locks, one of which debouched into Vélār, close to which the Porto Novo Iron Works existed. Before this sea-route facility came about, Heath had dug a short canal newly from Vélār to the backwaters adjoining the embouchure of the Kollidam, through which Heath moved iron ore in parisal (basket boats, small, circular ferries).

A graphic description of the layout of Heath’s iron works and the yard is available in de Closets¹⁰ (p. 368; Figure 2):

‘In front of the blast furnaces, along with a platform ran the pigs bed and the foundry hall.... The foundry was 100’ × 60’ (30.48 × 18.29 m) in size and had proper cranes, air furnaces, cupolas, and other foundry appliances, and was terminated by drying stoves, with their tracks and railway. ... The forge consisted of several sheds – The first containing the refinery and afterwards the puddling and reheating furnaces. Another adjoining the helve (note 10). Another shed contained the rolling mill, driven by an engine of 50 horsepower. The mill was provided with several sets of rollers of round, square, and flat iron bars, bending gear, rolling plates, saws and shears.’

This facility included two blast furnaces when the factory started (1830?). Two more were added later (date not available). The boilers occurred close to the engine and the flues were communicated via a 150’ (c. 50 m) tall chimney (note 11).

Difficult and better days

Smelting operations during early days were a disaster. The most significant first hiccup was deciding on the shape of the hearth for a charcoal-fired furnace suiting the chemical nature of the ore and the charcoal used as the energy source. Secondly, the workers brought from Britain were unfamiliar with charcoal-fired furnaces. Conversion of the cast into

wrought iron was the next hiccup the British workers (note 12)²⁰ and engineers grappled with, although they solved that problem in the near future, by following the then prevalent methods in France and Germany, using finery fires (note 13). The Porto Novo Iron Works managed to produce good-quality iron and steel and could sell produce to the Government (whether in Madras or in Britain, not clear) for use in their arsenals. The weakness, however, was that they could never achieve and guarantee consistent quality. By 1833, Heath’s debt to the Government was a whopping Rs 571,000. The Porto Novo Iron Works raised a capital with some of the EEIC surgeons in Madras becoming shareholders. The Advocate General of Madras drew up the contract for shareholders. The Porto Novo Iron Works became the Indian Steel and Iron Company in 1833. Neither dividends nor interests appear to have been paid to the shareholders at any time²¹. By 1838, the company sank into intense debt. Heath suffered substantial loss. Hopefully he sailed to England, where he floated a public limited company in the name East Indian Iron Company, empowered by the British Parliament. Robert Brunton (note 14) joined Heath at this stage. Brunton’s joining seems to have enabled Heath and his iron works to tide over troubled times. Brunton devoted his energy and enterprise in improving the quality of the pig iron, by resorting to more economical tactics of smelting. Finished iron was exported to Britain, which soon received favourable reports from several British ironmasters, who found the Porto Novo material was of top-class for the manufacture of annealed castings and boiler plates. de Closets¹⁰ (p. 382) indicates:

‘The plates made with this (*sic*. Porto Novo material) iron ... were found of such good quality, that they were used in the construction of Britannia bridge by Stevenson (note 15).’

Gradually some signs of prosperity were showing up, with the pig iron produced in Porto Novo shipped to UK free, since the boats carried the iron as ballast during their return haul to the UK. In short, a tonne of pig iron produced at a cost price of £3 was sold in Britain at £6.

In 1840, an improved process in iron production was found in France: the gas emanating from the furnace was re-used

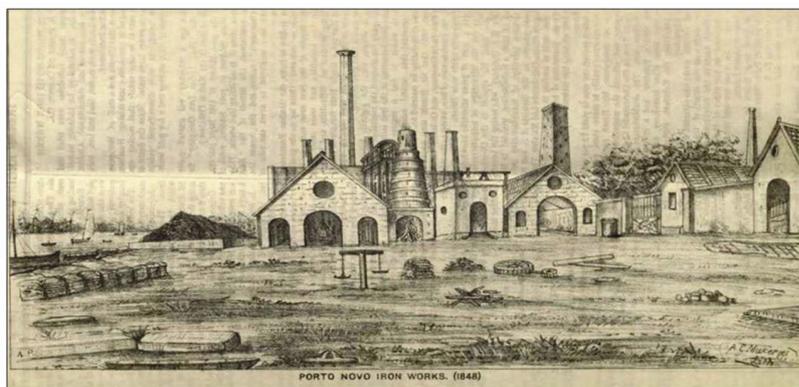


Figure 2. Porto Novo Iron Works (1848) (Source: de Closets¹⁰). The 150’ [c. 30 m] tall chimney is visible in the background, which in the 1880s was turned into a beacon for the ships sailing beside the Porto Novo coastline.

as fuel, which enabled greater money savings in the generation of steam and reheating and repuddling iron. Brunton went to Paris. The patentees of this process, viz. Thomas and Laurens in Paris enabled Brunton's training at Tusey and Treveray (France) in this new technique. Eventually a combined steam engine for rolling mills and blowing apparatus was installed in Porto Novo. de Closets¹⁰ (p. 383) remarks:

'The conversion of iron in these furnaces was very rapid and the quality of iron exactly like the best Swedish iron.'

Nevertheless, the new process had a flaw as well, which was diagnosed slightly later in time – the level of heat energy the furnaces discharged was so high that they ceased functioning regularly and required periodical repairs. By 1849, losses incurred at the Porto Novo precinct rose to Rs 822,240 (ref. 4). Heath returned to England in 1849 and lived in Sheffield until his death in 1851. He was interred in Kensal Green Cemetery.

The Government at Fort St George took over the administration of this works in 1853. Records indicate that the East Indian Iron Company (the Porto Novo Iron Works) produced 2150 tonnes of pig iron in 1855, yet continuing to suffer substantial losses. The Board of Directors of the East India Iron Company directed that a new precinct of this firm was necessary. Beypore, along the Malabar Coast, near Calicut, was identified. The responsibility of building the Beypore precinct was entrusted to George Brunton, nephew of Robert Brunton. George established the Beypore precinct with agility by putting up blast furnaces, a rolling mill for merchant iron, and a train of rollers for the railway rails. However, George had to leave this enterprise, which he enthusiastically built, because of a serious misunderstanding between him and the Board of Directors of the East India Iron Company¹⁰. With George's departure, the Directors decided to revert to the old method of converting iron in the puddling furnaces by firing charcoal. The iron produced in later years using charcoal with high sulphur content was still of good quality and much of the iron produced here was procured and used by the gun-carriage factory (note 16) in Madras. In the next few years charcoal supply was in short-

age, mainly because of injudicious felling of trees in the neighbourhood, which had an intense effect on this factory's performance.

Shortage of charcoal resulted in the Directors of the East India Iron Company shifting wrought-iron production to Beypore, so that they could supply the rails for the then nascent concept of Madras Railways in India (note 17). This decision resulted in vacating the Porto Novo precinct and moving every machine – except one blast furnace – to Beypore. The story of Porto Novo Iron Works technically ends here, although some remnant efforts were made at Palampatti (Salem) in the next few years, because by then Henry Bessemer's process (1856) had hit the science of metallurgy like a thunderbolt.

Steam-engine trials at the Porto Novo Iron Works

In May 1838, when Robert Brunton was superintending the Porto Novo Iron Works, trials using steam locomotives in generating required energy were attempted, which sparkle as fascinating historic moments in India's science history. Ambrose Foster and William Avery of New York (USA) were making great strides in improving the efficiency and performance of stationary steam engines to generate power in the 1830s. In 1831, Foster and Avery applied for a patent of their design of a 'reacting steam engine', which especially included flat, oblate revolving arms besides a stationary drum. In their patent claim made in 1831 and approved in the early months of 1836 (ref. 22), they have indicated that the revolving arms would experience far lesser resistance than the designs made before from the surrounding air, thereby enabling greater power generation.

Arthur Thomas Cotton (1803–1899), a senior engineer of the Madras Army, who pioneered in building dams (popularly referred as anicuts) and weirs in Madras Presidency, launched trials in various towns of the Madras Presidency using Foster–Avery steam engines for power generation. The Foster–Avery engine used at Porto Novo Iron Works (note 18) was adapted as follows²³ (p. 97):

'... a pair of arms was fitted to a common boiler, the evaporating

power of which was not measured, but which was estimated by the Engineers (Mr. Robert Brunton) to be sufficient to supply a five Horse engine in the common way, that is, evaporating about 7 or 8 cubic feet [0.20–0.23 m³] of water per hour. At an effective pressure of 50 lbs. [22.67 kg] the arms which were each 30 inches [72.6 cm] long and of a circular form 1¼ inches [3.175 cm] diameter, attained a speed of 1,000 revolutions per minute, indicating a velocity at their extremities of 15,078 feet [4596 m], without any load.'

On 31 May 1838, another pair of arms was attached to the boiler, which evaporated close to 41 cubic feet [1.16 m³] of water per hour. This embellishment improved the capacity of the engine substantially. To verify the efficacy of the improvised engine the amended system was attached to an iron lathe, which was found to 'work very well'²³ (p. 97).

Conclusion

Heath blazed a new trail in the Madras Presidency by setting up an iron–steel factory in Porto Novo (now part of Cuddalore district, Tamil Nadu) long before other efforts of similar magnitude and size were made elsewhere in India. His factory survived the longest, although it changed name from the Porto Novo Iron Works to India Iron Company, and a little later to East India Iron Company. His science and rationalization are impressive. Novelty in thinking by using manganese to accelerate the reactions is worthy of praise. Unfortunately I could grab no details of Heath's higher education before he entered the Madras Civil Service and rose in ranks from a relieving Commercial Resident to a full Commercial Resident. His passion about science and its offspring technology obviously pushed Heath to resign his lucrative job with the Government of Fort St George in Madras and test waters in iron–steel production, although undeniably, similar to any British officer of the EEIC, whatever were his aims, they were meant for the better economic growth of Britain. However, his life reveals to us that Heath was a person of greater scientific acumen than of economics: his disastrous failures in generating profits substantiate that he lacked economic acumen.

It is not clear how much Porto Novo (*Parangipéttai*) benefited economically from Heath's iron-steel works. The only available details are that the finished material produced in his factory, especially after the arrival of Robert Brunton matched in quality with those produced in Sweden and Russia, and the British steel market looked forward to obtaining Porto Novo products. The Central and Egmore Railway stations in Madras have been built using the Porto Novo steel, and an unverifiable Internet site indicates that the seal and logo of the Porto Novo Iron Works are visible in some of the iron beams today.

The reasons for Heath's choice of Porto Novo are not clear. de Closets¹⁰ does not list them either, although he apprenticed with Robert Brunton at some stage. de Closets' report¹⁰ essentially elaborates on the science and engineering skill of him, more as a tribute to him, keeping the Porto Novo Iron Works as a starting point. Nevertheless, reading the difficulties Heath and his staff experienced while 'importing' the ore from Salem via sea route is both amazing and stunning.

The most remarkable dimension in the story of Heath and his efforts to make iron and steel is that the Porto Novo factory was the only large-scale iron and steel factory in the whole of India in the 1830s. Every other extant facility was a cottage industry-like enterprise. Nothing matched with the Porto Novo factory in size and production capacity, which also included the state-of-the-art methods of production of that time. Moreover, the Porto Novo factory serviced the needs of India and Britain for iron and steel for more than 25 years, although after 1849, it changed names.

Bessemer²⁴ (p. 260) in his autobiography speaks positively on the efforts and intelligence of Josiah Heath. Quoting his words, I believe would decently conclude this article:

'... From the foregoing long list of claimants to the use of manganese in various ways in steel making, it must be evident that a knowledge of its beneficial effect was widely known and highly appreciated nearly a century ago; but the most prominent, and the most practically successful, of all these patentees was a Mr. Josiah Marshall Heath, a civil servant under the Indian Government, who, notic-

ing in the native Wootz steel-making of India the marvellous effect of manganese, conceived the idea of producing steel of superior quality from inferior brands of British iron by its use in the cast-steel process then extensively carried on in Sheffield. Heath came over to this country, and obtained a patent, bearing date the 15th of April, 1839, for the employment of carburet of manganese (that is, manganese in the metallic state) in the manufacture of cast steel: an invention of very great utility, as by its use cast steel of excellent quality could be produced from British iron that had been smelted with mineral fuel. Such steel possessed the property of welding either to itself or to malleable iron. The Sheffield cutlers were thus enabled to weld iron tangs on to the cast-steel blades of table-knives, and also to weld many other similar articles: a process which was not successfully carried on previous to the use of metallic, or carburet of, manganese under Heath's patent.

In consequence of this successful invention of Heath's, no British iron that has been smelted with mineral fuel is ever made into cast steel in Sheffield without the employment of carburet of manganese. In the early days of Heath's invention, he supplied the carburet in small packages to his licensees; he made this by the deoxydation of black oxide of manganese mixed with coal-tar, or other carbonaceous matter, in crucibles heated in an ordinary air furnace. This was a costly process, and as the demand increased he suggested to his licensees that it would be cheaper to put a given quantity of oxide of manganese and charcoal powder into their crucibles, along with the cold pieces of bar iron or steel to be melted. These materials would, when sufficiently heated, chemically react on each other, and produce the requisite quantity of carburet of manganese in readiness to unite with the steel as soon as the latter passed into the fluid state. But Heath's licensees said, "This is not precisely your patent, Mr. Heath," and they claimed the right to carry out this suggestion without paying him any royalty. This was the cause of some eight or nine years of litigation, by which poor

Heath was ultimately ruined, although his patent was established by a final decision of the House of Lords alas! only too late; for Heath died a broken-hearted, ruined man, wholly unrewarded for his valuable invention. Thus we see that both in the use of a carburet, and also by the use of a mixed powder, consisting of oxide of manganese and carbon, Heath's process has been successfully and commercially carried on from the date of his patent, in 1839, up to the present hour.'

Notes

1. 1 seer = 0.93 kg.
2. A report prepared by John Campbell published in the *Public Consultations* (16 August 1842, Madras Records Office, refers to multiple details of wrought-iron manufacture in India (southern India?), which I could not access. Campbell belonged to the Madras Army at the rank of Captain. He was the Assistant Surveyor General of Madras (1830s–1840s). He was a keen explorer of minerals and geology of India. A few articles by Campbell, such as on the formation of granite in Salem and Barramahal, solar radiation, the self-calculating sextant, and meteorology could be read in the *Calcutta Journal of Natural History and Miscellany of Arts and Science in India* (II, 1842).
3. Whether this association was a formal group or an informal gathering is not clear.
4. The 1–1.25 m long, sturdy iron rod, can be used to crack hardened soil and with some effort can even break rocks. This tool is variously referred as wrecking bar, pry bar, pinch bar, prise bar, jemmy bar, and pig foot.
5. My efforts to search more details of A. Pierre de Closets were in vain. In his article in the *Indian Engineering*, de Closets does not explain why he was writing a story on Josiah Heath's bid to manufacture iron and steel in Porto Novo, which would have finished at least 30 years before his article. The letters 'C.E.' after his name mean 'Civil Engineering'. In part II of de Closet's article (p. 383), I found a remark, which provided a link between him and the Heath story: de Closets trained under Robert Brunton, who was the Chief Engineer at Porto Novo Iron Works in the 1840s. During de Closet's traineeship, he was directed to build puddling and reheating furnaces suitable for gas works.
6. An intricately decorated filigree casket is currently on display in the Addis Gallery of Islamic Art of the British Museum

- [BM] (<http://blogs.ucl.ac.uk/eicah/files/2013/05/BM-Casket-Final-PDF-19.08.14.pdf>), which was taken away from Tippu Sultan's palace, when the Sultan was killed by the British troops. This casket was handed to the BM by one Henry Fraser, to whom it was handed by Josiah Heath. Heath seems to have acquired this casket through his wife Charlotte Catherine, whom he married in the Old Capper House, located towards the southern end of the Marina of Madras (presently it is a part of the Queen Mary's College for Women).
- Carburet of manganese is a heavy black powdery compound – pyrolusite (MnO₂) and carbon – used extensively as a powerful oxidizer. Also used extensively also as a decolorizer in glass-making industry to remove the green shade of impure glass.
 - The location of the Salem Steel Plant of the Steel Authority of India in Salem is mainly because this region is rich in ferruginous and manganiferous sediments embedded in granulite terrains (<https://www.sail.co.in/special-steel-plants/salem-steel-plant>).
 - Férangi* means 'foreign' (root: Arabic, Persian), here referring to the Portuguese; *pétã* refers to a residential locality (root: Têlugu). The capital city of Benin (West Africa) is also known as Porto Novo (6°29'N, 2°36'E).
 - A helve today would mean the handle of a weapon or a tool. In high possibility, helve meant a kind of a large hammer (sledge hammer?) used in iron-smithies in the 1880s.
 - The chimney existed in 1887, although the rest of the components of Heath's factory were demolished. The 150' tall chimney was used as a beacon (and a landmark) for ships in 1887 (ref. 10).
 - From Cotton²⁰, we get to know that at least the following four from UK worked at the Porto Novo Iron Company in differing capacities: John Milward (smelter), Robert Wood (plate roller), John Jones (puddler), and William Brazier (shingler), who had died in 1836 and interred in Porto Novo.
 - An intermediate type between a blast furnace and a forge.
 - Robert Brunton trained at the Chain & Young Foundry, Claude Girdwood & Co. in Glasgow, where he 'informally' graduated as an engineer. For sometime Robert assisted his brother William, who was a reputed engineer in Britain. Subsequently he joined Isaac Dodds, Horsley Iron Works, Staffordshire. Based on this experience he was appointed as the Engineer in Heath's Porto Novo Iron Company factory. Robert's reports on the manufacture of iron and steel in India are invaluable. His failing health forced him to return to England, but his connexion with the East India Iron Company continued at intervals until his death in 1852.
 - The Britannia Bridge (Pont Britannia) was built across the Menai Strait connecting Anglesey and mainland Wales in 1850. George Stephenson (not Stevenson) (1781–1848) was a renowned engineer and inventor.
 - The Naval Hospital in Madras ceased to function in 1831 and the building was turned into a gun-carriage factory²².
 - The construction and working of a railway connecting Madras to the West Coast terminating at Bypore was completed in 1861.
 - John Smith (1839) indicates to the steam engine trialled in Porto Novo Iron Works as 'Avery Steam Engine'. It was 'Foster–Avery Steam Engine' patented jointly by Ambrose Foster and William Avery of New York State in 1836 via an application lodged to the American Government in 1831.
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