

Variants of Soho Slide Rules

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Introduction

Soho slide rules are known as the first engineer's slide rules. James Watt (1736-1819) together with his assistant Southern – a skillful mathematician – established the criteria for a rather simple but exact slide rule. Watt considered that the existing and well-known slide rules for excise (Everard), for navigation and surveying (Partridge), and for carpenters (Coggeshall), had severe disadvantages. They were made for the requirements of specific users with especially developed scales, mostly overloaded and therefore very expensive. Furthermore, in most cases, they were rather inaccurate, very often because they were unauthorized copies of copies. Jane Wess¹ and Paul Zoller² in their excellent articles have written in detail about the history, development, and the features of the Soho slide rules.

Generally, Soho slide rules are characterized by the scale arrangement A/B C/D, where A, B, C have a double radius line, and D is a single radius line. Scales A and D are arranged on the stock, scales B and C on the slide. This was not quite a new design. Henry Coggeshall (1623 – 1690) had already designed in 1677 a slide rule for the timber trade with the same scale arrangement but with the D-scale broken at “4”. There are three versions of this carpenter's slide rule; the most popular is with the slide on the upper leg of a hinged rule. However, there are also normal slide rules (See Figure 1). The general design is exactly as the later standard Soho slide rule (See Figure 2) with an 11" scale.

Watt's Workshop

In Watt's workshop, which has been preserved after his death and can now be seen in the Science Museum London, four slide rules all made of boxwood were found. Two of them are unmarked and have just four scales, the typical scales on the Soho slide rule. They have neither scales nor tables on the reverse of the slide nor on the back of the stator. The scales with the length of 10 inches do not have the letters A, B, C, and D. Jane Wess assumes that these slide rules were made on site for use in the Soho workshop; perhaps they were just prototypes.

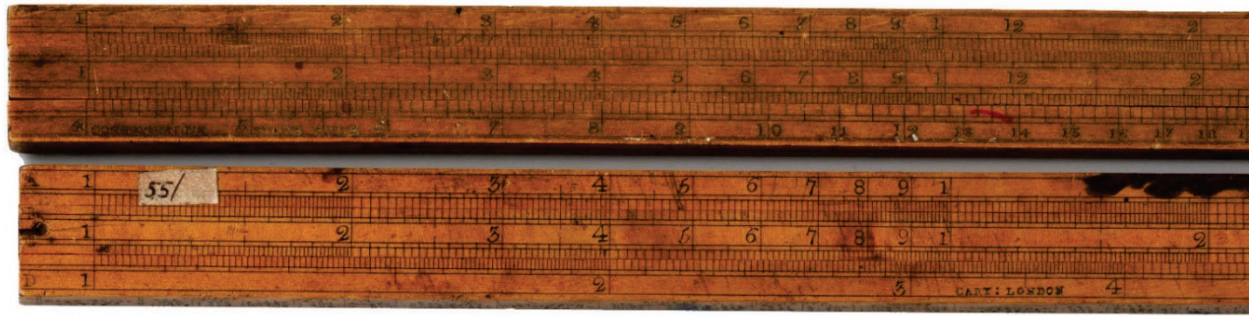
Another slide rule found in the workshop is a commercial one made by W & S Jones in the early part of the 19th century. This slide rule has a 10 inch scale

length with the standard Soho scales A/B C/D, but this time marked with the letters identifying the scales. On the back there are useful tables for engineers, plain scales, and a line of chords. The reverse of the slide has logarithmic scales for sines (S) and tangents (T) and an inverted scale N (mantissa). On the edge there are rulers from 0 to 10 ½ inches, divided in tenths and in eighths respectively. Under the slide, the ruler is extended to measure lengths from 10½ inches to 21 inches. Table 1 is a comparison of the main features of these Soho slide rules and several variants.

The fourth slide rule found in Watt's workshop is a Bevan engineer's slide rule made by Cary around 1815. This slide rule has a scale length of 11 inches and slides on the front and the back. There are rulers marked in inches and divided into tenths and eighths on one of the edges, while the other edge has plain scales. On one side are the standard Soho scales, but now 11 inches long. Under the slide (in the gutter of the stator) there is a scale H for *Present Worth* and *Annuity*. On the reverse of the slide there are the logarithmic sines, tangents, and mantissa scales.

On the back of the stator there are the following: a scale of double radius A, two triple radius scales E on the slide, and below (on the stator) a scale G for *Compound Interest – Principal – Amount*. The gauge point tables are on the reverse of this slide. Under the slide are scales F marked *Amount* and *Annuity Forborn*. Photographs shown in the article are by Wess.¹

Zoller² calls this a “curious rule” because the slide rule contains additional scales relating to such non-engineering activities as the calculation of *interest*, *principal*, *present worth*, and *annuity*. Zoller assumes that this rule was used at Soho for general financial planning or for works associated with the Insurance Society belonging to the Soho Manufactory. Watt might have found this slide rule useful in connection with his investments in retirement.



FIGURES 1 & 2: Comparison of a Coggeshall and a Soho Slide Rule

TABLE 1. Comparisons of Various Soho Type Slide Rules

Source ►	Found in Watt's workshop after his death		Author's Collection	Farey	Author's Collection	Author's Collection	
Parameter ▼							
Maker	¹	W&S JONES	CARY LONDON/ BEVAN'S	CARY/BEVAN'S	BATE	CARY, 181 STRAND	W. RANSLEY
Year	before 1796?	≈1800	≈1815	≈1815	1827	1821 – 1890	1865 – 1885
Measures (mm)	?	260 * 22 * 5	?	304.8 * 22.2 * 7.9	?	304.8 * 22.2 * 7.9	304.8 * 25.4 * 8.7
Measures (inch)	≈10½	10½ * 0.8 * 0.2	12	12 * 7/8 * 5/16	?	12 * 7/8 * 5/16	12 * 1 * 11/32
Material	Boxwood	Boxwood	Boxwood	Boxwood	Boxwood	Boxwood	Boxwood
Weight (g)	?	?	?	48	?	44	58
Specific Gravity	?	?	?	0.92	?	0.80	0.88
Movement by	?	Brass buttons, right side only	Brass button (small)	Brass buttons (small)	?	Brass buttons (small)	Brass button (large)
Scale length (inches)	10	10	11	11	10, 24, 28 & 56	11	11
Side 1, Scales	A/B C/D unmarked	A/B C/D unmarked	A/B C/D	A/B C/D	C/D, A/B, [folded at "3"]	A/B C/D	A/B C/D
Back of Slide	No	T, S, N (inverted)	S, T, N (inverted)	S, T, N (inverted)	N, E (inv.)	N/S	No
Under Slide (in the gutter)	No	Ruler 11" – 21"	H = PRESENT WORTH // ANNUITY	H = PRESENT WORTH // ANNUITY	No	No	No
Side 2 Scales or Tables	Blank	Gauge point table ²	A/E, E/G ³	A/E, E/G ⁴	Gauge point table	A/E, E/SINES	CUBE E/E, E/ROOT D
Back of Slide	No	No	Gauge point table	Double radius, inverted	No	T, Double radius, inverted (2.5 – 1 – 10)	No
Under Slide (in the gutter)	No	No	F = AMOUNT ANNUITY FORBORN	AMOUNT ANNUITY FORBORN	No	No	Initials W and S, intertwined letters
Upper Edge	No	Inches 1/10	Inches 1/10 & 1/8	Inches 1/10 & 1/8	?	Inches 1/10 & 1/8	Foot Measure
Lower Edge	No	Inches 1/8	Plain scales	Gauge point table	?	Gauge point table	Inches 1/10
Bevelled Edge	No	For S, T, N	?	For S, T, N	?	No	No
Remarks	¹ made on site at the workshop?	² includes Plain scales & Line of chords	³ E = Cubic scale G = Compound Interest	⁴ G = Compound Interest/Present Worth			

A Different Bevan's Rule

Another Bevan's engineering slide rule in the author's collection, also made by CARY: LONDON, is slightly different from the one found in Watt's workshop (See Figure 3 a & b). The slide of side 2 has - deviating from the rule in Watt's workshop - an inverted line of double radius running from 1.44 to 1 and from 10 to 14.4, i.e., two decades broken at 1.44 = 1.2². The other

differences are the gauge point tables on the lower edge (See Figure 9 a & b), giving the volume of different substances weighing 1 pound for cubes, cylinders, and globes in FFF (Foot * Foot * Foot) or FII (Foot * Inch * Inch) or III (Inch * Inch * Inch). The volumes are given for Cast Brass, Bricks, Copper, Cast Iron, Wrought Iron, Lead, Linseed Oil, Marble, Proof Spirit, Salt, Tallow, and Water. As the edge is only 7.82 mm thick, there is not much space for all the data.



FIGURE 3a. Bevan's Engineering Slide Rule, Front, Left Side



FIGURE 3b. Bevan's Engineering Slide Rule Front, Right Side

Thus, the characters and ciphers had to be very small; actually they are only 1.25 mm high. Just for the table, the maker had to engrave – besides the lines and divisions – 219 characters, 318 ciphers, and 83 dots³. This work not only required good eyes but also high concentration. Therefore, by considering all the other scales, the manufacturing of Bevan's engineer's slide rule was very time-consuming and rather expensive.

Farey's Improvement

Most of our knowledge about Soho slide rules we owe to John Farey. In his book, *A Treatise on the Steam Engine* of 1827⁴, he described in chapter VII (pages 531 – 572) the “Application of the sliding rule for calculating the dimensions for the parts of Steam-Engines”. However, he not only explained the scales on the Soho slide rule and their use, but he also suggested important improvements. His intention was to create a slide rule with only one slide, but with new scales.

Firstly, there is an inverted one-radius scale, which additionally is broken (folded) at “3” (See Figure 4). This arrangement allows convenient calculation and is more accurate as the scale length is doubled compared with the usage of the A/B-scales on the standard Soho slide rule. In a footnote, Farey mentioned the Rev. Wm. Pearson, who was the first to propose a slide rule with the slide inverted. According to Farey, Dr. Wollaston was the first to arrange this inverted or more properly the reversed slide rule.

To avoid the inconvenience of changing the slide, and to make a complete slide rule with only one slide for engineers, Farey has made the following arrangement

of four lines, all placed on the front of the rule (See Figure 5). Three lines have a single radius and one a double radius. Scale A and the broken, inverted line B are used to perform multiplication, division, and simple proportion on the inverted method. All cases of squares, or square roots, may be solved by means of the line of single radius D, acting against the line of double radius C. As normal multiplication and division are performed on single radius lines, their divisions are twice as large and therefore more exact and less fatiguing to the eye.

Secondly, Farey introduced another scale on his “New Sliding Rule”: the line of one and a half radius on the back of the slide marked E. This is a logarithmic scale with a cycle length of two thirds of a single radius ranging from 2.5 to 1 to 10 (see Fig. 5). This scale enables one to raise to the 1.5th power any number, being equal to the square root of the cube of a number. To use this scale E the slide must be taken out of the groove and turned upside down. E is applied against the lower scale B of the rule.

One example for the use of line E given by Farey is to calculate the quantity of water which will flow over the edge of a weir or through an aperture or notch in the edge of a board being open at top.

On the back of the slide, Farey had placed another scale N, which is a mantissa scale. The slide has to be turned in such a way that N is set against B with “0” on N and “10” on B.

Farey did not place any trigonometric scales on his “New Sliding Rule”. Obviously he was of the opinion that these scales would not be used by engineers very

often and would just increase the cost for engraving. The back of Farey's rule contains tables to calculate the solidities (volumes) or weights of square prisms, cylinders, or globes (Table 2). Farey mentioned in a footnote on page 557 that he had calculated the divisors and that they are more complete and exact than tables usually engraved on the back of slide rules. Gauge points on Farey's tables are to be taken upon the single radius line D while the divisors on a Soho slide rule are based on A, a double radius line. A few examples are given by Farey for the usage of the tables. In addition to these gauge points Farey suggested an additional table of specific gravities (See Table 3).

There are also "Directions for the choice of a Sliding Rule". For short rules up to 13 inches, Farey recommended white ivory, for longer ones light-coloured boxwood. The slide must fit accurately into the groove and must slide very freely without being too loose.

The goodness of the divisions on a slide rule depends upon the accuracy of the original patterns and the skill of the engraver. Farey stated that the rules made by Mr. Bate, optician in the Poultry, London, are more correctly divided than any others he had examined. He considered the original or standard Soho slide rule of 10 inches as a very convenient size for the pocket, but

24 inches rules are preferred for the office. Farey himself even used 28 inches and 56 inches slide rules (made by Bate), which allow the reading of four places of figures without estimation.

The Science Museum in London owns a "Farey's Improved Soho Slide Rule" (INV 1922-84) with a length of 2 feet $1\frac{7}{16}$ inches. This slide rule by Rooker, East St. Lamb's Conduit St. London, was probably made between 1843 and 1846, and has on the front the scales described by Farey, but the scales under the slide are missing. The reverse of the slide is blank¹.

Hinged Engineer's Slide Rules

Coggeshall's idea was adopted by many others, initially by Joshua Routledge (1775 – 1829). He put the standard Soho scales with a D-scale running from 1 – 10, upon a hinged carpenter's rule. Figure 6 shows a pocket version signed I. ROUTLEDGE ENGINEER BOLTON and was made by BUCK & HICKMAN, No. 281 WHITECHAPEL ROAD LONDON. This design was again improved by W. WILKINSON (See Figure 7). He placed an inverted double radius scale next to the slide with the consequence that the scale D is not in direct contact with the slide. Many others varied the hinged rules with slightly different scales and gauge point tables for their specific requirements.

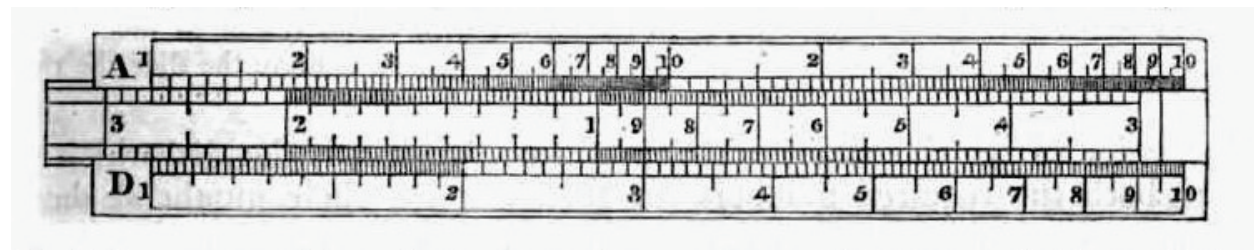


FIGURE 4. Farey's⁴ Slide Rule, First Improvement

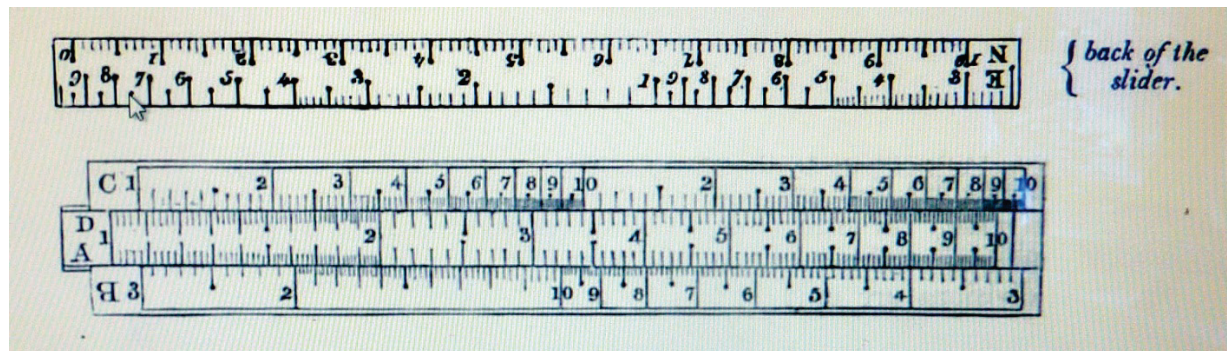


FIGURE 5. Farey's⁴ Slide Rule, Second Improvement

TABLE 2.⁴

Table of Divisors for calculating the solidities or weights of square prisms, cylinders, or globes.

Solids.	Solidity in cubic feet.			Solidity in cubic inches.		Water pounds, a cubic foot 62.5 lbs.			Cast iron lbs. a cubic foot 450 lbs.			Wrought iron lbs. a cubic foot 485 lbs.		
	FF	FI	II	FI	II	FF	FI	II	FF	FI	II	FF	FI	II
Squares ..	1	144	1728	.08333	1	.016	2.304	27.648	.00222	.32	3.84	.002062	.2969	3.563
Cylinders	1.273	183.3	2200	.1061	1.273	.02037	2.933	35.203	.00283	.4074	4.889	.002625	.378	4.536
Globes ...	1.91	—	3300	—	1.91	.03056	—	52.804	.00424	—	7.334	.003938	—	6.805
						Specific gravity 1.			Specific grav. 7.2			Specific grav. 7.76		

Solids.	Lead lbs. a cubic foot 710 lbs.			Copper lbs. a cubic foot 555 lbs.			Brass lbs. a cubic foot 525 lbs.			Stone lbs. a cubic foot 155 lbs.			Brick lbs. a cubic foot 125 lbs.				
	FF	FI	II	FF	FI	II	FF	FI	II	FF	FI	II	FF	FI	II		
Squares ..	.00141	.2028	2.434	.00180	.2595	3.114	.0019	.2743	3.291	.00645	.929	11.148	.008	1.152	13.824		
Cylinders	.00179	.2582	3.099	.00229	.3304	3.964	.00243	.3492	4.191	.00821	1.182	14.195	.01019	1.466	17.601		
Globes00269	—	4.648	.00344	—	5.946	.00364	—	6.286	.00123	—	21.292	.01528	—	26.402		
			Spec. grav. 11.36			Spec. grav. 8.88			Specific grav. 8.4			Specific grav. 2.48			Specific gravity 2.		

TABLE 3.⁴

A Table of the Specific Gravities of different Substances, and the weight of a cubic foot in pounds; adapted to be engraved at the back of a sliding rule.

Platina	21.04	710	Lead	11.36	Glass	2.88	163	Purbeck	2.61	Ivory	1.92
Gold	19.36	555	Copper	8.88	Marble	2.72	160	Portland	2.56	Horn	1.84
Mercury	13.55	525	Brass	8.40	Slate	2.67	155	Millstone	2.48	Bone	1.65
Silver	10.51	485	Iron	7.76	Granite	2.64	152	Paving	2.43	Box	1.33
Steel	7.84	450	Cast Iron	7.20	China	2.38	125	Brick	2.00	Coal	1.28

60	Wax	.96	44	Ash	.70	Carbonic acid gas 544 Oxygen gas . 747 Azotic gas . 854 Common air . 830 Hydrogen gas 11960	Times lighter than water. Barom. 30 inches. Thermom. 60 degr.
58	Oil	.93	40	Fir	.64		
55	Oak	.88	37	Elm	.59		
47	Beech	.75	35	Deal	.56		
45	Mahogany	.72	15	Cork	.24		

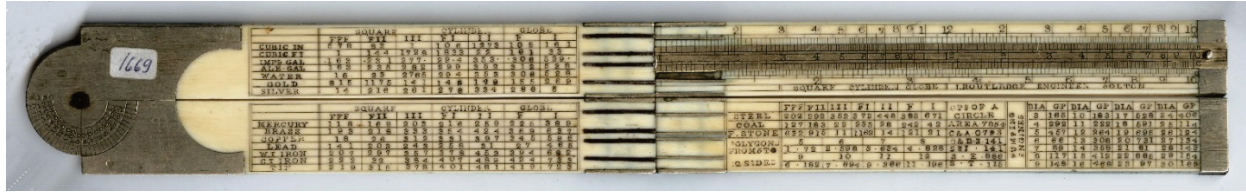


FIGURE 6. Routledge's Hinged Engineer's Slide Rule

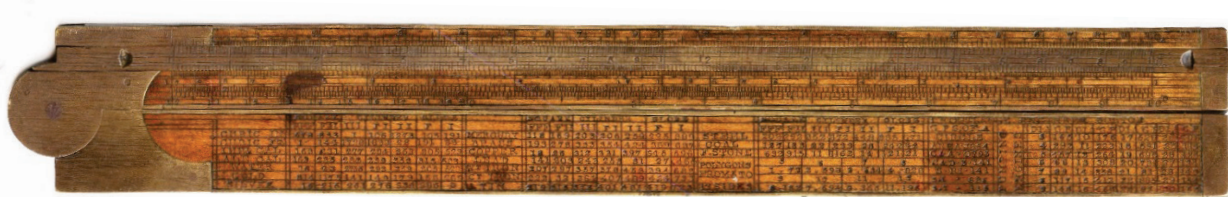


FIGURE 7. Wilkinson's Hinged Engineer's Slide Rule

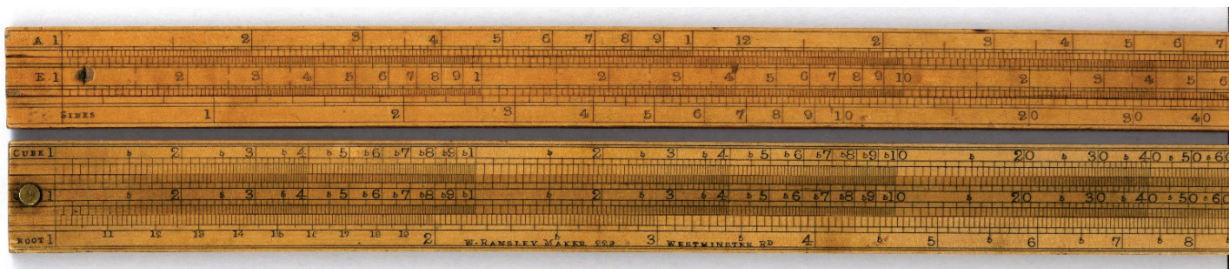
Later Soho Variations

Variations of the standard Soho slide rule continued to appear with an improved scale arrangement and with a cursor decades after Amédée Mannheim had invented his slide rule. Figure 8a shows the second face of a Soho rule made by CARY 181 STRAND LONDON with the scales A (two cycles), and a triple radius scale E on the slide and a SINES-scale at the bottom. As the SINES-scale ranges from 1 to 90°, one must use the slide from the other side with a double radius scale. The back of the slide with the E-scale carries a tan-scale T from 1 to 45° and a double radius scale, broken (folded) at 1.42. On the back of the slide upon the other (Soho) face we find an inverted mantissa-scale marked N and a sin-scale S from 1 to 90°. One edge carries a 12-inch scale, divided into eighths and tenths. The

other edge – similar to Bevan's slide rule – contains very tiny gauge point tables (See Figure 9b).

Another version (See Figure 8b) made by W. RANSLEY MAKER 229 WESTMINSTER RD. has two adjacent triple radius E scales, which, together with the root scale at the bottom, allows us to find the cube root of a number, while the Soho side allows us to find the square root. One edge has a decimal divided inch scale, the other a foot measure divided into 100 equal parts. The back of both slides are left blank.

There exists many more variations of Soho slide rules. For example, Jane Wess¹ mentioned a 9-inch rule by the inventor Bryan Donkin and a 12-inch slide rule made by Elliot Bros., both in the collection of the Science Museum London.



FIGURES 8a & b: Back of Soho Variants by Cary & Ransley

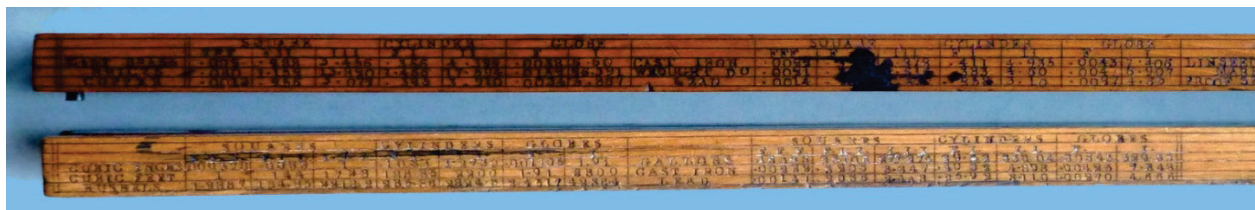


FIGURE 9a: Edges of Two Cary's Slide Rules, Left



FIGURE 9b: Edges of Two Cary's Slide Rules, Right

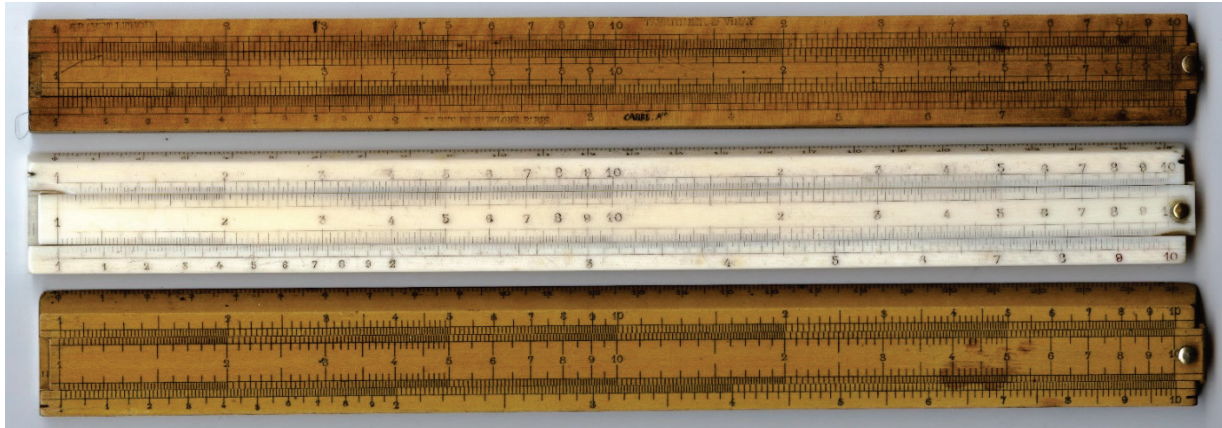


FIGURE 10. Three French Soho Slide Rules

The Rule Book by Jane and Mark Rees⁸ shows an ivory Soho slide rule made by E. BRYAN, MANCHESTER (1865 – 1871). On the back of the rule there are Routledge's gauge point marks.

The *Journal of the Oughtred Society* 5:1 includes drawings of a Soho slide rule made by W & S Jones. These drawings were part of an article by M. Jomard published in 1815, which was the beginning of interest in slide rules in France.

Even after Mannheim's new scale invention in 1850, Soho slide rules were still made in France in the second half of the 19th century. In Figure 10, three French Soho slide rules are shown, all with a 25 cm scale length:

- One is signed GRAVET LENOIR and made by TAVERNIER & VINAY. Slide rules with this name were only sold in 1874. As the rule is also marked GRAVET LENOIR it was made earlier, i.e., before the company's name was changed. Several marks on the rule have been added later:

- 1' stands for $\pi/(180 * 60) = 0.0002909\dots$
= 1 minute.

- The second mark 1'' is in the wrong place:
 $1'' = \pi/(180 * 60 * 60) = 0.000,004,848\dots$
= 1 second.

- The meaning of the note "CARRÊ" A^{lc} is unknown. Perhaps, Alexandre Carrê, a seller or owner.

- The second rule with the beveled edge is signed TAVERNIER-GRAVET, RUE MAYET 19. PARIS, and thus was made after 1882.

- The unsigned ivory rule was obviously also made by Tavernier-Gravet.

All these French slide rules have tables on paper glued to the back. This was certainly much cheaper than punching each letter and cipher individually by hand. On the other hand, tables on paper are less durable, but less prone to errors of transcription. Each of the three slide rules has S, T, and mantissa scales on the back of the slide and cm-scales on the edges with an extension under the slide. The notches at the ends most probably were made to firmly fix the stock during the process of engraving the graduations on the rule.

A detailed history of early French slide rules can be found in an article by Francis Wells and Tom Wyman for the *Journal of the Oughtred Society*⁷.

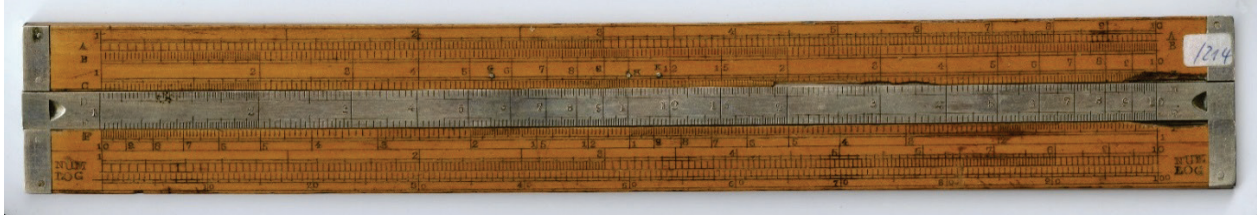


FIGURE 11a: Hogg-Stanley Slide Rule, Front

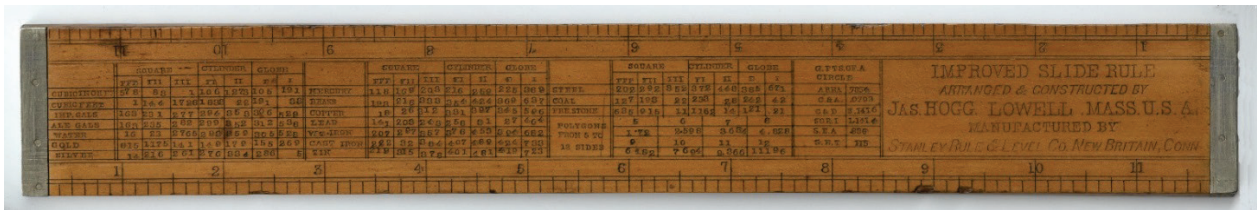


FIGURE 11b. Hogg-Stanley Slide Rule, Back

An American improved slide rule arranged and constructed by JAS. HOGG, LOWELL, MASS. USA and manufactured by STANLEY RULE & LEVEL Co. NEW BRITAIN, CONN. is rather strange (See Figure 11a). One single radius scale marked NUM is placed below the inverted double radius line F. This means that the inventor preferred – like Farey – to work with the inverted line. Interestingly, he arranged the mantissa scale LOG below the NUM scale to facilitate the reading of the logarithms.

A second single radius scale A has been placed above the B-scale. Thus one could directly find squares and square roots. The reverse of the rule contains several gauge tables and inch-scales divided into tenths and eighths (See Figure 11b). James Hogg (1851 – 1930) was an English engineer who went to the United States in 1880. In 1888, he invented this slide rule made of wood and German silver that was sold, including the instructions⁵, for USD 4.

Notes

1. Wess, Jane, *The Soho Rule*, Journal of the Oughtred Society, 6:2, Fall, 1997.
2. Zoller, Paul, *The Soho Slide Rule: Genesis and Archaeology*, Bulletin of the Scientific Instrument Society No. 57, 1998.
3. Rudowski, Inge C., *My Favorite Slide Rule in my Husband's Collection*, Slide Rule Gazette, Issue 8, Autumn, 2007.
4. Farey, John, *A Treatise on the Steam Engine*, London, 1827.
5. Smithsonian, The National Museum of History, Collections.
6. Editor, *Description of Centerfold-Illustrations*; Journal of the Oughtred Society, 5:1, March, 1996.
7. Wells, Francis and Wyman, Tom, *La Règle à Calcul: Lenoir, Gravet Lenoir and Tavernier- Gravet Slide Rules*, Journal of the Oughtred Society, 11:1, Spring, 2002.
8. Rees, Jane and Mark, *The Rule Book, Measuring for the Trades*, Astragal Press, Lakeville, Minnesota, USA, 2010.

Conclusion

Essentially James Watt took slide rules that were already in use and relieved/purged them of all the scales that he thought engineers did not need. His intention was a cheap but exact slide rule with a minimum of scales. However, later inventors again added scales or a second slide and gauge marks on the scales.

The same process happened later with the simple Mannheim slide rule. We find additional scales and gauge marks on the Rietz, the Darmstadt, and on the sophisticated slide rules after WWII. What might Watt have thought if he had seen slide rules especially designed for steam engines?

Acknowledgements

The author is grateful to Marc Thomas for the information on French slide rules and to Jane Rees for information on fabrication dates of the maker W. Ransley.