On Her Majesty's Service

Extracts from
'John Smeaton FRS'
Prof. A W Skempton

WASC 1413.

John Smeaton FRS.

p 62-3 Edge runner stones for gunpowder.
p 219 drawings with his own hands.
App III pp 253 et seq.
254 } .... Waltham Abbey
255 } Powder mills .... Worcester Park.
256 } .... Hounslow Heath.

P/copies for 1413

John Smeaton, FRS
(engraving by W. Holl, after the portrait by Mather Brown)

JOHN SMEATON, FRS

Edited by
PROFESSOR A. W. SKEMPTON
Department of Civil Engineering
Imperial College of Science and Technology
University of London

Thomas Telford Limited
London, 1981

ISBN 0 7277 0088 X

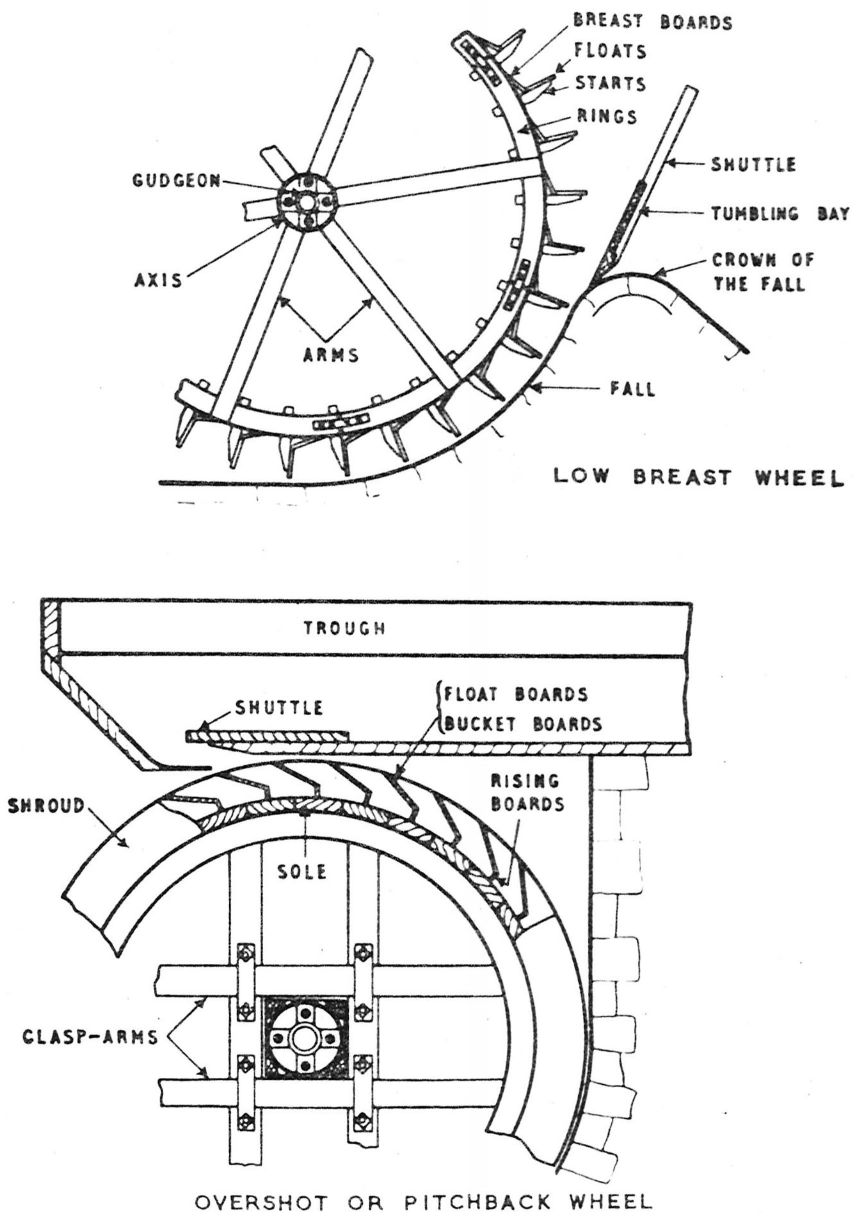

Fig. 8. Smeaton's typical waterwheels (drawing by P.N. Wilson, Trans. Newcomen Soc., **30***)*

there were to be 36 buckets. Smeaton required "the rising boards to be 4½ inches broad, and the breadth of the bucket board such, that the point of one bucket may advance to the centre line of the heel of the next bucket, and the cutting edge to be thrown to the outside".

A decision would also have to be made about the number of buckets or float boards on a given wheel. Early in his career Smeaton stated that with breast wheels the minimum criterion was to ensure that "one float entered the curve before the preceding one quitted it".[7] Analysis of his designs reveals that he regarded a circular pitch of about 1 ft as satisfactory—that is there would be one float, or bucket, per foot of perimeter circumference, though for wheels exceeding about 20 ft this pitch was increased somewhat. The diameter of a wheel relates, of course, the rotational speed in revolutions per minute to the peripheral velocity in feet per second. Smeaton appears to have used the latter as a fundamental parameter, saying in 1759 that:

> "Experience confirms that a velocity of 3 feet in a second is applicable to the highest overshot wheels, as well as the lowest . . . however . . . I have seen a wheel of 33 feet high, that has moved very steadily and well with a velocity but little exceeding 2 feet."[7]

In a letter to Mr Whatman about his papermill in Kent, written in 1787, however, he says:

> "I have now gone thro' the Calculation for your mill at Loose, and have settled the sketch for the wheel, the water trough, and the shuttle . . . I propose the wheel to be 19 feet diameter or height, to be 5 feet out and out and 4 ft. 8 in. within the shrouds and to make $4\frac{8}{10}$ turns a minute."[8]

This would give a peripheral velocity of 4.7 ft/s, and indeed his later practice appears to have been to use somewhat greater speeds of this order.

Power transmission

Smeaton designed mill machinery for a variety of purposes. Shafts and gearing transmitted rotary motion to the common face stones for grinding corn, edge-runner stones for oil-mills and gunpowder manufacture, and for driving rolling, slitting, and boring-mills in ironworks. Reciprocating power take-off was required for water pumping, furnace blowing engines, and sawmills. Stamp mills, fulling stocks and forge hammers were tripped by rotating cam drums.

In his corn-mill designs Smeaton followed common practice in having a vertical "pit-wheel" fixed to the waterwheel axle which for which others would contract to supply materials and carry out the construction. He described his own role thus:

> "They who send for me to take my advice upon any scheme I consider as my paymasters; from them I receive my propositions of what they are desirous of effecting; work with rule and compass, pen, ink, and paper, and figures, and give them my best advice thereupon."[10]

Smeaton regarded drawing as an important part of his work saying: "the rudest draft will explain Visible things better than many words";[11] and again: "I do not think it within the compass of human knowledge, to form the best possible Design *at once*. Things are far better finished by touching and retouching as is usual, and necessary to the greatest Painter."[12] John Farey, a friend of Jessop, described the activity of the third-floor drawing office:

> "Mr. Smeaton was a man of laborious habits and made all his drawings with his own hands. . . . His earliest designs, which were executed under his own inspection, show signs of having been used as working drawings . . . [but] After he became more established and employed a draughtsman he still continued to draw the lines of all his drawings to the proper scale in pencil on cartridge paper. . . . These sketches were fair copied on drawing paper by the draughtsman Mr. Wm. Jessop at first and afterwards Mr. Henry Eastburn, and Mr. Smeaton's daughters frequently assisted in the shadows and finishing, in indian ink which was very well executed."[13]

The collection of Smeaton's excellent drawings in the library of the Royal Society are amongst the earliest examples of their kind. That Smeaton intended them to be used on site as scale drawings is clear from a typical remark in a report:

> "The position and shapes of the other parts will be readily determined from the eye, or by measurement from the design; but it must be carefully observed, that wherever the measures marked upon the plan differ from those resulting from the scale, the figured measures are to be adhered to."[14]

The assistants mentioned above are the only ones Smeaton had in his office throughout his career. Indeed, up to the mid-1760s he effectively had none, for when William Jessop arrived in 1759 it was as a pupil aged 14 and he ranked as a qualified assistant only from 1767 until he set up on his own in 1772.[15] Henry Eastburn followed Jessop as a pupil in 1768 and, after 7 years' training, stayed on at Austhorpe until about 1788.[16] Thus, as Smeaton explains in reply to a letter asking if he had a vacancy for a pupil:

> "I have never trusted my reputation in business out of my own hand, so

APPENDIX III
List of Works

It is important to determine which of Smeaton's many designs were actually carried out and, where possible, to provide dates of construction. Much care has therefore been taken in compiling the following tables, but we cannot claim that they are complete and accurate in all respects.

Smeaton himself drew up a list in 1780 of watermills and windmills executed to his plans (*Reports*, Vol. 2, pp. 439–40). These are tabulated here, together with two horse-mills and the winding machinery at Griff and Long Benton collieries. After 1780 our list is based on evidence from Smeaton's letters and diaries and from notes by John Farey on the drawings and in Rees' *Cyclopaedia*.

Apart from his experimental engine Smeaton designed seventeen steam engines, as well as remodelling the engine at York waterworks and improving some others. Of the seventeen, there is clear evidence that nine were built, and their completion dates are given in the table. It is probable that the four other engines listed were constructed. Of the rest, one was not built and we have found no information, positive or negative, on three others. For the record, these were designed for collieries at Dunmore Park in 1778, Kinnaird 1778–79, and Thwaite 1779–80.

Ample evidence exists for the civil engineering works; in the form of minute books, Smeaton's own writings and, in many cases, the works themselves. It is possible, however, that one or two have been missed.

Design dates are taken from reports and/or drawings. Construction dates have been checked from original sources such as Smeaton's letters and minute books. Where we have been unable to establish a date within a year or so it is simply omitted.

Little information appears to be available on the actual cost of mills in the eighteenth century; but Telford in an unpublished manuscript (in the Institution of Civil Engineers library) gives the following figures for mills erected about 1789 in Shropshire: watermill with two pairs of stones £350 including the building and machinery; with two wheels and four pairs of stones £650; windmill with two pairs of stones £500. John Farey in his *Treatise* (London, 1827, pp. 232–3) gives details of the cost, amounting to £2,000, of a medium-sized steam engine (48 in. dia. cylinder) built in the 1770s, this including the engine house and pumping machinery. For canals and drainage schemes the tabulated costs include land purchase, parliamentary and other charges. For most of the other civil works, the cost relates to construction only. Comparisons with modern figures are difficult to make, but it may be mentioned that in Smeaton's day a building craftsman earned about 15*s* (£0.75) per week, a resident engineer's annual salary typically ranged from £50 to £120 depending on the scale of the works, and the unit cost of excavation rarely exceeded 6*d* (£0.025) per cubic yard in soft ground.

An idea of the rates of construction achieved can be gained from (i) the piers of the harbours at St Ives (1767–70) and Aberdeen (1775–80) where in both cases about 8,000 tons of masonry were built per year; (ii) the excavation of approximately 380,000 cu. yd/year on the Forth & Clyde Canal (1768–70), equivalent to something like 750 cu. yd/man per year, and (iii) the steam returning engine and winding machinery at Walker colliery (1783) were built and brought into operation 8 months after delivery of the drawings.

Mills and other machinery

Location	*Source of power*	*Purpose*	*Waterwheels* *No.*	*Type*	*Diam. (ft)*	*Design*	*Built*
Halton, Lancs	water	flour	no details				1753e
Wakefield	water	flour	1	LB	20		1754e
Wakefield	wind	oil and wood	smock mill			1754	1755e
Colchester	water	fulling	1	LB	14	1760–61	e
Hounslow Heath	water	copper	2	HB	16	*c.* 1760	e
Kew Gardens	2 horses	water	Archimedes screw			1761	1761
Stratford, E. London	water	water	1	LB	16	1762	1763e
Thornton, Fifeshire	water	paper	1	OS	15	1763	e
Kilnhurst Forge	water	blowing	4	LB	15		} 1765e
Kilnhurst Forge	water	hammers	2	LB	15		} 1765e
Kilnhurst Forge	water	slitting	1	LB	18		} 1765e
Carron ironworks	water	blowing	1	HB	27	1764	e
Sowerby Bridge	water	fulling	1	LB	12	*c.* 1766	e
Knouchbridge, Yorks	water	flour	2	OS	11	1767	e
London Bridge	water	water	1	US	32	1767–68	1768e
Wandsworth	water	flour	3	LB	14	1768	e
Keswick	water	grist	1	LB	16	1769	e
Carron ironworks	water	blowing	1	OS	20	1769	e
Thoresby	water	water	1	OS	7	1769	1770e
Templenewsam	water	water	pressure engine			1769	1770
Carron ironworks	water	boring	2	LB	18	1770	1771e
Dalry, nr Edinburgh	water	flour	1	OS	11	1771	e
Waltham Abbey	water	powder	1	LB	15	1771	e

Location	*Source of power*	*Purpose*	*Waterwheels* *No.*	*Type*	*Diam. (ft)*	*Design*	*Built*
Worcester Park	water	powder	1	OS	9	1771	e
Griff colliery	water	winding	1	OS	37	1774	
Leeds	wind	flint	5-sail mill			1774	e
Woodhall, Northumb.	water	grist	1	OS	32	1775	1776e
Coquet ironworks	water	rolling	2	HB	15	1776	
Scremerston	water	grist	1	N	11	1776	e
Hull	water + steam*	oil	1	OS	27	1776	1778e
Carron ironworks	water	clay	2	LB	18	1777	e
Long Benton colliery	water + steam	winding	1	OS	30	1777	1777
Carshalton	water	oil	1	LB	18	1778	e
Deptford	water	water	1	LB	16	1778–79	e
Cardington	water	flour	1	LB	8	1779	1780e
Seacroft ironworks	water + steam	blowing	2	OS	30	1779–80	
Gosport	2 horses	water	horse-gin			1779–80	
Wanlock Head mine	water	lead	1	LB	14	1780	1780e
Austhorpe (Sykefield)	wind	oil	5-sail mill				1781
Carshalton	water	flour	2	OS	8	1780–82	1783
Beaufort ironworks	water + steam	blowing	1	OS	42	1780–82	
Deptford dockyard	water + steam*	flour	1	OS	30	1781	*c.* 1784
Newcastle-on-Tyne	water	snuff	1	OS	24	1781	1782
Newcastle-on-Tyne	wind	flour	5-sail mill			1781–82	1782
Walker colliery	water + steam	winding	1	OS	30	1783	1783
Waren, Northumb.	water	flour	1	OS	21	1783	1785
Loose, Kent	water	paper	1	OS	19	1787	
Carshalton	water	paper	1	LB	15	1789	1790
Wandsworth	water	oil	1	LB	16	1789–90	
Custom House, London	2 men	crane				1789–90	
Waddon, Surrey	water	flour	1	OS	8	1789–91	

OS = overshot; US = undershot; N = Norse; LB = low breast; HB = high breast;
water + steam = waterwheel with returning engine;
steam* = steam engine not designed by Smeaton;
e = in Smeaton's 1780 list of "mills executed".

The following mills for which no dates have been found are included in Smeaton's list of "mills executed", drawn up in 1780.

Location	Source of power	Purpose	Waterwheels No.	Type	Diam. (ft)
Nine Elms	wind	flint			
Barking	wind	wood	no details		
Heath	water	pumping	no drawings		
Ridge	water	wood	no details		
Honeycomb	water	? flour	no drawings		
Bretton Furnace	water	blowing	1	HB	20
Hounslow Heath	water	powder	1	LB	16
Bussey, Perthshire	water	flour	1	OS	13
Horsley	water	wire	no drawings		
Horsley	water	tilt			
Alston, Cumb.	water	grist	1	OS	30
Whittle	water	grist	no drawings		
Throckley	water	grist	no drawings		
Welbeck	water	pumping	1	OS	4

The total numbers in the above lists are:

windmills	6
watermills	46
watermills with returning engines	6
horse-mills	2
winding engines	3

Steam engines

Location	Purpose	Cylinder diameter (in.)	Design	Set to work
New River Head	water supply	18	1767	1769
Long Benton colliery	pumping	52	1772–73	1774
Chacewater mine	pumping	72	1774–75	1775
Kronstadt docks	pumping	66	1774–75	1777
Long Benton colliery	winding*	26	1777	1777
Lumley colliery	pumping	34	1777	
Gateshead Park colliery	pumping	60	1778	c. 1779
Seacroft foundry	blowing*	30	1779–80	c. 1781
Middleton colliery	pumping	72	1779–80	
Carron ironworks	returning	72	1780	c. 1780
Beaufort ironworks	blowing*	36	1782	
Bourn Moor colliery	pumping	72	1782–83	
Walker colliery	winding*	36	1783	1783

* Returning engine with waterwheel.

Civil engineering works

	Design	Construction	Cost (£)	Resident engineer
Eddystone Lighthouse	1756	1756–59	16,000	Josias Jessop
Calder & Hebble Navigation	1757, 1759, 1767	1760–70	75,000	Joseph Nickalls, 1760–61 John Gwyn, Matthias Scott 1762–65 James Brindley, engineer in charge, 1765–66 Luke Holt, Robert Carr 1769–70
London Bridge foundations	1763	1763		
Coldstream Bridge	1763–65	1763–67	6,000	Robert Reid
Potteric Carr Drainage	1762, 1765	1765–68 1772–77		Matthias Scott, 1765–74 Henry Cooper, 1774–77
Perth Bridge	1763–69	1766–71	23,000	John Gwyn
Adlingfleet Drainage	1764	1767–72	7,000	John Grundy, engineer in charge David Buffery, assistant
St Ives harbour	1766	1767–70	9,500	Thomas Richardson engineer–contractor
River Lee Navigation	1766	1767–71		Thomas Yeoman, engineer in charge Edward Rubie, assistant, 1769–71
Ure Navigation & Ripon Canal	1766	1767–72	16,500	John Smith
Forth & Clyde Canal (Grangemouth–Glasgow)	1767–72	1768–77	164,000	Robert Mackell Alex. Stephen, assistant
Eyemouth harbour	1767	1768–70		
Newark flood arches	1768	1768–70	12,000	
Rye harbour, new channel	1763–64	1769–73	19,000	William Green
Spurn Lighthouse	1767, 1770	1771–76	8,000	William Taylor, engineer–contractor
Portpatrick harbour	1770, 1774	1771–78	10,000	John Gwyn, 1771–75
Banff Bridge	1772	1772–79	9,000	James Kyle
Stonehouse Creek Bridge	1767	1773		
Aire & Calder Navigation, new cuts and locks	1771	1775–79	30,000	William Jessop, engineer in charge John Gott, resident engineer
Aberdeen harbour, north pier	1770	1775–80	16,000	John Gwyn
Peterhead harbour	1772	1775–81	6,000	John Gwyn
Dunipace dam	1773	c. 1775		
Amesbury Turnpike Bridge	1775	1775	2,000	
Nent force level	1775	1776–		