Why are tabular calculators almost forgotten?

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Abstract

The authors' earlier paper [1] described the development of Ready Reckoners. This paper surveys the development of tabular calculators which were used primarily for multiplication in commerce. Tabular calculators use Ready Reckoner style tables mounted on slides, disks, cylinders or rolls. The relatively disappointing story of most of them and the likely reasons for this are compared with the much more successful computing scales in which the tables are connected to a weighing device. These were very widely used especially in retail premises, for simultaneously weighing and pricing customers' purchases, and later included pioneering optical projection technology.

1 Introduction

The authors' earlier [1]described the development of Ready Reckoners. The current paper surveys the development of tabular calculators which were used primarily for multiplication in commerce. Tabular calculators use Ready Reckoner style tables mounted on slides, disks, cylinders or rolls.

Tabular calculators were used between about 1630 and the 1950s. They were intended to make it easier and quicker to identify the cell at the intersection of the required price and quantity, sometimes at the expense of having fewer cells. This appears to be a good idea. Many people must have thought so, since over 50 devices survive and 400 patents were granted from 1800 to the 1990s. However, tabular calculators had very limited success in terms of market penetration and hardly rate a footnote in the history of computing. In this paper we seek to quantify the level of success, and assess the relative importance of the factors that limited success. This task is somewhat impeded by the paucity of price, production, and sales data. But there is enough information available to provide some sensible answers to these questions. The argument is developed in this paper as follows

2 Tabular calculators were defined mainly by Patent Offices

3 There are four main classes of free standing tabular calculators

4 The Literature is sparse

5 Tabular calculators addressed the market for calculators in offices

6 Illustrations of real devices and the related patent drawings show how inventors addressed the KFBD

7 Price and Value for money

8 Computing scales flourished from the 1890's to the 1960's.

2 Tabular calculators were defined mainly by Patent Offices

2.1 GB Patent Office had an informal definition

The definition of the term tabular calculator is debatable, as it was rarely used by the makers, designers, or vendors. Author Williams first became interested in this class of device while compiling his complete listing of GB patents for calculating devices [2]when he noticed that many patents were classified by the GB Patent Office in the Abridgements as tabular calculators. A range of different devices were all classified as tabular calculators by the GB Patent Office. These included:

- 3703/1909 by Burt for a *Measuring rule to give area and volume of planks*,
- 14589/1910 by Champeix & Champeix for a *Multiplying apparatus, Cylinders for comparing the equivalents of weights, measures, or money in different systems*,
- 29574/1912 Clarke & Debenham for a *Multiplying a dividing apparatus* and
- 167,699 of 1920 by Darnley & Richards for a *Tabular calculator… two superimposed hollow cylindrical members.*

(Note that GB patents before 1919 are specified by a year and a number, as they started again at 1 each year) Thereafter the number series is continuous and the date is informative but not a necessary part of the reference.

2.2 US Patent Office had formal definition and classification

Further searches for similar US patents revealed the US Patent and Trademark Office had a more structured classification given at http://www.uspto.gov/web/patents/classification/uspc235/defs235.htm#C235S085000.
Tabular calculators are a sub class of Class 61:

61 CALCULATORS … *Subject matter comprising calculating-machines. In this group are classified machines for mechanically performing the various mathematical operations, usually those of addition or subtraction, frequently that of multiplication, and occasionally of division. These machines generally comprise registers and keys or equivalents for operating them, together with necessary auxiliary devices.*

85 Tabular *This subclass is indented under subclass 61. Calculators comprising a table showing results calculated from certain data so arranged that by properly manipulating the same any desired result is obtained.*

86 Belt *This subclass is indented under subclass 85. Tabular calculators having the tables placed upon belts which are movable back and forth, as desired.* (Referred to in this paper as Roll)

87 Cylinder *This subclass is indented under subclass 85. Tabular calculators having tables formed or placed upon cylinders.*

88 Disk *This subclass is indented under subclass 85. Tabular calculators having tables placed upon disks which rotate about their centers.*

89 Sheet *This subclass is indented under subclass 85. Tabular calculators having tables placed upon sheets, the sheets being attached to a frame either permanently or temporarily and a guiding-strip or the like being provided to used in connection with the sheets.* (Referred to in this paper as Slide)

177 *WEIGHING SCALES, subclasses 34+ for a tabular type computer combined with a weigher.*

The authors propose a working definition of a *tabular calculator* as follows: *a device incorporating pages from a ready reckoner or similar table, these pages or tables usually containing cells showing the product of two factors such as a price and a quantity.*

This definition deliberately includes both free-standing devices and computing scales where the device is connected to a weighing mechanism. It rules out a small class of devices known as slide cards. These devices consist of a card bearing tables of figures or logarithmic scales like slide rules, moving within a jacket of card or plastic having windows. They were cheaply made and often given away as promotional materials. Those with logarithmic scales are often regarded as a sub set of slide rules, and as such are discussed in the standard work on slide rules [3] and under the name of slide charts in [4]. These logarithmic slide cards are excluded because they do not contain a table with cells. Slide cards with price/quantity multiplication tables are included, but **not** similar cards containing tables of data for selecting wire or pipe sizes etc because they lack cells containing products.

3 There are four main classes of free standing tabular calculators

These classes are arbitrary and are illustrated in Figure 1.

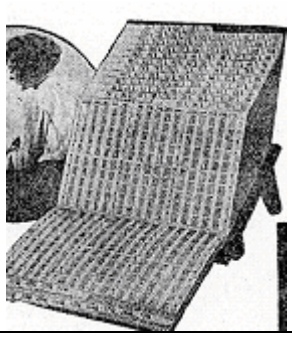
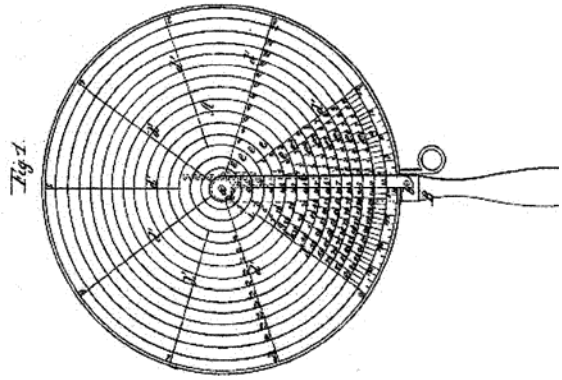
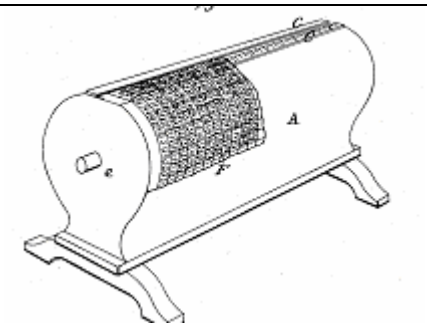
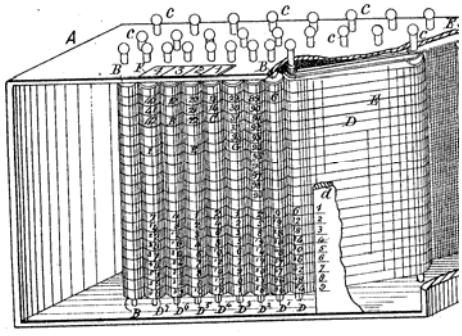
Type	Example	Thumbnail
1.Sliding Plate or sheet Simple slides were often just a set of cards for different interest or tax rates in slides, grooved boxes and the like	Meilicke [5] Card-Index type Several hundred sheets possible	
2. Disk. Usually about 15 25 cm diameter Single or double sided and Radial cursor	Smith's pricing device US Patent 87111 of 1857 Limited number of prices	
3**.Cylinder**- Single Diameter 5- 25 cm, length 20-40cm. Could be vertical or horizontal axis. Usually paper or parchment table on wood or metal drum	Petty's multiplication device US Patent 221186 of 1879 Typical of many later single cylinder examples, See Meilicke below. .	
4. **Roll or belt** The roll itself could be 80cm wide by 250 cm long Not very practical, unwieldy, perishable materials: linen and paper based	Charpantier of New Orleans. GB Patent 7976 of 1886 27 cylinders, to multiply two 9-digit numbers. Later devices usually less than ten cylinders. See Robertson below.	

Figure 1 Characteristics of the Main Free-standing Classes.

4 The Literature is sparse

Despite the level of Patent Office interest, the literature is sparse. Tabular Calculators are briefly discussed in the Napier Tercentenary Volume [3] and in d'Ocagne [4] but the latter dismisses them in favour of his own hobby horse, Nomograms, a graphical technique for solving some types of equations. Turck [5] in his 1921 article on the origin of modern calculating machines ignores them. He was a designer for Comptometer and a disciple of Dorr E Felt, its inventor. Walter Dyck in his 1892 Catalogue [6] does not mention them but he was mainly interested in academic instruments.

Lipka's splendid book on Graphical and Mechanical computation of 1918, [7], does not mention them: He was an M I T Professor, also interested in nomograms. Finally, there is no mention at all in the standard works by Martin, [8], Cortada, [9], Campbell-Kelly and Aspray, [10], Marguin, [11] or Brabandere [12].

However, despite this low level of relevant literature, we have enough data from the surviving devices, patents, trade literature and advertisements in the Trade Press to provide a detailed analysis in following sections.

5 Tabular calculators addressed the market for calculators in offices

In the nineteenth and twentieth centuries business people needed computing aids capable of multiplying for working out invoices, interest, taxes, wages, and general multiplication.

5.1 This was a very competitive market with powerful players

Tabular calculators had to compete with a range of devices capable of multiplication. These included mechanical adders, since many, such as the Comptometer, were capable of multiplication by repeat addition; long-scale slide rules and mechanical multipliers.

5.2 There was a steady growth of tabular calculator patent activity up to 1919, followed by decline

The authors have assembled a data base containing both patent and other information on about 400 tabular calculators. However, the production dates of most of these devices are not reliably known. Historians of technology are wary about using patent data for time trend analysis for two reasons. First, patents may never be exploited, and second, exploitation may be some years after the grant of the patent. In this case we have a great deal of patent information and little on actual year of manufacture. The problem of making use of the patent data is addressed here as follows. In analysing the data base we have used as the date for each device the higher of the date made or the date patented, coded as Year MAX.

The complete data base in Excel can be accessed on the Johnson's web site //www.dcs.bbk.ac.uk/~rgj.

Each device in our data base is, by definition, either:

1. Patent identified and known to have been made but not necessarily when
2. Patent identified but no evidence of manufacture
3. Device known to have been made but no patent identified.

The percentage of items made to items patented is erratic in the early years. But from 1849 to 1969, shaded in the table, it is always between 0% and 28.6%, with a mean of 13.9%. From the beginning to 1999, the mean was 13.4%, shown in the bottom row. We take this to mean that *the number made is a reasonably constant percentage of number of patents and thus that the number of devices patented* would be a reasonable indicator of the number of devices made and would show that activity grew steadily from 1849 to 1929 and thereafter went into decline.

Decade to	Total Devices Known	Total No. of Patents Found	Devices Both Patented and Made	Devices Made but no Patent found	Patent found but no device known	%age Made to Patented
Up to 1849	7	3	2	5	1	233.3%
1859	1	5	1	0	4	20.0%
1869	3	12	2	1	10	25.0%
1879	4	18	3	1	15	22.2%
1889	6	31	5	1	26	19.4%
1899	2	40	1	1	39	5.0%
1909	6	70	5	1	65	8.6%
1919	8	70	8	0	62	11.4%
1929	6	68	6	0	62	8.8%
1939	2	15	1	1	14	13.3%
1949	1	21	1	0	20	4.8%
1959	0	7	0	0	7	0.0%
1969	2	7	2	0	5	28.6%
1979	4	3	2	2	1	133.3%
1989	0	0	0	0	0	na
1999	0	0	0	0	0	na
SUM decades	52	370	39	13	331	14.1%

Figure 2 Tabular Calculator Patents 1849-1999

5.3 Cylinders were the most common type and multiplication the most common usage.

The bottom line of Figure 3 shows the numbers for the whole period of the data base. In order of number of entries; the order for types is Cylinders 176, Slides 79, Discs 68, Rolls 60 and the order or usage is Multiplication 170, Interest 79, Pricing 58, Wages 57 and Conversion 19.

	TYPES					USAGES					
DECADE to	CYL	DIS	ROL	SLI	Tot Types	INT	MUL	PRI	CON	WAG	Tot Usages
Up to 1849	3	5	0	0	8	6	2	0	0	0	8
1859	2	1	1	1	5	1	2	1	0	1	5
1869	5	4	2	2	13	4	4	2	1	2	13
1879	10	3	5	1	19	5	8	3	0	3	19
1889	6	8	11	7	32	14	8	4	2	4	32
1899	13	10	5	13	41	10	20	5	1	5	41
1909	36	11	8	16	71	13	29	12	0	17	71
1919	35	8	16	11	70	15	32	9	2	12	70
1929	32	11	7	18	68	8	31	14	7	8	68
1939	8	3	2	3	16	1	11	4	0	0	16
1949	13	2	3	3	21	1	12	3	1	4	21
1959	6	0	0	1	7	0	6	0	0	1	7
1969	5	1	0	1	7	0	3	1	3	0	7
1979	2	1	0	2	5	1	2	0	2	0	5
1989	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0
SUM decades	176	68	60	79	383	79	170	58	19	57	383

Figure 3 Free-standing Devices by Type and Usage (Items per decade)

5.4. GB tabular calculator patents were 14 percent of all GB calculating device patents, and comparable with slide rules and mechanical multipliers.

Tabular calculator patents were 14 percent of all calculating device patents, and were in total, almost as many as for all types of mechanical multipliers such as pin wheel and stepped drum, sold under brand names such as Odhner, Brunsviga and Facit.

5.5 Slide rules and mechanical multipliers sold in considerable quantity.

Since we have no direct evidence of the sales or production of any tabular calculator we are forced to suggest that given the similar levels of patent activity, they could have had comparable levels of production to long scale slide rules and mechanical multipliers data for these is available, but we do not claim that tabular calculator volumes were in fact anything like of the same order, because of the few surviving devices, and the low level of trade interest.

The Thacher split-scale slide rule was very successful, and its production volumes in thousands have been described in [13] which includes Figure 4.

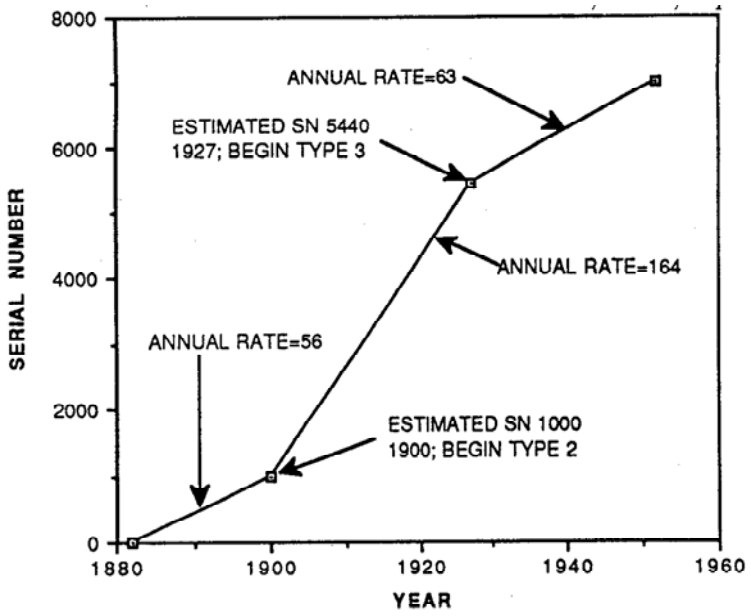


Figure 4 Thacher Cumulative Production

Fuller helical slide rule production was similarly impressive in thousands of units, as Feely and Schure wrote in [14] which included Figure 5.

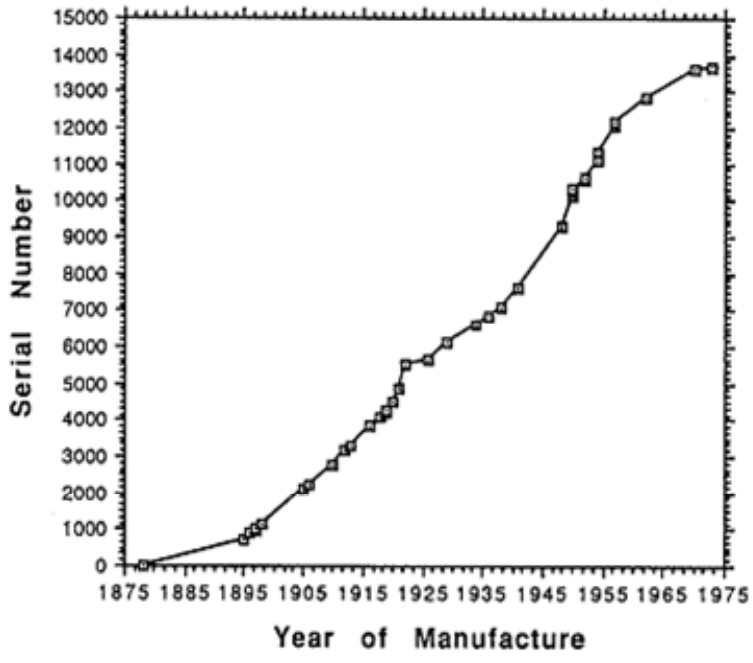


Figure 5 Fuller Cumulative Manufacture

Brunsviga mechanical multiplying machines sold in tens of thousands, being mass produced and well promoted, as detailed by Faulstich, [18]. An English summary of the main article, which is written in German, is: "*Production numbers are given for each of the six decades from 1892 to 1952, totalling c.270,000 machines. There is an interesting internal 1948 paper, listing all the models of which more than 100 were built. In the early series, model B ranks first with 27,000 machines; the Nova series' top selling machine was the model 13 with 35,000 machines (observe that these data only comprise the years from 1892 to 1947). These relatively large production figures made the trade mark Brunsviga known throughout the world. Brunsviga took up advertising simultaneously with calculating machine production. Already in 1893 a Brunsviga machine was on exhibit in the Chicago Exposition. Successful sales depended except from mass production - on marketing, consulting, and customer services. All three were thoroughly planned; especially customer service went hand in hand with guarantees of different levels of service. Advertising was only done in newspapers and journals, but both for the specialist and the general public. This is shown best by a survey of publications; local newspapers, entertaining periodicals and specialised journals were addressed. A 1911 advertisement in the "Gartenlaube" (a then widely read family journal) described the Brunsviga as the most wide-spread calculating machine. A flier for the German Army, Navy and Colonial Forces Exhibition in 1907 stated: "Brunsviga - our daily bread, and thus indispensable".*

5.6 There were four principle quantifiable Key Factors in the Buying Decision KFBD in this market

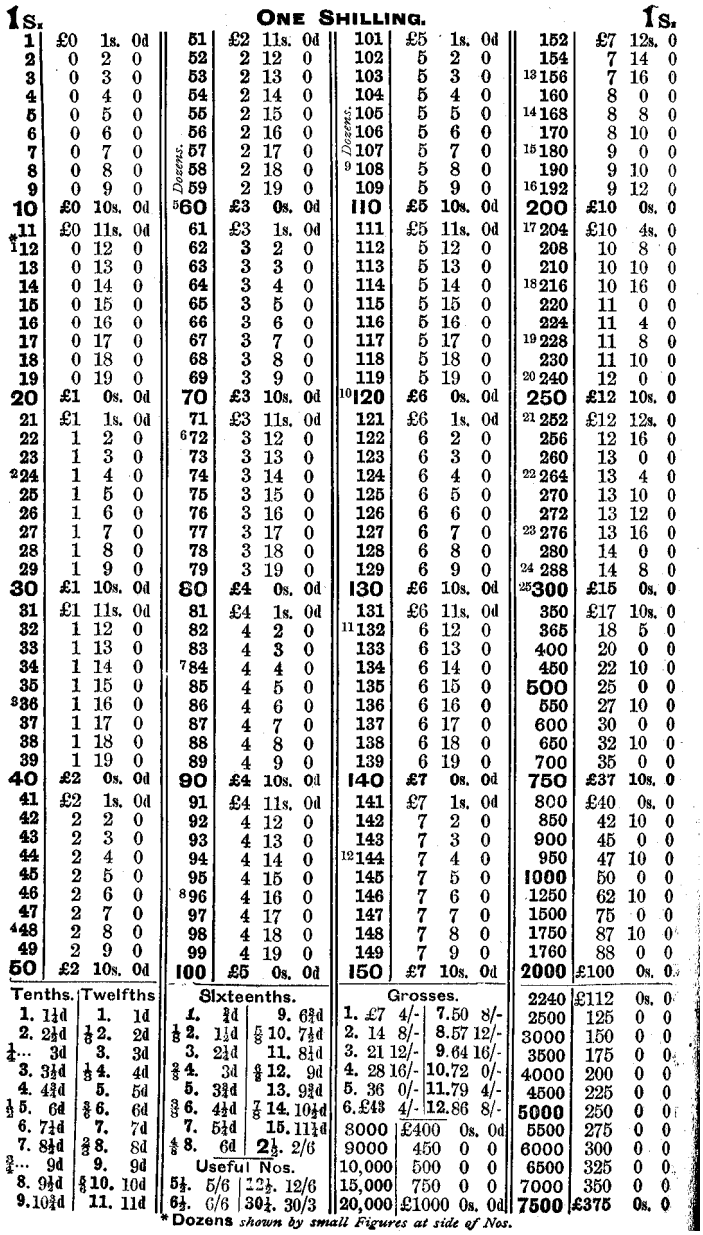
Some business strategists use the concept of KFBD to help them design and market their products. KFBD include the characteristics, capabilities, price and market surround, such as advertising and brand name, distribution and service.

5.6.1 Cell count quantifies the capacity of reckoner type devices

In our previous article on Ready Reckoners, [1], we sought to relate price to usefulness, and we wrote:

> *"The number of calculations in the Reckoner seemed a likely measure, and indeed publishers emphasized this measure. For example, the cover of Chadwick's 420 page Weight and Number Calculator, [15], published by Crosby, Lockwood states it contains "250,000 direct calculations producing by a single addition to each a combination of over 20 million calculations!"*

The typical pocket Ready Reckoner, e.g Ward Lock Pocket Ready Reckoner no date ca. 1900 had 100 pages and each page had 5 columns and 34 rows, giving 170 cells per page and 17,000 cells in the book. A typical desk top Ready Reckoner, *The Ideal Office Reckoner,* published by Gall and Inglis ca. 1900 had 500 pages, each of 50 rows by 4 columns, giving 2,000 cells per page and 100,000 cells in the book, see Figure 6. Another Gall & Inglis publication was the *Ideal Ready Reckoner Six Complete Reckoners in One,* claiming 300,000 calculations by pennies right up to £3, by ½d to 5s, by ¼d to 2s 6d. This cost 3s 6d in 1915.



ONE SHILLING.

1s.													1s.
1	£0	1s.	0d	51	£2	11s.	0d	101	£5	1s.	0d	152	£7 12s. 0
2	0	2	0	52	2	12	0	102	5	2	0	154	7 14 0
3	0	3	0	53	2	13	0	103	5	3	0	13 156	7 16 0
4	0	4	0	54	2	14	0	104	5	4	0	160	8 0 0
5	0	5	0	55	2	15	0	Dozens. 105	5	5	0	14 168	8 8 0
6	0	6	0	56	2	16	0	106	5	6	0	170	8 10 0
7	0	7	0	Dozens. 57	2	17	0	9 107	5	7	0	15 180	9 0 0
8	0	8	0	58	2	18	0	108	5	8	0	190	9 10 0
9	0	9	0	59	2	19	0	109	5	9	0	16 192	9 12 0
10	£0	10s.	0d	5 60	£3	0s.	0d	110	£5	10s.	0d	200	£10 0s. 0
11	£0	11s.	0d	61	£3	1s.	0d	111	£5	11s.	0d	17 204	£10 4s. 0
1 12	0	12	0	62	3	2	0	112	5	12	0	208	10 8 0
13	0	13	0	63	3	3	0	113	5	13	0	210	10 10 0
14	0	14	0	64	3	4	0	114	5	14	0	18 216	10 16 0
15	0	15	0	65	3	5	0	115	5	15	0	220	11 0 0
16	0	16	0	66	3	6	0	116	5	16	0	224	11 4 0
17	0	17	0	67	3	7	0	117	5	17	0	19 228	11 8 0
18	0	18	0	68	3	8	0	118	5	18	0	230	11 10 0
19	0	19	0	69	3	9	0	119	5	19	0	20 240	12 0 0
20	£1	0s.	0d	70	£3	10s.	0d	10 120	£6	0s.	0d	250	£12 10s. 0
21	£1	1s.	0d	71	£3	11s.	0d	121	£6	1s.	0d	21 252	£12 12s. 0
22	1	2	0	6 72	3	12	0	122	6	2	0	256	12 16 0
23	1	3	0	73	3	13	0	123	6	3	0	260	13 0 0
2 24	1	4	0	74	3	14	0	124	6	4	0	22 264	13 4 0
25	1	5	0	75	3	15	0	125	6	5	0	270	13 10 0
26	1	6	0	76	3	16	0	126	6	6	0	272	13 12 0
27	1	7	0	77	3	17	0	127	6	7	0	23 276	13 16 0
28	1	8	0	78	3	18	0	128	6	8	0	280	14 0 0
29	1	9	0	79	3	19	0	129	6	9	0	24 288	14 8 0
30	£1	10s.	0d	80	£4	0s.	0d	130	£6	10s.	0d	25 300	£15 0s. 0
31	£1	11s.	0d	81	£4	1s.	0d	131	£6	11s.	0d	350	£17 10s. 0
32	1	12	0	82	4	2	0	11 132	6	12	0	365	18 5 0
33	1	13	0	83	4	3	0	133	6	13	0	400	20 0 0
34	1	14	0	7 84	4	4	0	134	6	14	0	450	22 10 0
35	1	15	0	85	4	5	0	135	6	15	0	500	25 0 0
3 36	1	16	0	86	4	6	0	136	6	16	0	550	27 10 0
37	1	17	0	87	4	7	0	137	6	17	0	600	30 0 0
38	1	18	0	88	4	8	0	138	6	18	0	650	32 10 0
39	1	19	0	89	4	9	0	139	6	19	0	700	35 0 0
40	£2	0s.	0d	90	£4	10s.	0d	140	£7	0s.	0d	750	£37 10s. 0
41	£2	1s.	0d	91	£4	11s.	0d	141	£7	1s.	0d	800	£40 0s. 0
42	2	2	0	92	4	12	0	142	7	2	0	850	42 10 0
43	2	3	0	93	4	13	0	143	7	3	0	900	45 0 0
44	2	4	0	94	4	14	0	12 144	7	4	0	950	47 10 0
45	2	5	0	95	4	15	0	145	7	5	0	1000	50 0 0
46	2	6	0	8 96	4	16	0	146	7	6	0	1250	62 10 0
47	2	7	0	97	4	17	0	147	7	7	0	1500	75 0 0
4 48	2	8	0	98	4	18	0	148	7	8	0	1750	87 10 0
49	2	9	0	99	4	19	0	149	7	9	0	1760	88 0 0
50	£2	10s.	0d	100	£5	0s.	0d	150	£7	10s.	0d	2000	£100 0s. 0

Tenths.	Twelfths
1. 1½d	1. 1d
2. 2½d	⅛ 2. 2d
¼... 3d	3. 3d
3. 3½d	⅓ 4. 4d
4. 4⅔d	5. 5d
½ 5. 6d	⅝ 6. 6d
6. 7½d	7. 7d
7. 8½d	⅔ 8. 8d
¾... 9d	9. 9d
8. 9½d	⅚ 10. 10d
9. 10½d	11. 11d

Sixteenths.	
1. ¾d	9. 6¾d
⅛ 2. 1½d	⅝ 10. 7½d
3. 2¼d	11. 8¼d
⅜ 4. 3d	⅞ 12. 9d
5. 3¾d	13. 9¾d
3/8 6. 4½d	⅞ 14. 10½d
7. 5¼d	15. 11¼d
½ 8. 6d	2½. 2/6

Useful Nos.	
5½. 5/6	22½. 12/6
6½. 6/6	30½. 30/3

Grosses.	
1. £7 4/-	7.50 8/-
2. 14 8/-	8.57 12/-
3. 21 12/-	9.64 16/-
4. 28 16/-	10.72 0/-
5. 36 0/-	11.79 4/-
6. £43 4/-	12.86 8/-

8000	£400	0s.	0d
9000	450	0	0
10,000	500	0	0
15,000	750	0	0
20,000	£1000	0s.	0d

2240	£112	0s.	0
2500	125	0	0
3000	150	0	0
3500	175	0	0
4000	200	0	0
4500	225	0	0
5000	250	0	0
5500	275	0	0
6000	300	0	0
6500	325	0	0
7000	350	0	0
7500	£375	0s.	0

*Dozens *shown by small Figures at side of Nos.*

Figure 6 Page from Gall & Inglis "Ideal Office Reckoner" ca 1900

From BOBW Collection

The corresponding metric for tabular calculators is the cell count, readily quantified as the number of rows times columns or the number of rings times segments for discs.

5.6.2 Accuracy is indicated by number of significant figures

A common measure of accuracy for machines and slide rules is the number of significant figures in the result Slide rules could only give four or five. Machines gave up to 12. Ready Reckoners and tabular calculators could give one old penny in a thousand pounds, which is 1 in 240,000, or 6 significant figures.

5.6.3 Range of usages and measure systems is relevant in the buying decision

The four main usages for this kind of multiplying device were Multiplication, Interest, Pricing, Wages and Conversion. Customers presumably wanted a versatile device, or a specialised device designed for pricing or wages. Buyers in sterling areas needed non-decimal capability, as did buyers in decimal currency countries when calculating with measures of time for interest and wages. We shall use non decimal capability as an important factor when comparing tabular calculators with other devices

5.6.4 User friendliness can be estimated by ranking on a number of factors

These include:

- Portability - rated as pocket=4, laptop=3, desktop =1
- Ease of use includes finding required results quickly, measured as calculation time in seconds and ready change of rolls, discs, or cylinders when needed. We can also estimate days to learn how to become proficient in the use of the device.
- Material - this may be regarded as an indicator of durability and scored as 4 for metal, 3 for plastic, 2 for celluloid on wood, 1 for plain wood and 0 for cardboard.

5.7 There are two kinds of qualitative key factors - reputation and awareness

5.7.1 Reputation and awareness can be roughly assessed

There was no well known "brand" of tabular calculator to compare with the big names such as Felt & Tarrant (Comptometer), Burroughs (Adding machines), Odhner and Brunsviga (Multiplying machines).

5.7.2 Price data are scarce but Value for Money estimates are just possible.

We list the price data available in section 7 and endeavour to evaluate value for money later.

6 Illustrations of real devices and the related patent drawings show how inventors addressed the KFBD

The following sections are by type in the order Discs, Cylinders, Rolls and within type in date order.

Readers will note that since there is a minimal size cell that can take a readable result, inventors of tabular calculators tried to increase the space available, by increasing the size of the device, or incorporating more than one disc, roll, cylinder, or slide in the device. Inevitably they had to make trade offs between the various KFBD, and as we shall see, with little success.

6.1 Discs had 500-3,650 cells per disc and were mainly used for interest calculations.

The highest number of cells found on a single disc was 3650 for the 1883 Jenne, see Figure 7. The highest number for a multi-disc device was 12,000 for the 1863 Maurand. The latest known product by Brimfield in 1923 had only 800 cells. This demonstrates that for purely geometric reasons the disc form had limited potential.

Maker designer	Date	Discs	Rings	Segments	Cells/disc	Total cells
Boisseau	1637	1	37	37	1369	1369
Schwenter	1651	1	14	37	518	518
Jelleff	1815	1	20	42	840	840
Riley	1839	1	20	40	800	800
Newham	1845	1	32	13	416	416
Maurand	1863	70	10	40	400	28000
Jenne	1883	1	10	365	3650	3650
Brimfield	1923	1	25	32	800	800

Figure 7 Listing of Discs

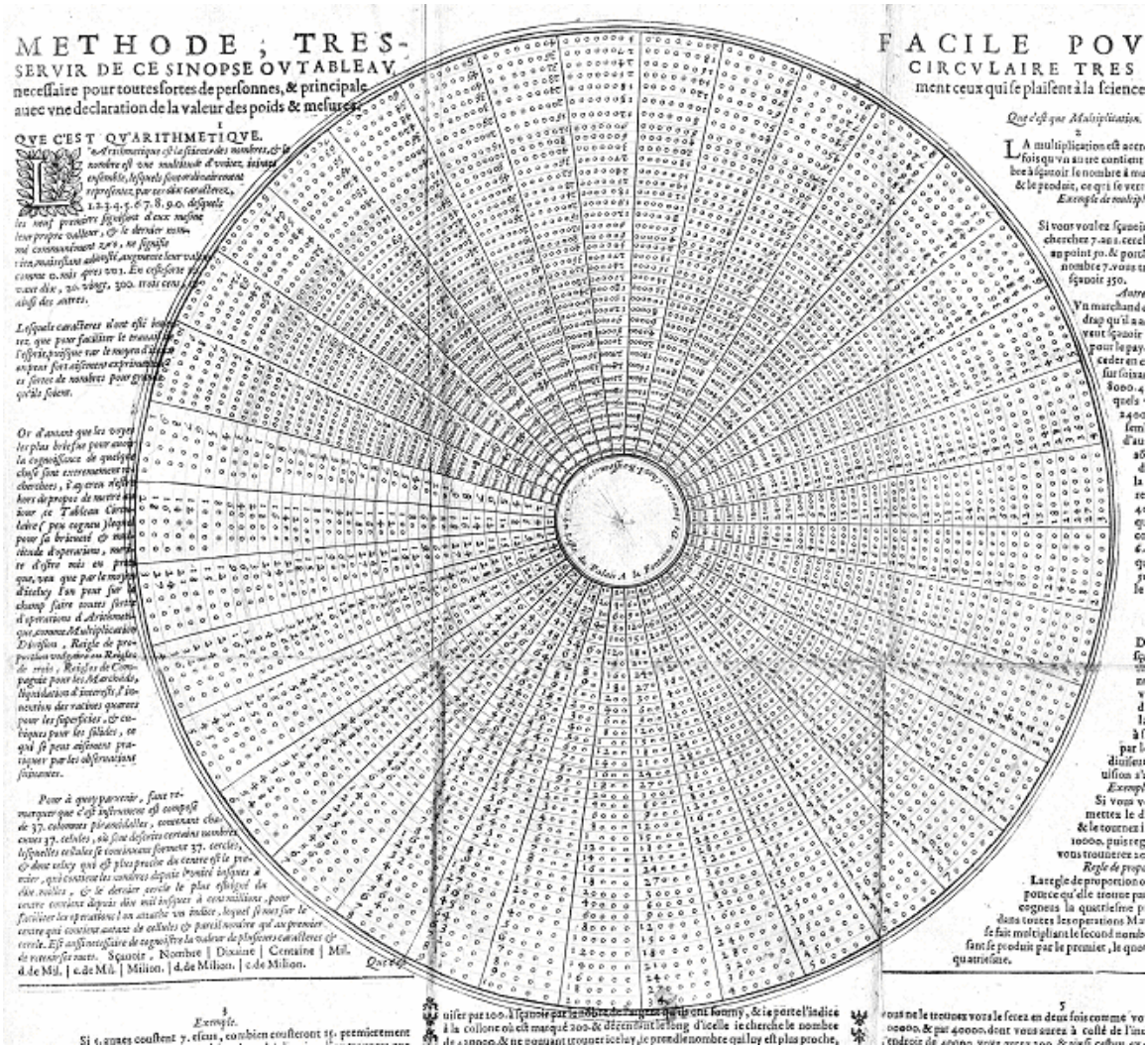
Figure 8 shows in the bottom row that, excluding the general usage of multiplication, discs were used mainly for Interest calculations with 20 out of 68 data base items while 8 were used for wages and only 6 each for pricing and conversions.

Decade to	INT	MUL	PRI	CON	WAG	TOT
1849	4	1	0	0	0	5
1859	0	0	1	0	0	1
1869	1	1	1	1	0	4
1879	2	0	1	0	0	3
1889	6	0	0	0	2	8
1899	2	4	1	0	3	10
1909	4	7	0	0	0	11
1919	0	5	0	0	3	8
1929	0	8	1	2	0	11
1939	1	1	1	0	0	3
1949	0	1	0	1	0	2
1959	0	0	0	0	0	0
1969	0	0	0	1	0	1
1979	0	0	0	1	0	1
1989	0	0	0	0	0	0
1999	0	0	0	0	0	0
ALL	20	28	6	6	8	68

Figure 8 Usage of discs by decade.

6.1.1 1637 Boisseau Radial arm disc calculator 1369 cells

Figure 9 comes from a book of 1637 by Boisseau [16]. Jean Boisseau was a French geographer and genealogist who was known as Enlumineur du Roi. This is a multiplication table in the form of a large circular volvelle (missing the movable pointer). The device consists of 37 concentric circles containing multiples of numbers found in the innermost circle. To multiply, one found the number (or one of its components, as after 10, only multiplies of 10, 100, or 1000 are shown) in the innermost circle, then moved the pointer (which evidently had the same markings as the sector with the multiples of 1 inscribed in it) to that sector. The product could be found by inspecting the value in the outer circle



corresponding to the multiplier (or one of its components).

Figure 9 Boisseau Calculator

6.1.2 1651 Schwenter 518 cells

The calculator in Figure 10 comes from Daniel Schwenter's book of 1651, [17]. The example in the British Library still retains the rotating arm used to read off the correct result.

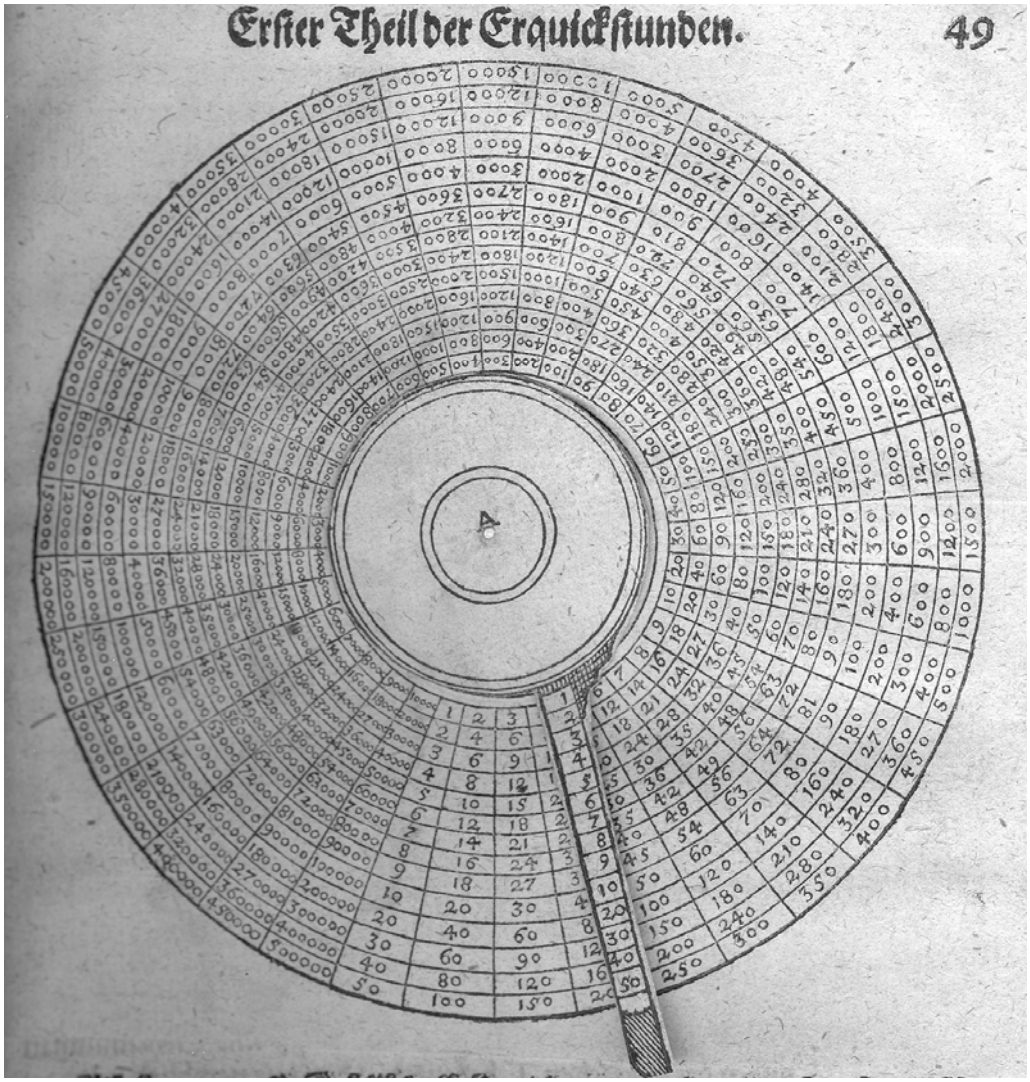


Figure 10 Schwenter calculator

6.1.3 Circa 1815 Jelleff's Patent Revolving Interest Table 840 cells

Jelleff's device is the earliest "modern" tabular calculator, noted in the literature by Karpinski [18]who recorded it as being in his collection in 1940. It is inscribed *Middlebury, VT Printed by T C Strong for L Walker & Co, Proprietor of*

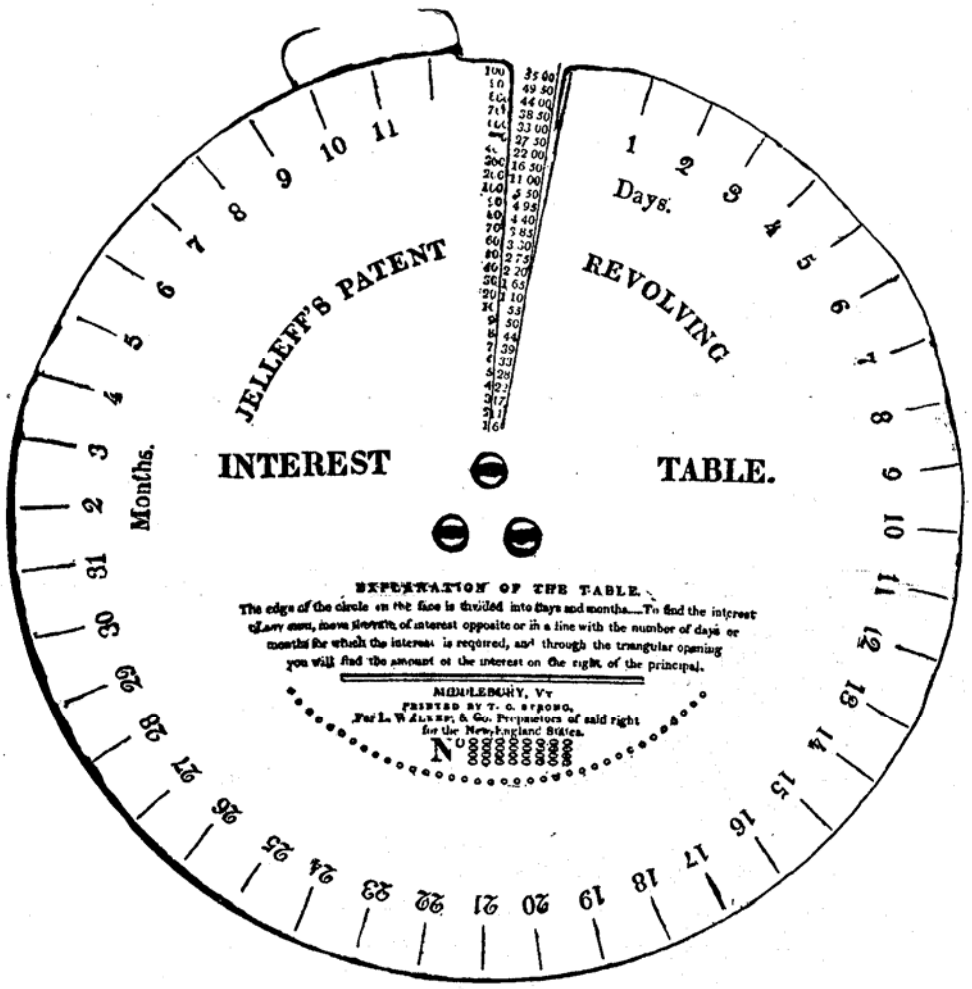


FIG. 275. *Jelleff's Patent Revolving Interest Table* (*c.* 1815), the table being set for interest at 5½ per cent on $1 to $1,000 for complete years

said right for the New England States. We have not traced the alleged patent.

Figure 11 Jelleff's revolving table from Kapinski's book

6.1.4 1839 Riley Another early surviving Disc Calculator: 800 cells

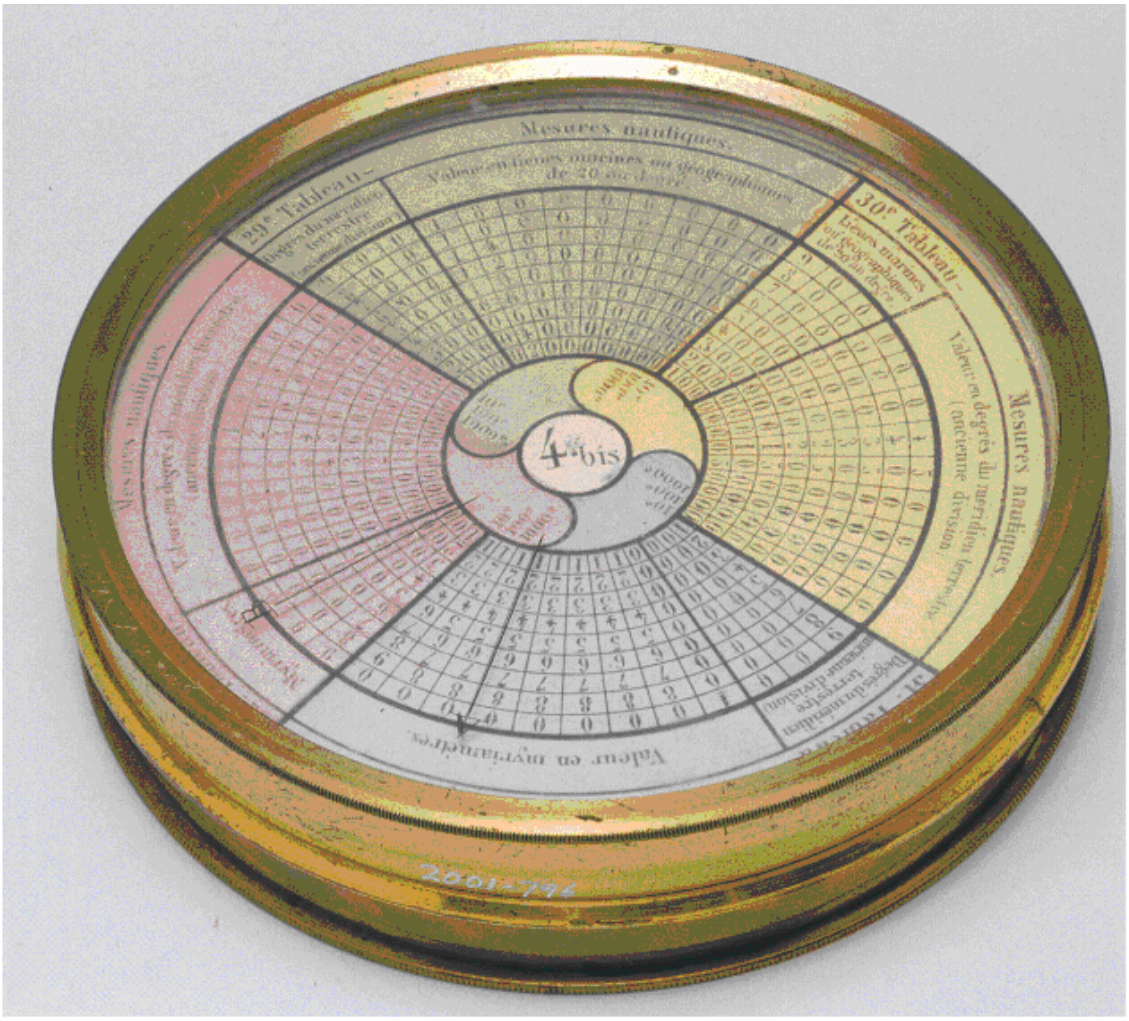
Riley's calculator is shown in Figure 12. It is described in Stirling [19]] as follows:

> *"By C.M. Riley; published in Cincinnati, c.1839. It is made of card, with a thin metal split-pin to hold the discs together. This particular example is inscribed with the owner's name and town, the date 1839 and the information that it cost him $1to buy. Interest obviously has many variable factors in its calculation, but the basic maths are not all that complex. The Patent Revolving Interest Table cleverly uses two printed discs, one on top of the other. The upper one has a cut-out section, and by turning the lower one to the required time period and reading down the table of values, the interest on a particular sum could be calculated."*

Figure 12 Riley Interest Table 1839

6.1.5 1863 Maurand multiple disc device 28,000 cells

Maurand's device was much more sophisticated as shown in Figure 13. It contained 35 double-sided discs in a glass topped brass box for a range of conversions of measures and money. By using multiple discs Maurand achieved a precision of up to 6 significant figures, similar to the roughly contemporary Thomas de Colmar mechanical Arithmometer, despite the usual limited capacity of each individual disc. Figure 14 illustrates how the device was used to carry out calculations. The illustration shows part of Plate No. 30, specifically Table No. 234.which is for calculating interest based on a sum of 100 Fr at a rate of 10 Fr per year (or 10% per year) based on "l'année commerciale" or commercial year of 360 days



Courtesy of Science Museum, London

Figure 13 Maurand Disc Calculator 1863

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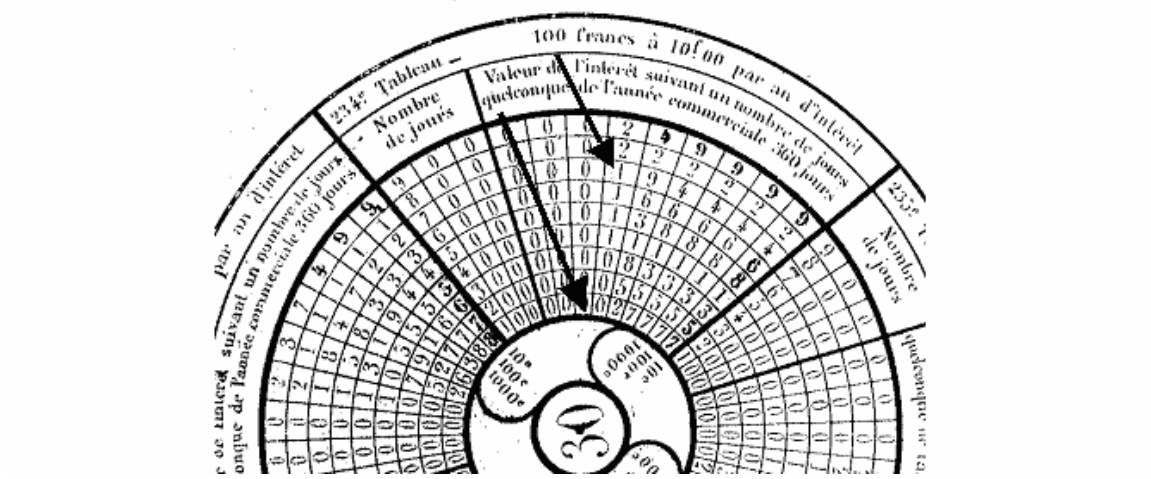
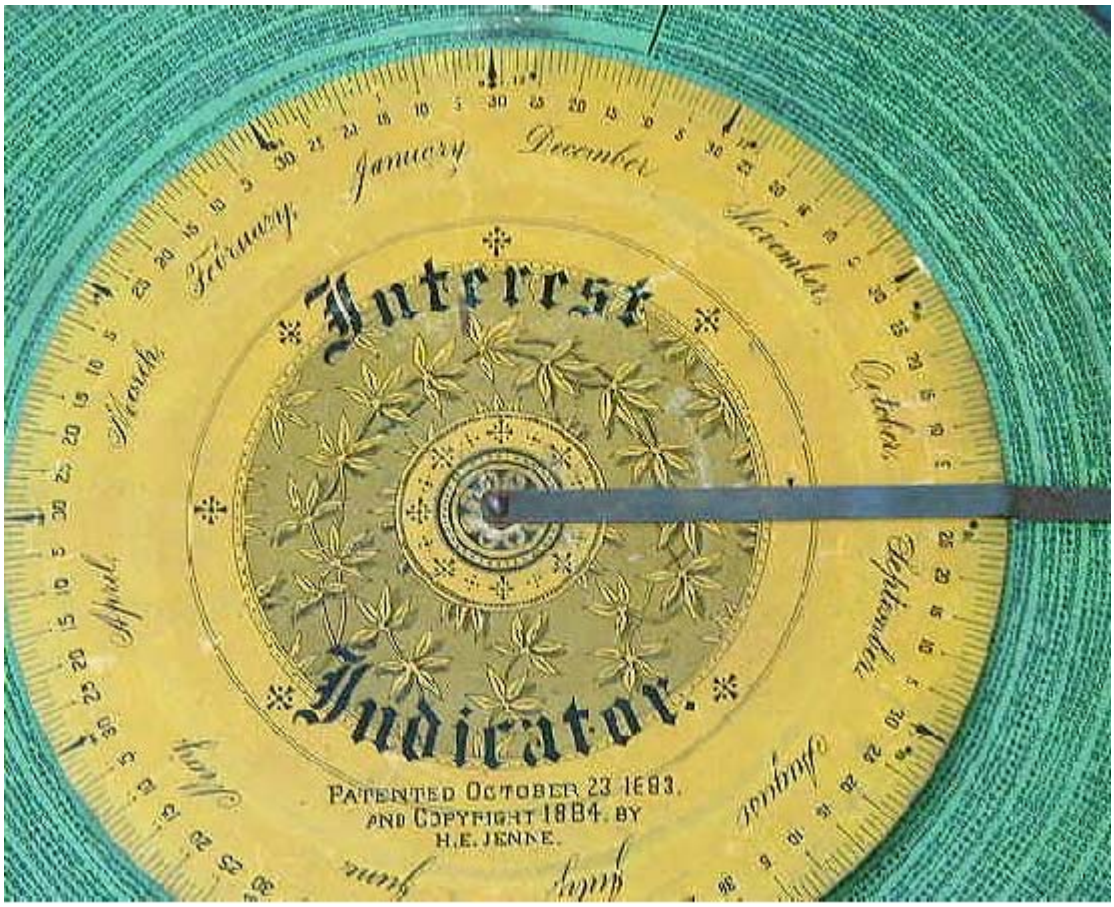


Figure 14 Maurand Plate 30, detail

6.1.6 1883 Jenne Disc 3650 cells

This is illustrated in Figure 15 and the corresponding patent shown in Figure 16.



Offered on eBay

Figure 15 Jenne Disc of 1883

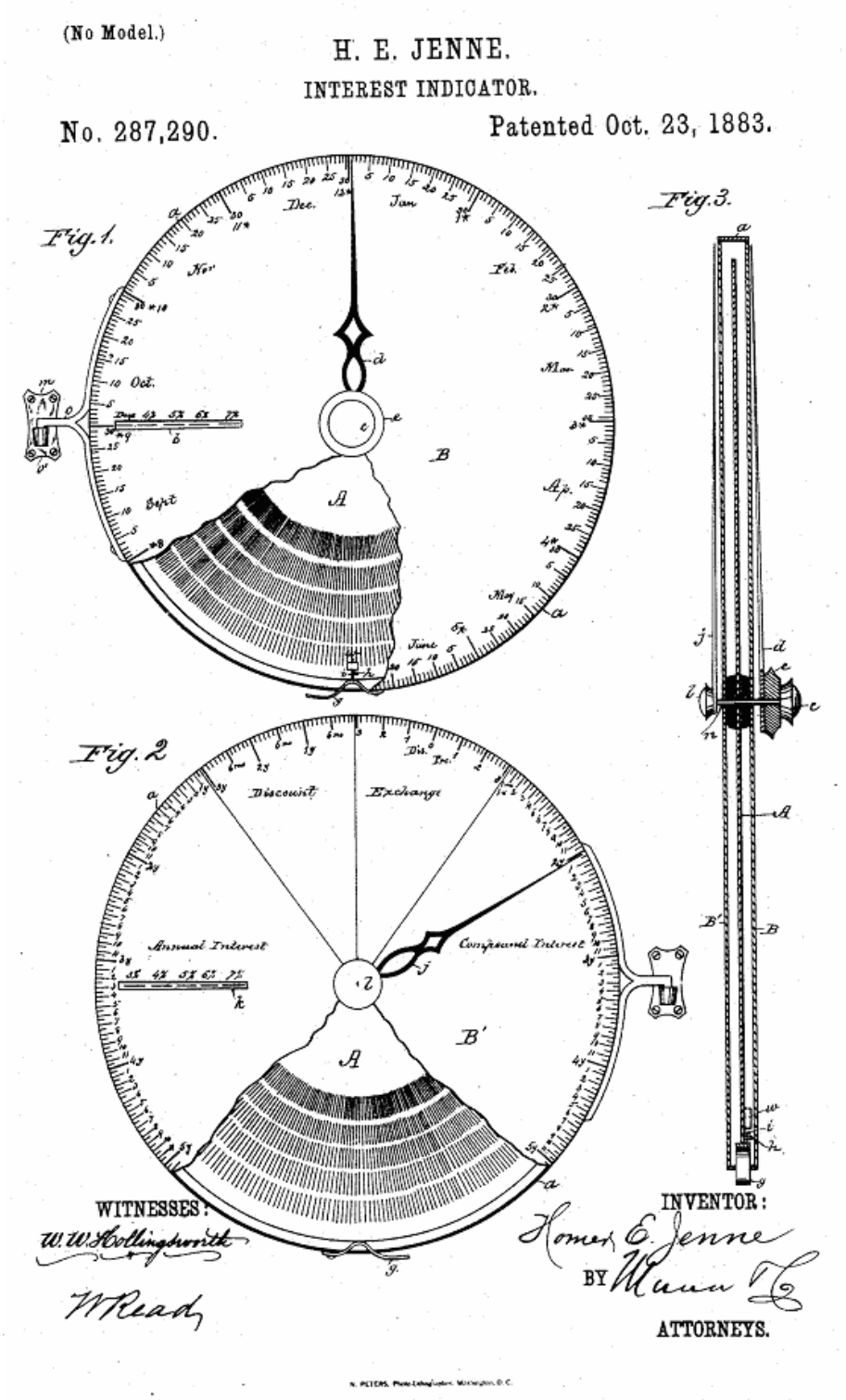
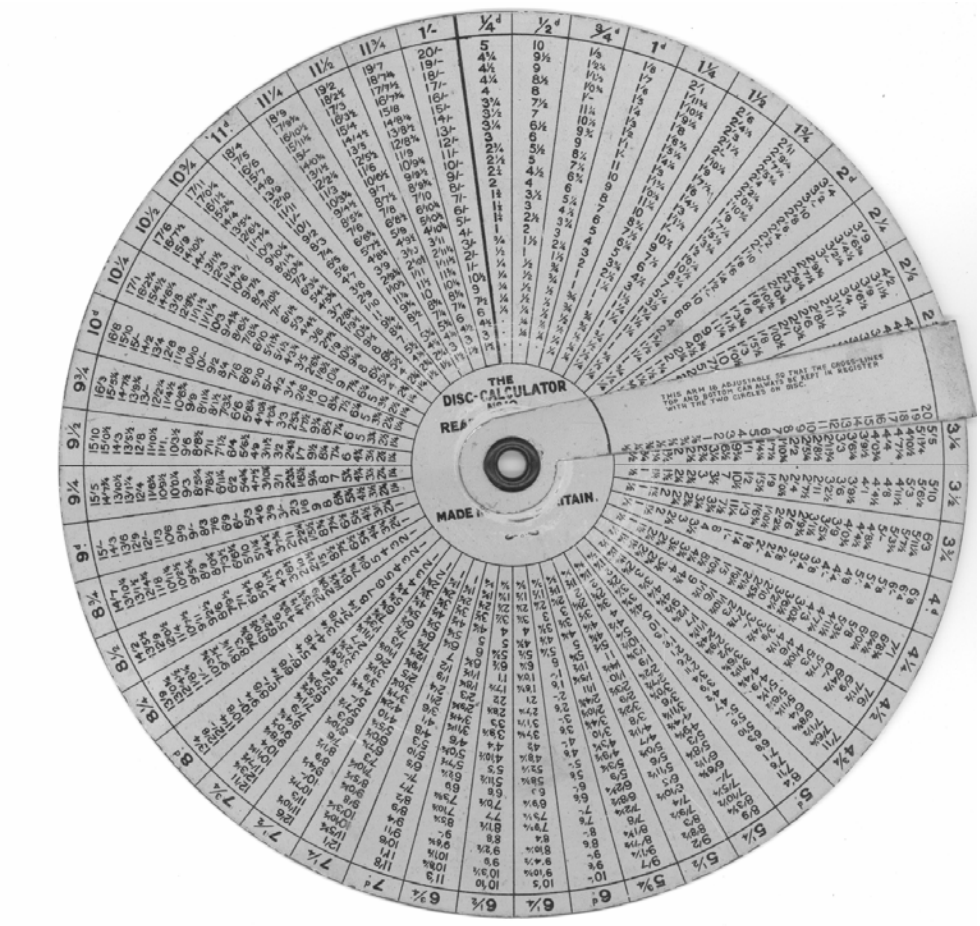


Figure 16 Jenne US patent

6.1.7 1923 Brimfield two-sided disc 960 cells

This came with a slip cover with instructions; the reverse of the slip cover reads:
"*Daintex Multiplies Comfort and Divides Labour and Expense*" so presumably it was a promotional give away. This device was dated by its match with the 1923 patent.



BOBWCollection

Figure 17 Brimfield Device

6.2 Cylinders 396 -2555 cells

The largest number of cells on a known single cylinder was 2555 on the Meilicke of 1906, see Figure 18.

Cylinders	Date	Device name	Cylinders	Rows	Columns	Cells/cylinder	Total cells
Baranowski	1851		5	14	21	294	1470
Peale	1865		1	15	30	450	450
Chambon & Baye	1880	Tachylemme	4	9	11	99	396
Meilicke	1906		1	365	7	2555	2555
Voss	1914		1	40	20	800	800

Figure 18 List of cylinder devices illustrated

Figure 19 bottom row shows that the order for usage was multiplication 75 items, Interest 33, wages 32.and prices 28.

Decade to	INT	MUL	PRI	CON	WAG	TOT
1849	2	1	0	0	0	3
1859	0	2	0	0	0	2
1869	1	2	0	0	2	5
1879	3	3	2	0	2	10
1889	1	0	2	1	2	6
1899	6	6	0	1	0	13
1909	5	12	7	0	12	36
1919	8	15	6	2	4	35
1929	5	11	7	2	7	32
1939	0	7	1	0	0	8
1949	1	8	2	0	2	13
1959	0	5	0	0	1	6
1969	0	3	1	1	0	5
1979	1	0	0	1	0	2
1989	0	0	0	0	0	0
1999	0	0	0	0	0	0
ALL	33	75	28	8	32	176

Figure 19 Cylinder usage by decade

6.2.1 1851 Baranowski Cylinder for Wages and Freight 470 cells

Figure 20 shows a picture of the Baranowski device from the catalogue of the Great Exhibition of 1851.

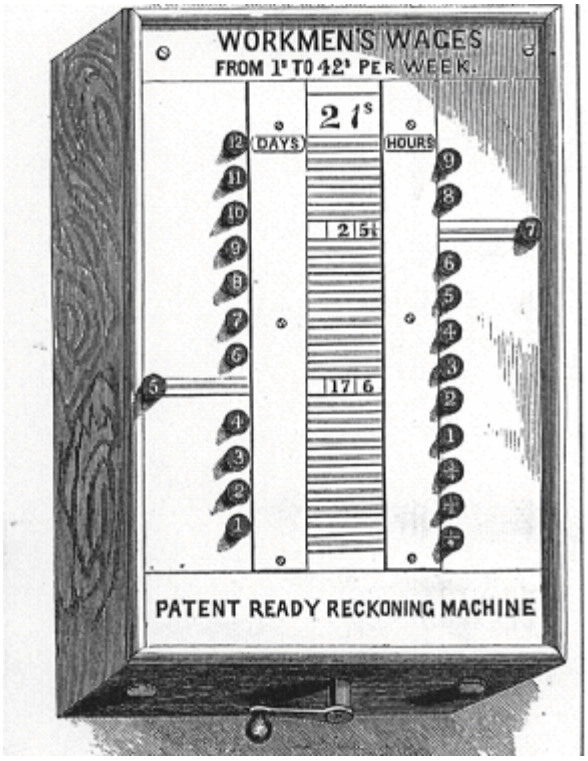


Figure 20 Baranowski device

There are some notes in *Inventions mécaniques et travaux littéraires de J. J. Baranowski, etc*. from which the following are translated:

> *Tax Machines: A very important machine that has won the inventor several medals, in particular the great one of 1847. He made a special machine for the Minister of Public Works to "control" the tariffs of all the French*

Railways. The machine has been exploited widely in France and England for calculating wages. One hundred machines were supplied to the various gold, copper and malachite mines of Prince Demidoff. They have also been used for calculating interest at different rates (3, 4, 5, 6%). One was specially built in 1849 with calculations in Russian money for the office of the Emperor of Russia.

6.2.2 1865 Peale Cylinder Device for Wages, 1865 450 cells

Peale's Wages Calculator as shown in Figure 28 an early example of a tabular calculator for where evidence survives of an effort to sell and shows the price as $6-10. This comes from the anonymous "Scientific American" article in 1865, [24], entitled "Improved Calculator"**.** The description says:

"It consists of a cylinder, on the surface of which is arranged a calculated table; the left-hand column contains the number of days and fractions of days to be calculated, namely, 1, 1¼, 1½ days, and so on for any number of days, to suit , for weekly, semi-monthly and monthly payments. This cylinder is inclosed in a zinc case, and revolves therein on pins having a bearing in the ends of the case. It is easily moved by a milled head at the left end, and the whole is neatly mounted on a walnut base. Running nearly the entire length of the case is an opening sufficiently wide to expose but one row of figures at a time. Immediately below this opening is placed, on the outside of the case, a row of figures denoting the several rates of wages, from the lowest to the highest ordinarily paid… Mr Peale will furnish the machines at $6 for weekly, $8 for semi-monthly, and $10 for monthly sizes."

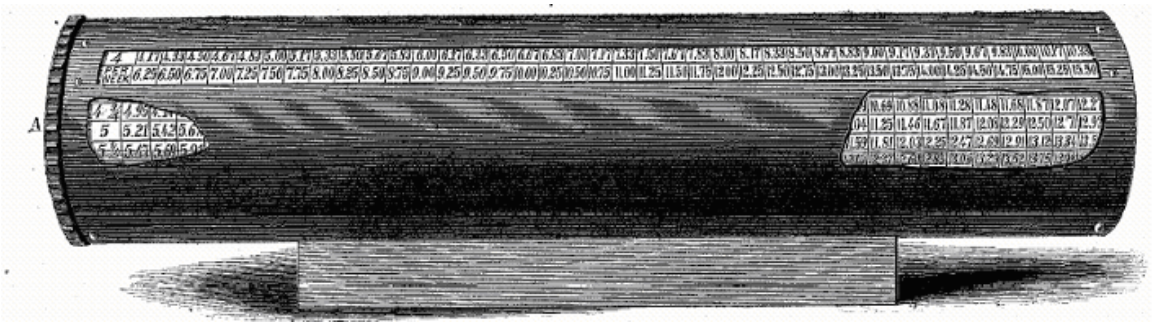


Figure 21 Peale Cylinder for Wages 1865

6.2.3 1880 Chambon& Baye Four cylinder Tachylemme; 396 cells

A calculating device see Figure 22 with four printed cylinders 1-9; 10-90; 100-900; and 1000-9000 so arranged that percentages for every half percent from one to six percent can be read through slits. The total of say 6,216 at 4 percent could be figured by adding the sums shown in the four rows. One was presented to the Science Museum by M. Malassis in 1936. Chambon also introduced similar "calculators" for the multiplication tables, called "Multiplicateur Enfantin". Note and picture found on http://www.thocp.net/index.html of The History of Computing Project.

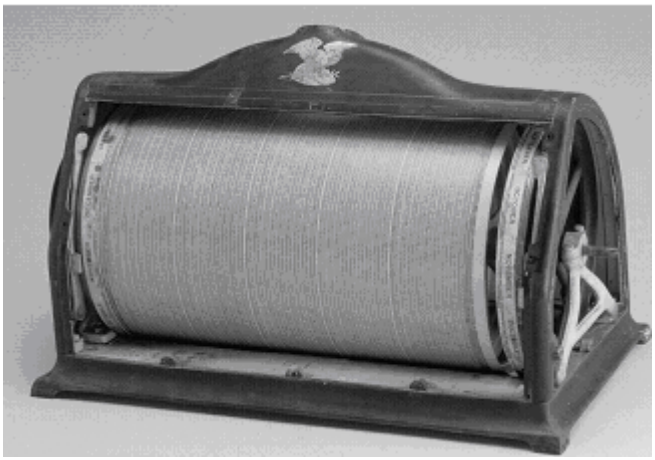
Figure 22 Chambon & Baye's Tachylemme of 1880

d'Ocagne [7] wrote:

> *"This arrangement of numerical table on adjacent cylinders has the further advantage of being extendable to certain tables having three entries. It is clear that, if by some means the numbers read from the cylinders can be made to vary according to the values of a third entry, then a triple barème has been achieved. It is this idea that Mr. Chambon most ingeniously put into practice in his Calculateur d'intérêts, which gives the interest payable, for any number of days, on capital sums up to 99,999 Fr. at raies of 3, 3.5, 4, 4.5, 5, 5.5, and 6%. The vertical columns of the table correspond to the first entry, the number of days. As in the Didelin device, the units, tens, . . . ,tens of thousands are assigned to the various cylinders, on each of which an endless loop contains the nine lines corresponding to the second entry.*
>
> *Although Chambon's arrangement is most ingenious, and most appropriate to the particular application for which it was developed, it does not allow any great increase in the number of distinct values for the third entry; consequently its use is rather limited."*

6.2.4 1905 Meilicke Cylinder devices 2555 cells

The Meilicke Company was in a fair way of business in the mid-West, with a range of devices, and was granted 11 patents in the US and GB from 1906 to 1915. The company was substantial (see below) but we do not know the price or sales volumes of the various machines. The interior of the cylinder device is shown in Figure 23 and the patent in Figure 24.



Courtesy Science Museum, London

Figure 23 1905 Meilicke Interest Cylinder Interior

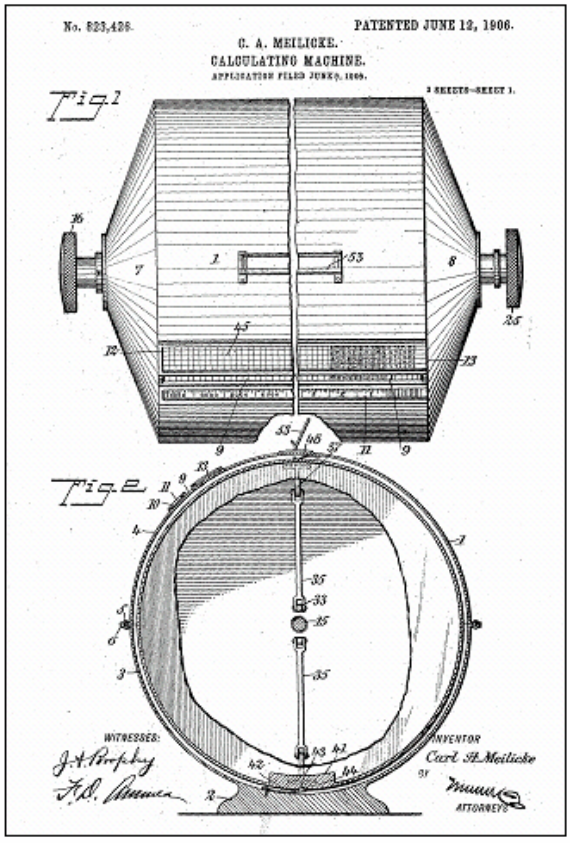


Figure 24 Meilicke 1906 US Patent

We have a contemporary description of Meilicke and his company, [20], from which we learn:

> *"In the manufacturing of the Meilicke Calculator and other remarkably efficient devices of inestimable value in connection with commercial and general business activities, this Chicago corporation holds a place of unique precedence, the company having been organized April 30, 1913, by Carl A. Meilicke, who, with about twenty-five*

basic patents on his valuable inventions, initiated the manufacturing of these various devices, he being president of the company which bears his name and which is incorporated with a capital stock of five hundred thousand dollars."..

"To the progressive founder of the business, however, has been left the heavy responsibility of supervising the production and distribution of the devices manufactured, and the unqualified success of the enterprise fully attests his executive and initiative ability, as well as his fine inventive talent"

"A machine that computes time, interest and discounts, gives the number of days between any two dates, indicates date of maturity and detects whether maturity date is a Sunday, Saturday or holiday. A valuable asset to bankers, merchants, companies dealing in insurance, real estate, lumber, etc., and to any manner of business involving interest-bearing transactions. A machine that eliminates four hard brain problems with one single movement of the hand. In operating the machine all that is necessary is to have it set for the current day of business and then to turn to the date when the note will be due or the date from which interest is to be computed in case accrued interest is wanted, and the figures are there immediately"

The same source says:

"Carl A. Meilicke was born in Windom, Minnesota, on the 24th of November, 1880, and he received his early education in the excellent schools of the Gopher state. He finally became cashier of the First National Bank of Falda, Minnesota,.."

From the US Patents we learn that from 1906 to 1909 he was a Timber Merchant in Hanley, Saskatchewan,

6.2.5 1914 Voss' Cylinder Calculator for Wages,

Another example of a cylinder device used for wages was made by the Voss Calculator Company. The patent drawing is shown in Figure 25. Voss noted in the patent that:

"In large commercial houses and manufacturing establishments, the pay of the major portion of the employees is figured on an hourly basis, and the scale per hour varies considerably according to the class of employees. In compiling a pay-roll, it is a tedious and laborious task to figure the pay of the various employees when it is computed upon the hourly basis; and, moreover, the liability of error in computing a mass of wage amounts is imminent and might result at times in a substantial loss of money. The present invention deals with a simple and accurate manner of computing the above results. Although, as stated, it is for analogous purposes by changing the character of the symbols on the various portions of the machine."

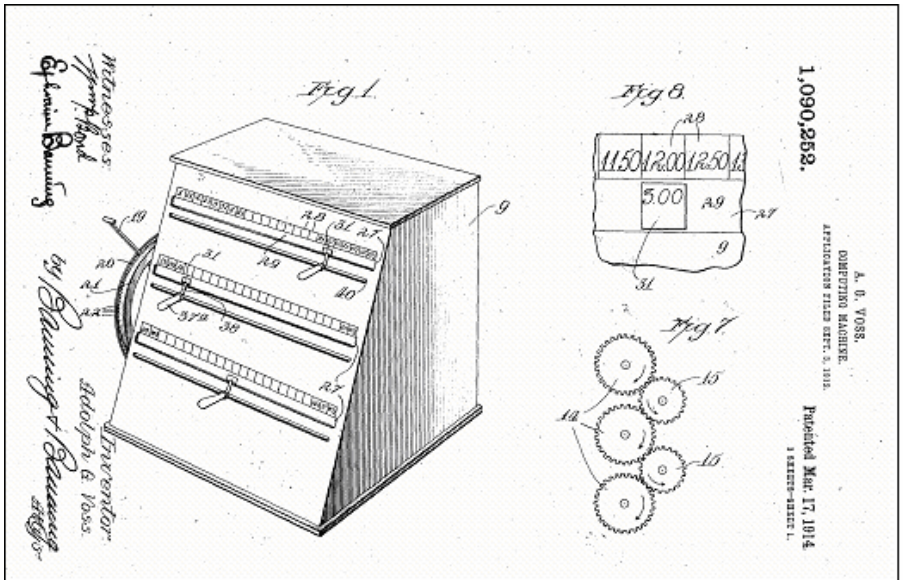


Figure 25 Voss 1914 Cylinder for Payroll US Patent 109052

Kidwell, [14], also notes a Voss device, remarking that "the Voss Calculator Company made a rotating multiplication table called the In-a-Jiffy Calculator. It sold around 1913." Her note was based on a magazine article ca. 1913. The illustration and description in the article correspond to the patent.

6.2.6 Tubular tabular calculators for children, patented and produced.

There are three different patents all of which were manufactured. BOBW has examples of each of these in his collection. Stanislaw Szenhak of Moscow took out two patents in 1898, US 619,432 and GB patent 70004 /1898. Darnley obtained a GB Patent 16769 of 1920.

6.3. Roll devices

The first roll was produced by Chambon in France. The idea was then taken up in Great Britain. The largest number of cells on a known single roll was 26,000 by Hartmann although this must have been of exceptional size and perhaps the realistic examples are the Hines with 3150 cells and the Robertson with 2640cells. See Figure 26.

	Maker designer	Date	Model	Rolls	Rows	Cols	cells/roll	Total cells
6.3.1	Chambon	1878	Enfantin	1	28	50	1400	1400
6.3.2	Chambon	1884	Tachypolyplasiasme	1	100	100	10000	10000
6.3.3	Hartmann	1886		3	260	100	26000	78000
6.3.4	Hines	1908		3	21	50	1050	3150
6.3.5	Robertson	1908		2	10	12	120	240

Figure 26 List of Rolls discussed

6.3.1 1878 Chambon Roll device Multiplicateur Enfantin 1400 cells

This was introduced by C L Chambon in 1876. It consists of a multiplication table giving the products of numbers from 2 to 50 and those from 2 to 28, arranged on two cylinders, which, by means of buttons on their lower ends, may be made to wind the printed table from one to the other. Figure 27 shows an example presented to the Science Museum by M. C L Chambon, 1884.

Two vertical slits, cut in the front of the box containing the cylinders, allow only two vertical columns of products to be visible at one time. To obtain the product of any number from 2 to 50 and any number from 2 to 28, the number to be multiplied is brought into one of the holes at the top of the apparatus. The left opening takes numbers from 2 to 25, and the right opening numbers from 26 to 50. The required product will then be found in one of the slits opposite the multiplier, which is in the vertical column between the slits.

The device is 18 cm long by 3.5 cm wide by 2 cm thick. The cylinders are less than 0.5cm in diameter. The roll is on very fine rice paper. Note as set for the photograph, the right hand window is not for 93, but is showing part of the column for 29 and part of the column for 30.

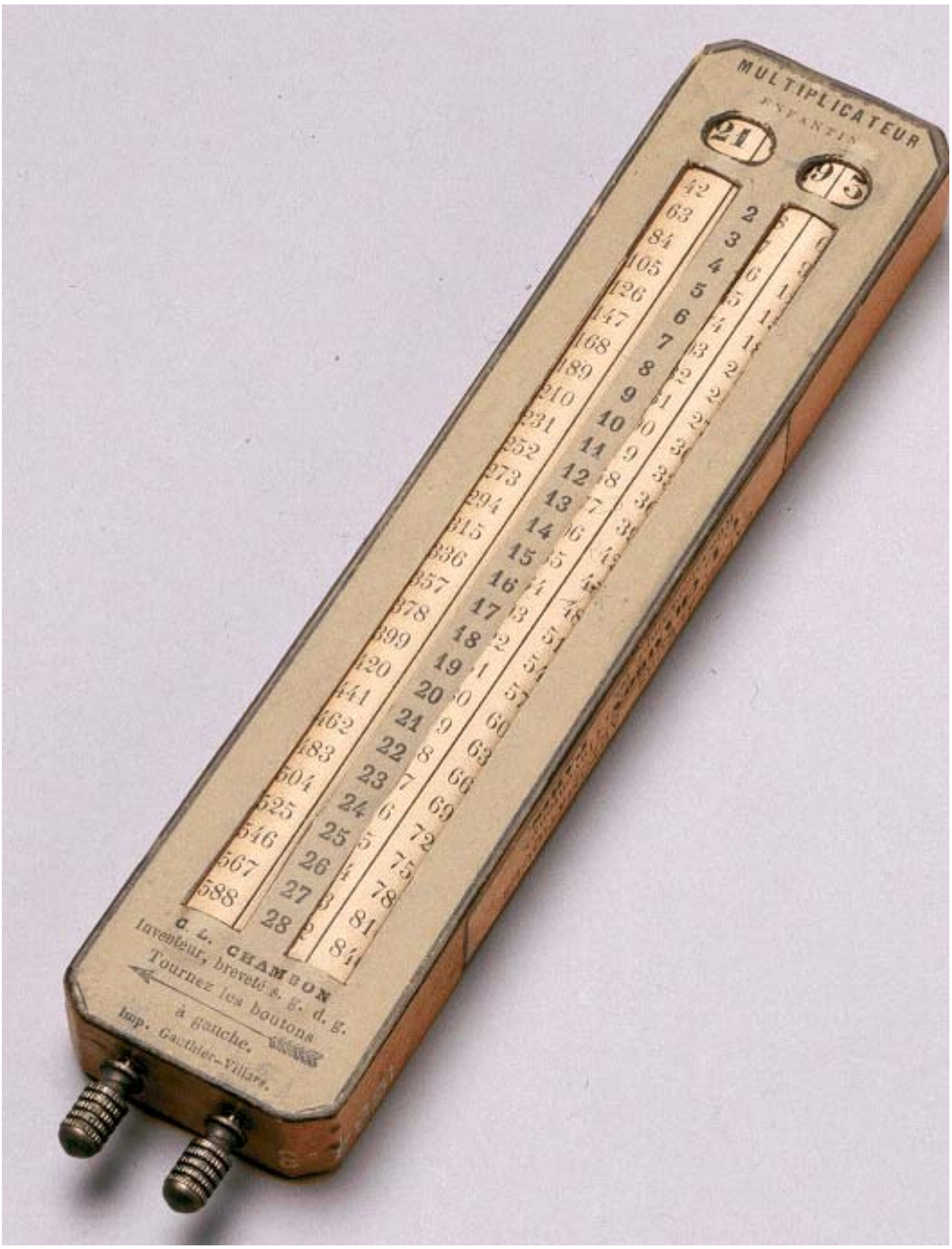
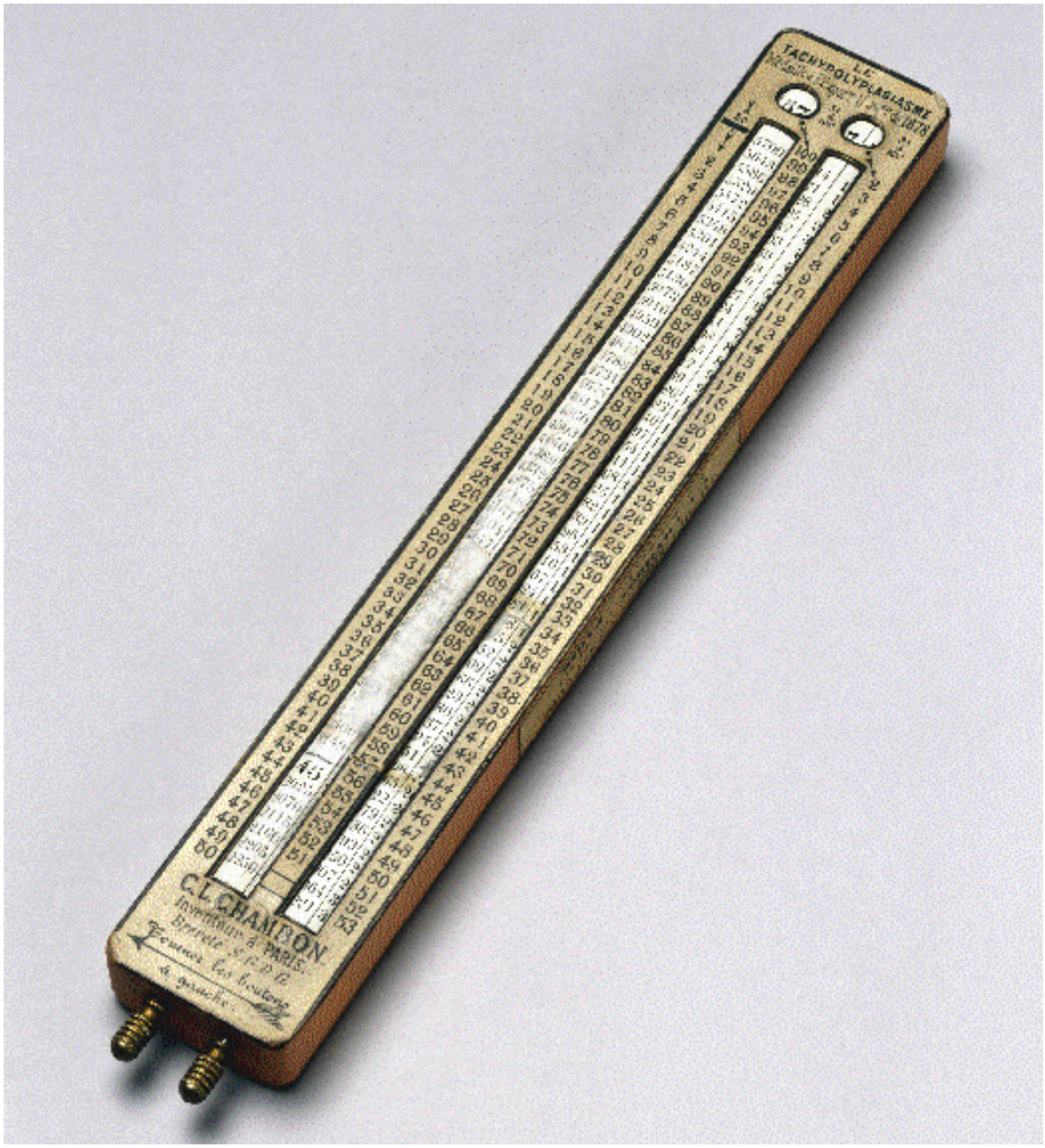


Figure 27 Chambon's Multiplicateur Enfantin

Picture Courtesy Science Museum

6.3.2 1884 Chambon's Tachypolyplasiasme 10,000 cells.

Figure 28 shows this device. The catalogue of Science Museum, London [21] records "*Presented to the Science Museum by M. CL Chambon, 1884. This is a larger modification of the Multiplicateur Enfantin, and gives the products of any number from 2 to 100 multiplied by any number within the same range. INV 1884-4. It won a medal at the Universal Exposition of 1878."* Williams recently measured the dimensions as 26cm long by 4 cm wide by 2cm thick.



Courtesy Science Museum, London.

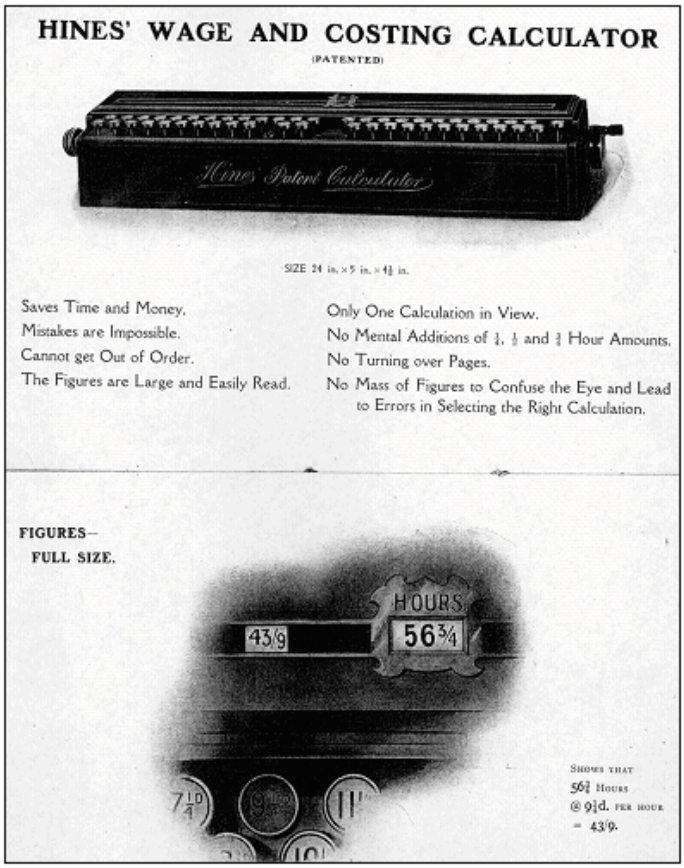
Figure 28 Chambon Tachypolyplasiasme

6.3.3 1886 Hartmann's Roll Calculator for Interest, 1886 7800 cells

C V Boys in an article in 1886, [22], enthused about a machine by Mr Hartmann. He described a machine using one cylinder and one roll mounted on two rollers (referred to in the text by Boys as a "pair of cylinders") for calculating interest, using difference columns to give high precision. These difference columns were not numbers, as often found in a table of logarithms but were sloping "contour" lines. No example or illustration of the device has been identified, and we have found no other descriptions. Boys' description is very detailed, but not clear on how the difference table was made, the only clue being that it was "graphical". The description reads:

> *"Passing from arithmometers to machines of another class, we come to one highly specialised .It does one thing only, and that it does well. I refer to an entirely novel instrument, invented by Hartmann, for calculating interest. It is certainly surprising that it attracted so little attention, and seems so little known. It consists essentially of tables, calculated by Hartmann with great labour, arranged as follows:- First, there are a pair of corresponding primary tables. The bottom line of the upper on contains the series of values 1d., 2d., 3d., 4d and so on, the figure in each column being one penny more than in the one to the left. In the line above this are the values 2d., 4d., 6d., 8d. &c., in the next line 3d., 6d., 9d., 1s., &c., and so on for 183 lines. This, then, is a multiplication table in which the unit 1d. is at bottom left hand corner. In corresponding columns in the table below are the capital sums which, at various rates of interest from 1 to 10 per cent., increasing by eighths, will yield as interest the 1d., 2d., 3d., &c., per day, which is tabulated in the bottom line of the upper table. Thus, if we take any row in the lower table representing any desired rate per cent., and find any sum marked in one of the vertical columns, the amount found in the bottom line of the upper table immediately above this will show the interest per day, the tenth line will show the interest for ten days, and so on for any number of days or any rate per cent. So far I have described a special multiplication table rather than a machine, and this it would still be, in spite of the mechanical mounting of the tables whereby the required squares can be almost immediately pointed out, if it were not for the graphical table attached. It is evident that the capital sums in the table must differ from square to square by considerable amounts, and not only this but the sums tabulated cannot be even amounts if they produce the 1d. a day exactly. The next lowest even amount is written in the table, and by the side a correction. As the sum on which we may require to calculate interest is not likely to be exactly found in the table, means have to be provided to find the interest due to any differences. This is the part of the machine which is specially ingenious. A second or graphical pair of tables is prepared with a horizontal line corresponding to each horizontal line in the two tables already described. Each of these lines is divided into a series of equal parts, such that the number of parts is equal to the difference between any pair of numbers in the primary tables. Thus in the lower part of the graphical table are capital sums, and in the upper part are pence, shillings and pence, or pounds shillings and pence, which are corresponding amounts of interest. This table is mounted on a cylinder, while the first being longer is mounted on a pair of cylinders. Two sliders are provide, one to be set to the rate per cent., and the other to the number of days. To find the interest on any sum the lower slider is set to the rate, the next lower capital amount than that given is set opposite to the pointer. The difference and correction are set opposite the other end of the same pointer on the graphic table. The upper pointer is set against the number of days On the one side is the interest on the chief amount, and on the other the interest on the difference and correction combined correct to a farthing. The time occupied is less than would be spent in looking over tables in the usual way, or in calculating by a machine. A pair of horizontal lines are specially divided for the calculation of brokerage and commission. I am able to show a complete machine and the tables separately amounted."*

The two tables would have needed very large pieces of paper, 280 columns by 260 rows. Together we estimate they would be roughly 1.5m by 1 m, or 4 ft by 3 ft. The need for a mechanical device using rolls to manage such large sheets and to align the results is clear in the difference tables is clear.



6.3.4 1908 Hines Roll device 800 cells

Figure 29 Hines Brochure

Hines Patents of Glasgow was a company with well-developed marketing activities: brochures, testimonials, exhibitions and so on. The main product comprised a device for wages or pricing with three rolls mounted on pairs of rollers and a key mechanism for selecting the required price. It sold for **£15:15:0d**, about $63. The company had ten sales offices in GB. No data has been found on sales volumes. The company took out four patents from 1905 to 1911. The device corresponding to 829526/1906 is illustrated in Figure 29.

A short-lived British Magazine called "The Organiser" carried a note on a Business exhibition in Nov. 1909. This had a picture and text as follows:

> *"Hines Patents Ltd, were showing a number of different varieties of wage calculators and weight and quantity calculators. One of these latter is an invention which has only been six weeks on the market. The three wheels at the side are for setting to the requisite quantity of tons, cwt., qrs, lbs or whatever may be desired, and the keys at the basis of the machine, numbered from 1d to a £1, are for striking when it is desired to find the answer to any given quantity of materials at so much per lb., dozen, gross, gallon, etc. The wage calculators are even simpler and show at once what money is due to a workman for so many hours work."*

6.3.5 1910 Robertson Roll device 2400 cells

The Robertson device, primarily for calculating wages, was an elaborate cage of rollers and rolls. This device was placed on the market, but does not appear to have been promoted very energetically. Again no information has been uncovered about the price or the sales volumes of these machines. There were three patents from 1905 to 1913.

A review of the Robertson device appeared in the Napier Tercentenary Handbook, [3], as follows:

> ***"The Robertson Rapid Calculating Machine Co., Ltd.***
> *THIS calculator is a type of ready reckoner, and is manufactured in Glasgow. The actual machines, so far as they are already produced, are not yet on the market for general sale, but have been designed for the company's own use.*
>
> *A ready reckoner is helpful in a certain way, but the idea contemplated was to go entirely beyond the scope of it, and at the same time to teach arithmetic by the use of equivalents in all sorts of measures, and to train the operator by educating his eye. This machine itself is a mechanical device for displaying printed tabulated matter, and is capable of showing an almost unlimited number of totals within a reasonable compass.*
>
> *The present model …. is set upon a desk-table. It has four distinct faces, each face showing different sets of equivalents. The operator, by simply pressing a small key, brings the required face opposite him, with the controlling handles ready for use. Each face of the machine with its printed records may be likened to a book with 200 or 300 pages open at the one time, allowing the machine to be operated, while showing the full sets of equivalents. The operator is thus enabled in many instances to do some thirty different calculations in five minutes, without requiring to re-set the machine."*

The interior of the Robertson device is shown in Figure 30.

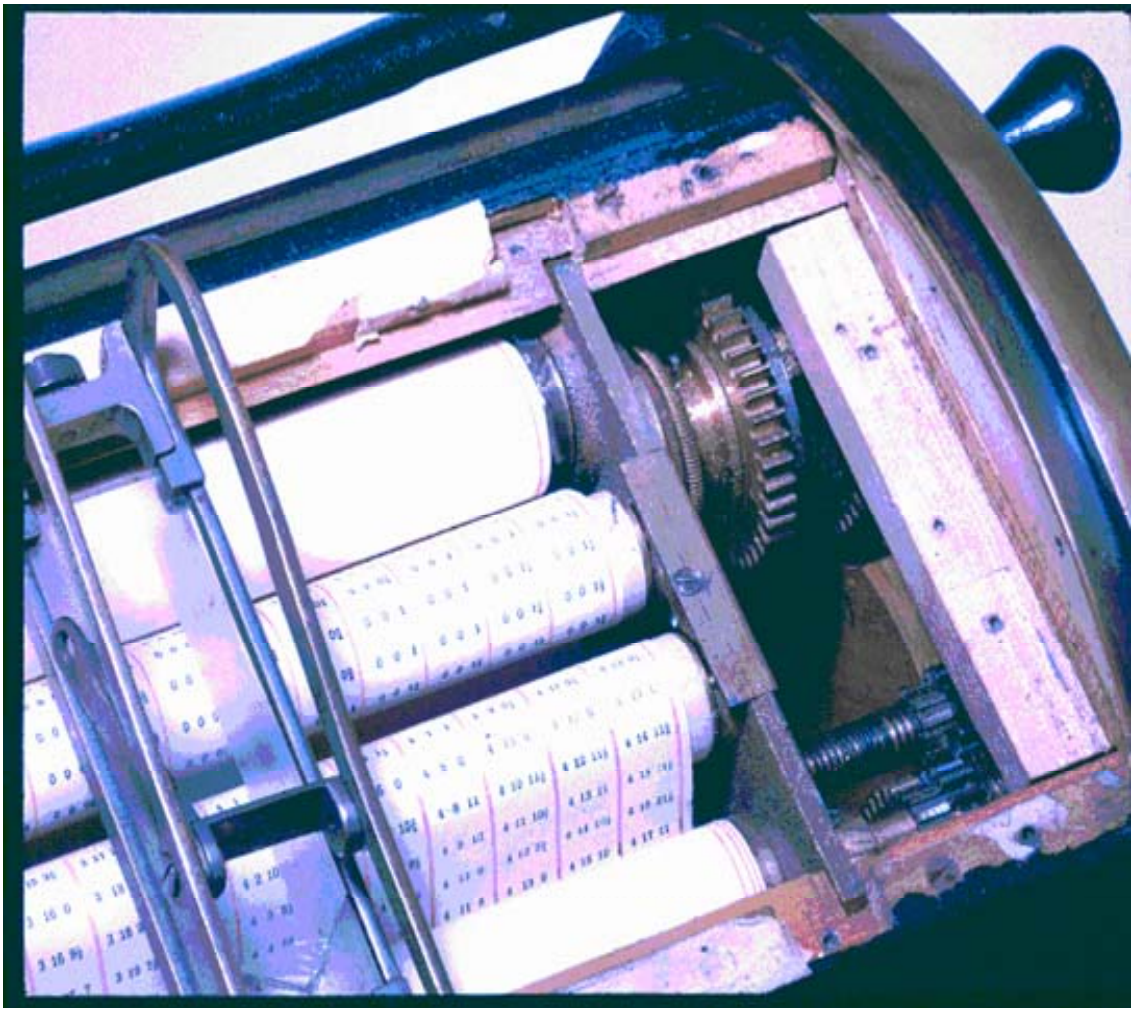


Figure 30 Robertson Device Interior showing two paper rolls each wound over two rollers

Courtesy Science Museum, London

6.4 Slides

The only important manufactured example we have found is the Meilicke card index with 4,000 cells.

6.4.1 Meilicke Slide/card index device

The early Meilicke machines we saw above were big cylinders for interest calculations. The later models, after 1909-15, were of the Card-Index type. This may have been because it was much easier to provide tables or different interest rates using cards rather than a cylinder. It was very difficult, and presumably costly, to change cylinders. The Card Index type was advertised for a whole range of usages, not just interest.

The advertisement shown in Figure 31 lists the following applications:

Interest calculations
Savings bank calculators
Time calculators
Pay Roll calculators
Bonus calculators
Unit basis calculators
Dozen basis calculators
Freight Calculators
Express calculators
Lumber
Coal
Commercial
Butter-fat
Yard Goods
Discount
Water Bill
Electric Bill
Gas Bill
Price Checkers
Vertical cataloguing
Phone Indexes

Figure 31 Meilicke advertisement "Scientific American" Jan -March 1926

7. Price and Value for money

7.1 Tabular calculator prices were cheap to medium

The very limited data that we have on tabular calculator and competitor prices is displayed in **Error! Reference source not found.**.

1	2	3	4	5	6	7	8	9	10	11	12	13
#	Year	Type	Manufacturer or Designer	ND	Mat	SF	LD	Port	Mult CS	Actual £1914	*Predicted Actual £1914*	VFM
1	1913	sr	Fuller	0	2	6	2.0	1	20	5.45	-12.70	-2.33
2	1906	sr	Smith -Davis Premium Calculator 3 ft scale	1	4	4	1.0	1	1	8.86	0.73	0.08
3	1869	sr	Wright Arithmeter	0	4	6	1.0	1	2	127.14	39.67	0.31
4	1914	ra	Comptograph	0	4	16	1.0	1	16	94.59	46.68	0.49
5	1914	pw	Ensign	0	4	12	2.0	1	6	92.59	58.12	0.63
6	1905	mre	Millionaire	0	4	20	1.0	1	1	125.74	89.64	0.71
7	1905	mre	Millionaire	0	4	12	1.0	1	1	85.33	62.20	0.73
8	1905	mre	Millionaire	0	4	16	1.0	1	1	103.29	75.92	0.74
9	1913	sd	K&E Peerless	0	4	20	1.0	1	20	68.12	52.61	0.77
10	1905	sr	Smith -Davis Piece Work Balance Calculator 11ft scale	1	4	9	1.0	1	1	22.20	17.88	0.81
11	1912	ra	Burroughs Calculator	0	4	13	0.1	1	6.5	53.32	49.81	0.93
12	1893	ra	Comptometer	0	4	12	5.0	1	6	79.69	75.11	0.94
13	1851	logs	Seven Figure Logs Filipowskii	0	0	7	0.0	2	20	0.63	0.63	1.00
14	1893	ra	Comptometer	0	4	16	5.0	1	8	79.69	84.94	1.07
1	1914	pw	Sanders	0	4	12	3.0	1	6	59.52	63.79	1.07
2	1914	pw	Archimedes Midget	0	4	20	1.0	1	6.5	65.00	78.92	1.21
3	1887	sr	Thacher	0	3	6	0.2	1	10	5.10	8.07	1.58
4	1905	pw	Baldwin	0	4	16	1.0	1	1	43.99	75.92	1.73
5	1912	pw	Colt/Teetzmann	0	4	15	2.0	1	7.5	35.71	65.49	1.83
6	1909	tc	Hines	1	4	10	2.0	1	1	14.53	26.98	1.86
7	1909	sr	Fuller	0	2	4	1.0	1	1	5.77	11.81	2.05
8	1890	pw	odhner	0	4	4	1.0	1	2	13.76	32.81	2.38
9	1880	sd	Thomas	0	4	16	2.0	1	16	20.47	52.35	2.56
10	1895	sd	Layton	0	4	16	1.0	1	16	16.88	46.68	2.77
11	1895	sd	Layton	0	4	12	1.0	1	12	13.50	40.76	3.02
12	1900	sr	Thacher	0	3	6	0.2	1	0	6.32	27.56	4.36
13	1865	tc	Peale	0	4	4	0.2	1	5	1.80	22.43	12.47
14	1890	pw	Odhner	0	1	2	3	4	5	4.59	58.77	12.81

Figure 32 VFM Data for 28 devices capable of payroll calculations – poorest VFM at the top

Col.3 is the type. ra is repeat adder such as a Comptometer; sd=stepped drum calculator, pw =pinwheel calculator

Col. 4 is the company or designer

Col. 5 ND is the score for non decimal capability. 1 for yes, 0 for non-decimal only

Col.6 Mat is the material score

Col.7 SF is the number of significant figures

Col. 8 LD is estimated days to learn to use the device

Col .9 Port is Portability, and is an amalgam of weight and footprint scored as follows: Pocket=4, Laptop = 3, Desktop=1

Col. 10 Mult CS is an estimate of the multiplication time in seconds

Col 11 is price in 1914 £, by applying exchange rates to foreign currencies and then using the GB price index to get 1914 £. The items included are all capable of handling wages calculations.

Item 1 in Figure 32, the Fuller long scale spiral slide has a negative projected price because, as shown in Figure 33, the regression equation for all products has a high negative intercept of -£72.76 and the Fuller has a negative

product, (contribution to projected price) for its slow calculating speed. The other Fuller positive factors do not compensate for these negatives.

Factor	Coefficient	Value	Product
ND	-34.0	0	0.00
Mat	11.5	2	22.95
SF	3.4	6	20.58
LD	5.7	2	11.33
Port	44.2	1	44.18
Mult CS	-1.9	20	-38.98
	Intercept		-72.76
	Total		-12.70

Figure 33 Calculation of Fuller projected price

Looking at the table we see that the Peale was £1.80 while the Hines was £104.50. We could say, the Peale was very cheap and the Hines medium-priced. For comparison, it should be noted that most Ready Reckoners cost about 1914 £1, cheaper than anything in the table.

7.2 Tabular Calculator Value for Money was reasonable

We can use the data in Figure 32 to carry out a more sophisticated value for money analysis taking into account the different capabilities and characteristics of the devices. Col 12 is the predicted 1914 £. This is the price calculated by regression analysis for the mix of properties in that particular device. In a market containing this set of competing products, Col 13 Vfm, Value for money index, is the predicted price divided by the actual price. When this is 1, the device is priced just right for the market in comparison to the other devices. Over 1 is good value for money. Under 1 is poor value for money. Col 1 shows the ranking order from 1 to 14 of the VFM Index. Peale comes at No13 out of14. which is good and Hines only at No 6 out of 14 on the edge of the lowest half, so our two priced tabular calculators come out reasonably well .

These regression and VFM analyses are based on the established concept of *hedonic pricing*. Hedonic pricing began in 1939 and is now well established. It involves regressing price or the logarithm of price on the characteristics of a product. The approach has recently come into vogue, as the number of hits for an enquiry via Google will attest. The history of its development is fully described in “Price and quality of desktop and mobile personal computers: A quarter century of history”, [23]. The US National Bureau of Economic Research is active in developing Price Indices for classes of product. Of particular interest here is their work on computers and Personal Computers, (PCs). A paper by Pakes [24] describes work on hedonic price indices for PC’s and in summary computes hedonic regression functions for PC's sold in the "home market" between 1995 and 1999 and computes and compares alternative price indices for PC's for this period.

7.3 Tabular Calculator branding and product awareness were too low compared with the big players to compensate for their modest performance

In principle, the tabular calculator manufacturers could have sought to overcome weaknesses in value for money by good marketing, branding, training, maintenance service and training courses. But we have that the low level marketing efforts of Meilicke, Hines, and even Chambon, were negligible compared with those of Comptometer, Burroughs and Brunsviga. Comptometer was famous for setting up training courses all over the world to overcome the product’s fundamental weakness as a multiplier if not used by a trained operative. None of the tabular calculator people tried anything comparable nor, as far as we can tell, did they set up any user friendly service organisations for their complex large cylinder and roll machines.

8 Computing scales flourished from the 1890’s to the 1960’s

We now turn our attention to computing scales. These devices that instantly weighed and priced retail sales are important in the story of tabular calculators as, unlike the free standing devices, they were manufactured and marketed

by large corporations. These corporations had the resources to carry out sophisticated research and development, and this led them to develop optical projection technology.

We have examined over 600 US and GB patents for computing scales. These have been characterised by type of computing device and by the manufacturing company. The US patents were mainly identified by looking at US Class 177/3, and then by checking against the copy of "Index of Patents issued" in the British Library. GB Patents are from an examination of the Group "Weighing Apparatus" Abridgments. We have looked at all the GB abridgments up to 1920 but not all the full specifications. The numbers of patents granted in each decade ending in the year is shown in Figure 34 on which shows fast growth from1870-1910, followed by a decline.

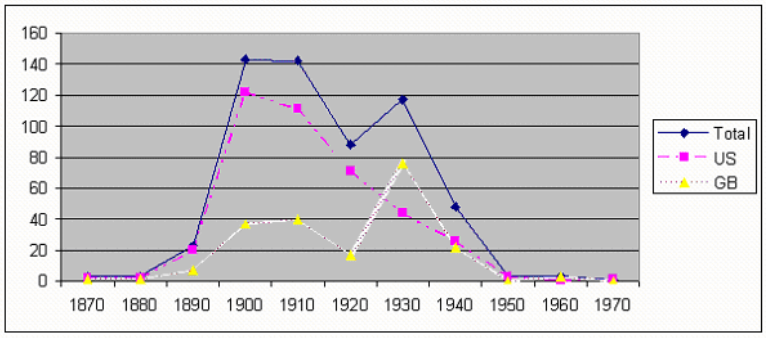


Figure 34 Computing scales patents per decade

Enough material is available for a complete article on computing scales, so what follows is a brief summary. First let us look at the main types of computing scale.

8.1 The types of computing scale paralleled those of free standing tabular calculators

The principal types of computing scale are shown in Figure 35. A retailer who bought a computing scale did not need any other form of calculator, and even more useful, he did not have to note the weight, then find the price, and finally do a calculation. The device did all that for the shopkeeper and the result was visible to the customer.

It is of course no coincidence that this table bears a remarkable resemblance to that in Figure 1 since possible constructions are limited mainly to discs and cylinders.

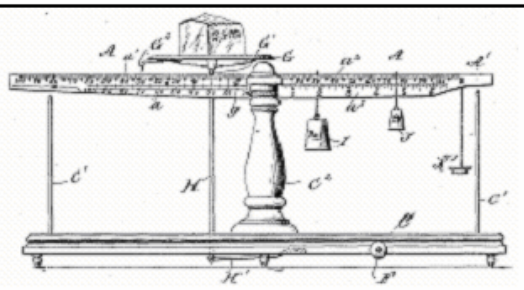
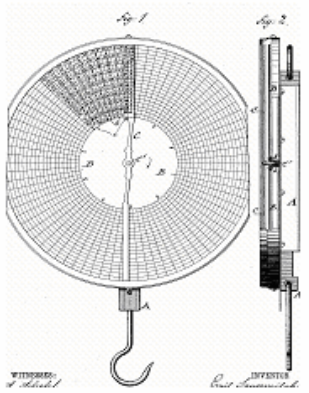
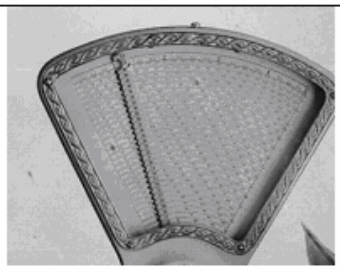
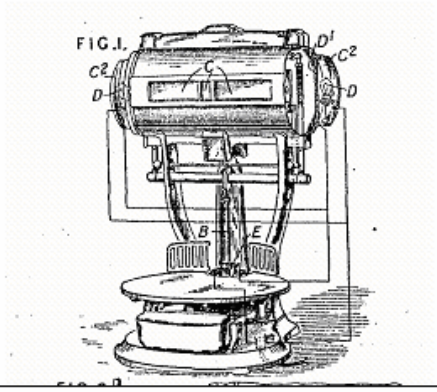
Type	Example	Thumbnail
1. Linear	Pitrat 1885	
2.Circle	Sauermilch 1885	
3.Fan	Avery 1928	
4.Cylinder	Longstreth 1910	

Figure 35 Four Main Types of Computing Scales. Thumbnail Size Patent Drawings

8.2 The computing scale industry was powerful and well organised

These scales were mass-produced by major manufacturers from the 1890's to the 1960's. So in contrast to the free-standing devices described above there are many more surviving examples and more corporate information and trade literature. But perhaps more important is that the US computing scale industry became so big that it had funds available for research and development.. So we shall see that potentially the most important advances in tabular calculators came from this industry.

The development of the industry is a tale of engineering ingenuity and a struggle for market share, focused primarily on the vicious competition between the Computing Scale Company and the Toledo Scale Company, both led by men (Thomas Watson see Figure 36 and Henry Theobald) who learned their trade from John H. Patterson of the National Cash Register Co, see Crowther, [25] and Maney, [26].

Figure 36 F L Fuller, Scale designer (left) with Thomas Watson, picture from [27]

Computing scales were big business from early in the last century. Between 1903 and 1905 Toledo sold 30,000 scales according to Terry, [28]. The Computing Scale Co sales were $3.5 million in 1921, after an earlier decline, according to Maney, [26].

8.3 Optical projection computing scales developed after WWI

We now come to the fascinating but only partially exploited technological breakthrough after WW I. From about 1916 there was an interesting development in this area, involving optical projection devices. At the beginning of this paper we defined a tabular calculator as a device incorporating pages from a ready reckoner or similar table, this page or table usually containing cells showing the product of two factors such as a price and a quantity. In most of the examples that we have looked at so far, the cells have been printed on an opaque material.. Now suppose the cells are printed on a transparent material such as glass.

Optical projection computing scales may be defined as those where a light source is projected through a transparent calculating disc or cylinder and then a train of lenses for direct reading by the user, or on to a ground glass screen for the customer or sales person to see, or on to a photographic medium if a permanent record of the transaction is required..

A small number of patents were granted for optical projection scales, but some of these only projected the weight, not the price, and were thus not computing scales. Four patents for ground glass screen or photographic computing devices are listed in Figure 37, the Avery, was made and marketed once WWII was over and fortunately the promotional materials remain available. We have not yet established whether the other patents were exploited.

#	Pat #	Pat applied	Pat granted	Inventor	Company	Type
1	1166 658	1911	1916	Buckingham	Standard CSC	Disk, Glass
2	1550735	1921	1925	Ogsbury	CSC	photographic
3	GB 275246	1927		Jacob, Berlin DE		
4	GB510785	1937	1937	Timson	Avery	Disc to screen

Figure 37 Patents for optical projection

8.3.1 1937 Design for Avery was produced and marketed after WWII

Avery applied for a patent for an optical device in December 1937, and this was accepted as GB 510,785 in August 1938 It described a rack and pinion gear driving a "transparent rotatable disc on which is recorded, preferably in a ring adjacent to the periphery of the disc, indicia of weight in the form of a sequence of weight numerals corresponding to the capacity of the weighing apparatus. Marked on the same disc in concentric rings and arranged in price sequence are numerals representing price computations based on the weight units at predetermined prices per pound, these price computations being arranged in a similar manner to that which is well-known in the art of today in association with what is known as drum computing weighing apparatus. The units representing the basic price per pound are marked upon another disc preferably formed from sheet metal, which disc can be rotated to indicate the weight value and the price computation the basic price per pound". The development may have been held up by WWII. The product was launched in 1960, see the brochure in Figure 38.

Avery Aristocrat 1960

What is the ARISTOCRAT?

The "Aristocrat" is a self-indicating automatic price computing scale of 20 lb. capacity. A precision optical system has been perfected to project the information contained on an 8 in. diameter glass disc inside the body of the scale onto the viewing screens. A new high-precision photographic process has made it possible to include more than 400,000 characters on this disc.

The "Aristocrat" is sensitive to 1 dram and a new high-speed action gives instantaneous indication of one weight and one computed price for any one weighing.

Styled by a leading industrial designer, the "Aristocrat", with its contemporary lines and two-tone colour scheme, has a display value of its own and will blend perfectly with any surroundings.

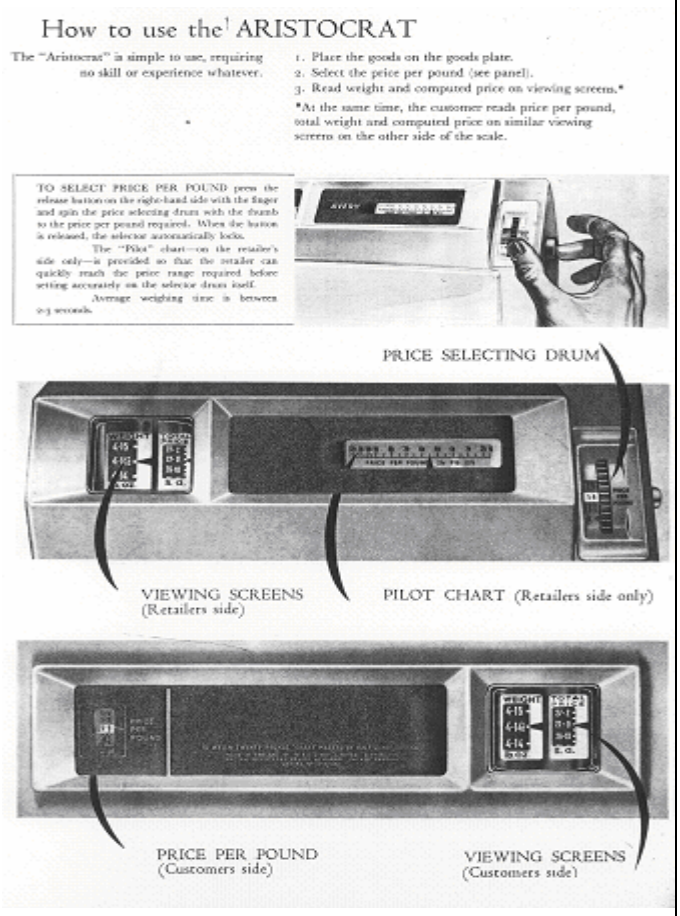
The Board of Trade has already given full approval to the design and special features of the "Aristocrat".

(B.O.T. **No.** 1271 9.8.60.)

The outstanding design and features of the "Aristocrat" offer the progressive retailer these advantages:

No more mental calculations

With its tremendous range of prices per pound, the "Aristocrat looks after present and future price trends. It includes a total of 109 prices per pound from: 1/6 to 9/- per lb. in 1 d. increments



Science Museum Library Trade Literature.

Figure 38 Avery brochure 1960

This Avery machine shows that by 1960 there was available a high quality device capable of projecting a selected part of a ready reckoner table on to a screen. The obvious question that comes to mind is, why not detach the weighing mechanism and adapt the rest as a user friendly free-standing tabular calculator? There were in fact two relevant developments of a related nature.

First, in 1954 Mario Abeille and Vincenzo Aquilechia of Rome, Italy were granted GB patent 71,080 for a logarithmic calculator with optically projected scales. Jay Francis in his article [35] stated that five prototypes were made in 1951 by the company Filotecnica Salmoraghi, and illustrated two examples found in the US.

Second, from a different line of development was the microfiche. The evolution of this device is explained in the Wikipedia entry: *"Microfiche is one of the most compact analog storage media in common use. It is normally used to provide a comprehensive research library in institutions (such as small college libraries) that could not otherwise afford the floor space. It was invented in 1961 by Carl O. Carlson, an employee of the National Cash Register Co. The US patent 185,026 was granted in 1965."*

9. Conclusion

9.1 Free standing tabular calculators failed to address enough KFBD and offered no compensating marketing efforts

Sales volumes are not known and we might have supposed that they were comparable to those of mechanical multipliers, given the similar patent activity. But we conclude that the volumes were lower because while the Value for Money was satisfactory in comparison with contemporary offerings, they were poor on the whole mix of KFBD if marketing and branding are taken into account, and much more expensive than Ready Reckoners. Without offering sufficient enhanced performance to justify the extra cost.

They were never as successfully marketed as were Ready Reckoners. Ready Reckoners could be bought in almost any book shop, but for free standing tabular calculators the marketing, sales and distribution were primitive. The ambitious entrepreneurs, Meilicke, and Hines, were indeed energetic but although their products were fair value for money, this was not good enough if potential commercial customers were not aware of their capabilities and availability. Compared with the publicity, training schools, and sales forces around the Comptometer They were silent.

9.2 Computing Scales succeeded as a mass produced item professionally marketed and distributed

In the case of computing scales' retailers of loose goods had to weigh the goods anyway and the calculation was easier than using a separate Ready Reckoner. The marketing, selling, and distribution channels were well developed. It is interesting to consider whether the later optical projection computing scales could have evolved into competitive free standing devices before the electronic calculators came along.

In our earlier paper on Ready Reckoners we noted: *"Given their general superiority concerning ease of use it is not surprising that Ready Reckoners were the dominant aid used for multiplication in trade from 1800 to 1950. Throughout this period their sales far exceeded any other calculating instrument used in trade to assist in making routine calculations"*. We can now add that their derivative products, Tabular Calculators, were in general much less successful in achieving mass sales, and only did this when attached to retail weighing devices.

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