Long-Scale Slide Rules Revisited

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Introduction

The quest for greater calculating precision with slide rules started at the beginning of slide rule history. This pursuit has resulted in the development of many different forms of long-scale slide rules with extended scale lengths. This report, an update of a paper on long-scale slide rules published by the Oughtred Society [11], was first published in the proceedings of the 9th International Meeting of Slide Rule Collectors, September 2003, in Holland. It reviews the historical development of long-scale slide rules, defines the different categories and formats, and presents many examples—including some new examples that have come to my attention since the OS and IM2003 papers were published.

The "long scales" that I refer to in this paper are the single-cycle number calculating scales (sometimes broken into segments) used for multiplication and division. "Long-scale slide rules" are those slide rules with calculating scale lengths greater than the lengths of the C and D scales on common 25cm slide rules. For time and space considerations, relatively common 50cm slide rules are not included in this report. They may be the subjects of another paper. However, for a sense of completeness, slide rules that provide relatively long scales in a small format, such as Fowler long-scale pocket watch style circular slide rules and the Nestler Präzision 25cm slide rule with segmented 50cm long scales on a 25cm scale body will be included, even though their scale lengths do not exceed 50cm.

In my *JOS* [11] article, I included an extensive discussion of the precision of long-scale slide rules. I will forego repeating that discussion here other than to say that the precision of the longest scale commercially made slide rule—the Loga 24-meter Rechenwalze—is four to five digits with interpolation, while the precision of the common 25cm long-scale slide rule is two to three digits. The precision increases about one digit for every order of magnitude increase in length of the calculating scale. The precision is greater at the beginning of the scale than at the end of the scale, and the precision of spiral slide rules is more nearly the same at both ends.

Long-scale slide rules have taken several different forms, including: 1) linear or straight; 2) circular; 3) cylindrical and 4) continuous ribbon or tape. There are also variants on these formats including multi-segmented, gridiron, spiral, concentric circle, helix and saw tooth scales. The following is a summary of the historical development of long-scale slide rules, and their formats and scale lengths. The slide rules discussed are tabulated in Tables I and II.

History of Long-scale Slide Rules

The Early Days of Oughtred and Delamain

The first known long-scale slide rule may have been the circular slide rule made for William Oughtred by Elias Allen, an instrument maker, in about 1632. This slide rule was featured on the front and back covers of the *Journal of the Oughtred Society* [29] in March, 1996. It is possibly the oldest slide rule known to exist. An original made by Elias Allen is in the Whipple Museum in Cambridge, England. The disk is about 32cm diameter, and the number calculating scale has a length of about 76cm. That makes this calculating scale about three times longer than the common 25cm calculating scale on 20th century slide rules. According to Cajori [10], Oughtred may have designed this slide rule as early as 1621, shortly after making a slide rule of sorts by placing two rulers with two cycles of Gunter's numbers adjacent to each other.

Prior to that, it appears that there were Gunter rules with two-cycle scales as long as 1.8m. Cajori [10] reported that in 1632 William Forster, a student of Oughtred, told him that he had been making "6-ft long" Gunter rules. Gunter rules were relatively common for men of science in England at that time. One cycle of the two-cycle calculating scale on Forster's Gunter rule would have had a length of about 90-cm. Oughtred responded to Forster by saying that it (Forster's six-foot-long Gunter scale) "was a poore invention" with a "trouble some performance". He went on to describe a slide rule of sorts made of ". . . two Rulers . . . to be used by applying one to the other. . .". He also showed Forster ". . .those lines cast into a circle or Ring, with another moveable circle upon it." Oughtred was describing a two-disk circular slide rule. He had also developed the idea of a circular slide rule with a spiral scale years before this conversation with Forster. Forster wondered why Oughtred did not mention his ideas earlier, when "he had bin so liberall . . . in other parts of Art [mathematics and science]" to his students. Oughtred responded that he believed strongly that the Artist [e.g., the student] should be "well instructed in the sciences" before succumbing to instruments as "doers of tricks". Oughtred simply believed that it was more important for his students to be well grounded in the mathematics of the day than to be proficient at making calculations that were normally left for a technician to do. As we shall see, this philosophy left him vulnerable to another of his students.

Forster respected Oughtred's views. However, another student at about the same time, Richard Delamain, apparently did not. Once Delamain found out about Oughtred's circular slide rules, he got busy, borrowing some ideas from Oughtred and developing some of his own. He began making and writing about circular slide rules. The story has been told by Cajori [10]. Delamain favored a two-disk configuration with a single indicator, while Oughtred preferred a single disk with a pair of indicators. The first (known) circular slide rule attributed to Oughtred was of the single disk type—the Elias Allen example discussed above. In his pamphlet, Grammelogia IV, published in 1632, Delamain showed the layout for a two-disk calculating device (Fig. 1) each disk with a pair of calculating scales laid out on five concentric circles. The scale length on the outer fixed disk was about 140cm and was about 112cm on the inner movable disk.

Before I go further with this discussion, I should state the differences between single-disk and double-disk circular slide rules. As Oughtred developed the circular slide rule, it consisted of a single disk with numerous circular scales. It had two indicators, pivoting around the center of the disk, to facilitate calculations. The pair of indicators were operated much as a pair of dividers would be on a Gunter rule, the spread of the indicators being equivalent to the spread of dividers. For Oughtred, it was a natural transition from the Gunter rule to the circular slide rule to employ the two indicators. In contrast, Delamain's double-disk circular slide rule had a smaller disk rotating inside a larger disk. The calculations were carried out much like on a common slide rule with the smaller disk being positioned much like a slide, and the single indicator being used to mark the result.

Figure 1. Delamain spiral circular slide rule—from Cajori [10]

Delamain's creativity may have been that he conceived of the long-scale slide rule in concentric ring format in deference to the spiral scale format that Oughtred had told him about, and that he promoted the double disk over the single disk format. However, one thing that Delamain apparently did not recognize, is that by running his outer scale inwards, he lost a big advantage of the spiral and concentric ring slide rule formats. That advantage being that for spiral scales running outwards on a disk, the precision is improved at the higher end of the scale because the gradation spacings increase as the diameter of the rings (or revolutions) increases.

Moreover, Delamain was really thinking big about long-scale slide rules. In addition to his concentric ring slide rule, he also conceived of a "Great Cylinder" slide rule a "yard" in diameter with ten or more pairs of ganged fixed and moveable calculating disks. It is doubtful that such a device was made; if it had been the scale length could have exceeded 30m. Delamain could be thought of as the father of the cylindrical slide rule, as that idea apparently did not come from Oughtred.

History of Long-Scale Slide Rules – 17th through the 19th Centuries

Most of the innovations in long-scale slide rule technology came in the period between Oughtred's invention of the circular slide rule in about 1621, and the advent of the modern age of slide rules in the 20th century. My source for much of this early history was the reprint of Florian Cajori's [9] *A History of the Logarithmic Slide Rule.* The different long-scale slide rules found in this study are listed in Tables I and II.

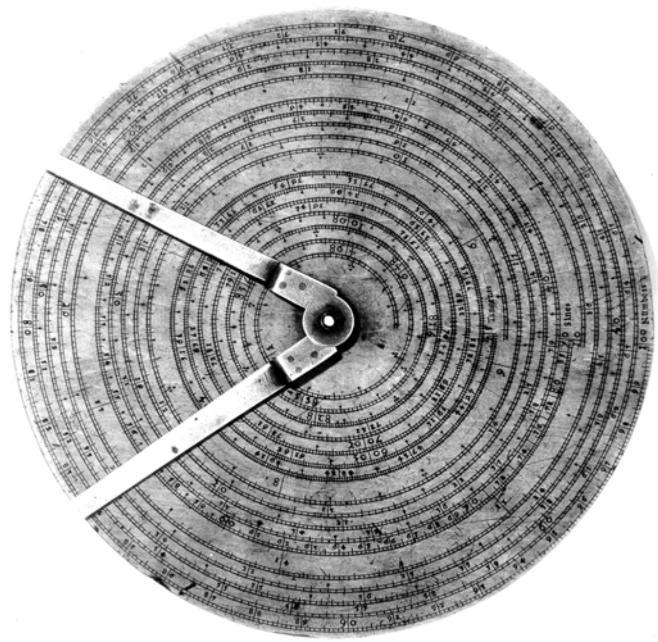

Figure 2. John Brown spiral slide rule, ca.1660—Science Museum/Science & Society Picture Library, London [57]

The 17th Century

Most of the early developments in slide rule technology were made in England. As we have seen, long-scale slide rules were among the first of the innovations that appeared. In addition to the work of Delamain, Cajori reported that Milburne of Yorkshire designed a spiral form of slide rule about 1650. Cajori also found that about this same time John Brown projected Gunter's line into a kind of spiral of 5, 10, and 20 turns.

Remarkably, the Science Museum in London has on display two very early long-scale spiral slide rules dating to the mid 1600s, including an original by John Brown [57] that dates to about 1660. The other is a copy of a spiral slide rule designed by William Oughtred, signed Henr Sutton fecit, and dated 1663 [58].

The John Brown spiral slide rule (Fig. 2) is made on a wooden disk, about 15cm diameter. This disk has three spiral scales: 1) the innermost one a 7-revolution tangent scale; 2) the outermost scale being a 5-revolution number scale; and 3) a 5-revolution sine scale between these two scales. The scales all wind their ways outwards on the disk. A pair of brass indicator arms facilitates the calculations. The number scale is about 213cm long. With care, the John Brown spiral slide rule can be read to about four digits. It should be mentioned that John Brown was probably mentored in the art of making spiral slide rules by his father, Thomas, who is credited by

Hopp [26] for making the first spiral slide rule in 1631. Hopp suggests that William Milburne may have been the inventor of the spiral slide rule, but as we have seen earlier, Oughtred has claimed credit for that invention.

The Sutton spiral slide rule (on the cover) is laid out on a brass disk about 34cm diameter. The scale layout is most curious. It starts near the center of the disk with four windings of a pair of scales for calculating functions of angles. The number scale starts at the beginning of the fifth winding and continues for five additional windings, while the angle scales continue for an additional two windings. A pair of brass indicator arms facilitates the calculations. The five-revolution scale has a length of about 280cm. Like its John Brown contemporary, the Sutton spiral slide rule can also be read with interpolation to about four digits.

Another finding of Cajori [9] was a slide rule made in England in the mid 1600s by Horner with a calculating scale made up of many parallel segments. This slide rule appears to be the forerunner of the gridiron slide rule that was developed later in the 19th century. Cajori did not report any details, so we do not know what scale lengths were obtained. He also mentions a semicircular slide rule conceived by a German writer named Biler in 1696. It is described as having sliding concentric semicircles, but no details are given.

The 18th Century

The idea of the long-scale slide rule was also promoted by John Ward in 1707. Ward found that pocket slide rules having a length of "nine inches or a foot long . . . at best do but help guess at the Truth." He recommended slide rules of "two or three feet" (60 to 90cm) in length to get the accuracy required for gauging liquid spirits in casks. One must recognize that a part of the problem that Ward and the gauging profession faced was that the calculating scales on ordinary slide rules were often crudely laid out. It was apparently easier in his time to lay out the scales more accurately on long slide rules.

In 1733, Benjamin Scott described a circular slide rule nearly 46cm diameter with a circular scale having a circumference of about 1.5m. According to Cajori, Scott was unaware of any forerunners of his work. A few years later, in 1748, George Adams, an instrument maker in England, engraved a spiral scale with 10 windings on a brass plate about 30cm diameter. Although it is not known for sure, the scale on Adams' slide rule may have been as long as 5m.

In the 1700s, there were also some developments in long-scale slide rule technology in other European countries. In 1717 in Italy, for instance, Bernardus Facini designed a spiral scale slide rule that had a scale length of about 120cm. Interpolation of readings was aided by the inclusion of vernier-like markings that run on a band just outside the spiraling scale. The only known copy of Facini's slide rule is in the Adler Planetarium & Astronomy Museum in Chicago. A photo of this disk appeared on the cover of the *Journal of the Oughtred Society* [31].

In Germany in the 1770s, scientist Johann Heinrich Lambert had linear slide rules made that had scale lengths of "4-feet" (about 130cm). In England (c1775) the Robertson [46] sliding Gunter slide rule employed a calculating scale about 72cm in length. Examples of this slide rule are known to be in two private collections.

In 1727 in France, Jean Baptiste Clairaut described a circular slide rule having a 53cm diameter, which had a large number of concentric circles, one of which was a long-scale number scale. While not known, the length of this calculating scale could have been greater than 1.5m. Even more impressive is another long-scale slide rule of Clairaut. In 1716, he designed a multi-segment linear slide rule laid out on a square of one foot, filled with parallel lines making up a single number calculating scale. Cajori [9] reported that this slide rule had a scale length of "1500 French feet". Given about 32.5cm per one old "French pied" (foot), the length would be an unlikely 500m. Perhaps something was lost in the translation. This slide rule appears to be one of the first of the gridiron type, but its details remain a mystery.

Later in the 18th century, the Englishman, William Nicholson, made several contributions to increasing the precision of slide rule calculations. In 1787, Nicholson described a straight slide rule having a double line of numbers (2-log cycles) 610cm long. According to his design, the scale was broken down into tensegments. This slide rule body must have been about 60cm long. Nicholson even devised a kind of runner to help with the calculations.

Nicholson was the first to design a gridiron slide rule. Gridiron slide rules break the calculating scale into a series of segments laid out one below the other in parallel. There is no slide in the conventional sense. Nicholson's gridiron slide rule had 10 segments (each successive segment repeating the last half of the previous segment) and a total scale length of over 3m. A beam compass-like device that slides over the surface of the rule facilitates calculations. It was described in the third edition (1798) of the Encyclopedia Britannica [17] and an illustration shown in my earlier long-scale paper [11].

Nicholson also developed a circular slide rule having a single line of numbers made up of three concentric circles, and in 1797 he described a ten-revolution spiral slide rule having a total scale length of 12.5m. Cajori shows illustrations of Nicholson's slide rules taken from his writings, but stated that it is uncertain if any of his slide rules were constructed and sold.

The 19th Century

The 19th century was characterized by great advances in improving and adopting slide rule technology. The industrial revolution, accompanied by expanding needs of science, technology, and commerce for efficient and accurate means of making calculations, caused a great rise in slide rule technology. This was also a period of maturity for long-scale slide rule technology.

The reader will recall that the first long-scale calculating rules based on the logarithmic scale were not slide rules, but were Gunter rules. In the early 1600s William Forster made Gunter rules with two-cycle calculating scales having a single cycle length of about 91cm. However, most Gunter rules made in later years have two-foot-long 2-cycle number scales, so the scale length for a single cycle (30.5cm) was not much longer than on the common 25cm (10-inch) slide rule. However, a modification of the two-foot Gunter rule in my collection, made in the mid-1800s, called the Donn Navigation Rule, carried a single cycle scale having a length of about 61cm.

The French were also busy developing long-scale slide rules in the mid- to late 1800s. Cajori [10] reported that Delamoriniere and Delaveleye made linear slide rules with scale lengths ranging from 50 to 115cm (c.1863), and long-scale bi-segmented slide rules were designed by Mannheim (c1850s), and by E. Praux, named the "chelle Logarithmique" (c1860s). Unfortunately, few details of these slide rules were reported.

However, we do have complete details of two different long-scale slide rules, based on bi-segmented scales, made by the well-known French slide rule maker, Tavernier-Gravet. One described by von Jezierski [69 & 70] is a 100cm long scale on a 50cm slide rule body (with one slide) designed by Lallemand (c1875). This slide rule broke the calculating scale into two segments, the scale pair at the top margin of the slide running from 1 to 3.16 on the upper stator and 3.16 to 10 on the upper edge of the slide, and on the bottom margin from 1 to 3.16 on the lower edge of the slide and 3.16 to 10 on the top edge of the lower stator.

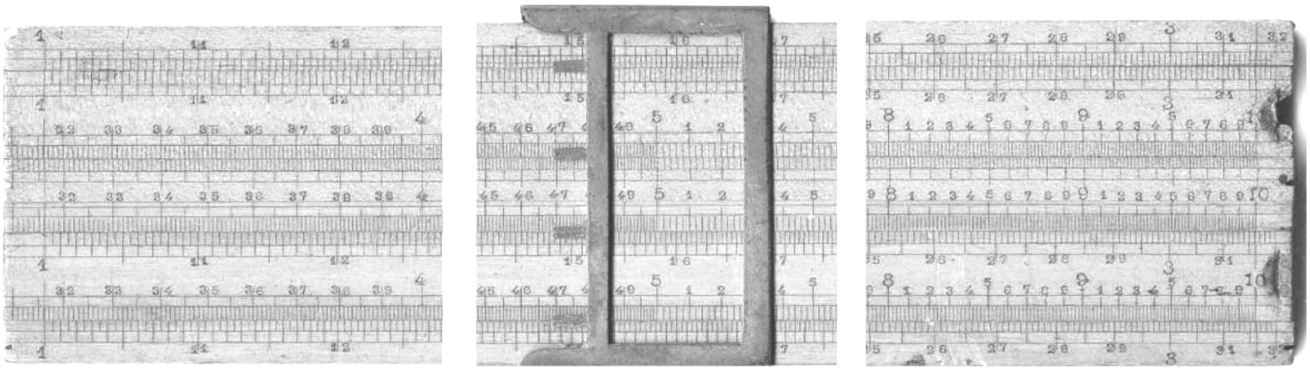

Figure 3. Tavernier-Gravet Long-scale Slide Rule— courtesy of Ron Manley [39] and Jim Bready [8]

Another of the Tavernier-Gravet long-scale slide rules with bi-segmented scales is shown (Fig. 3) on Ron Manley's slide rule web site [40]. This example has two slides and has 50cm long-scale sets on a 25cm slide rule body. It has two different sets of long-scales. The scale pair at the top margin of the top slide running from 1 to 3.16 on the upper stator and 1 to 3.16 on the upper edge of the slide, and from 3.16 to 10 on the lower edge of the slide and 3.16 to 10 on the edge of the stator. The scale pairs on the lower slide are identical to those on the Lallemand T-G slide rule. The precision of calculations with the Lallemand 100cm version may be a little better than on the 50cm version, but the 50cm version is a little more efficient because the two slides provide the choice of using matched or folded scales. Perhaps the two-slide version of the T-G long-scale slide rules was designed by Mannheim, for it is well known that Tavernier-Gravet made slide rules with Mannheim's designs.

It was in the 1800s before any important developments in long-scale slide rule technology occurred in the United States. It appears that the first long-scale slide rule made commercially in the United States was the 20cm diameter circular slide rule designed Aaron Palmer in the 1840s. John E. Fuller improved this slide rule with the addition of a Time Telegraph scale on the reverse, and copyrighted in 1846. Details of this slide rule have been reported by Feazel [18]. It sold under the Fuller-Palmer name in fairly large numbers over the next 20 years. A copy in my collection has a calculating scale of about 67cm in length.

The Nystrom "Calculator" (circular slide rule) appeared in the US in 1851, shortly after the Fuller-Palmer. The Nystrom [41] is elegantly engraved on a 24cm-diameter brass disk—somewhat a reminder of the early Oughtred circular slide rule. A kind of vernier scale is built into the slide rule and cursor markings to aid in the interpolation between gradations. It appears that, with the vernier, readings can be resolved to four digits at both ends of the scale. Unfortunately, I did not have a copy of this slide rule to examine closely. The Nystrom Calculator is very rare, and highly desired for collections. One sold at the Skinner Science & Technology auction [62] in 1997 for \$10,350.

In the mid 1800s, Ferdinand R. Hassler developed a 68cm-long slide rule for his personal use at the US Coast and Geodetic Survey. This slide rule was arranged so that two broad wood rules could slide adjacent to each other. Brass end posts on opposite ends of each piece and a tongue and groove arrangement kept the sliding pieces adjacent to each other. There must have also been a sliding indicator, but it is missing from the example studied. On one side, there is a pair of ten-segment calculating scales, one scale set on each of the wood strips. One long-scale set runs from 1 to 100 and the other runs folded from 8.92×10^2 to 8.92×10^4. The length of a single cycle in this scale pair is about 3m. This slide rule could make calculations to about four digits precision. The other side of the Hassler slide rule had ten-segment scale sets for 2- and 3-cycles. These scale sets ran from 1×10^6 to 1×10^8 and 1×10^6 to 1×10^9. The Hassler Geodetic slide rule was obviously a special-purpose long-scale slide rule. The only example known is shown on the Internet site of the National Institute of Standards and Technology Virtual Museum [42]. It may be one of a kind.

Clairaut's and Nicholson's 17th century ideas about gridiron scales were followed up in the 19th century by Everett, Hannyngton, Cherry, Billeter, Scherer, Evans, and Proell, but not until the latter half of the 19th century. The most successful (in terms of examples making it into collections) was designed by Hannyngton. Hannyngton's gridiron slide rules (1880s-1920s) broke the scale into segments on parallel boxwood square rods [14, 30]. Each rod on the base set of scales repeated half of the scale segment on the previous rod. The sliding set of rods is ganged and nests into the spaces between the base set of rods so that the scale markings are adjacent to each other. The sliding set of rods is one half the length of the base set. This arrangement keeps the slide from falling off one end of the base when making calculations. Aston & Mander, the English maker, made at least two versions of the Hannyngton, one with five rods per scale and a long-scale length of 159cm and the other with ten rods per scale and a scale length of 318cm. These are sometimes referred to as Hannyngton's small (60-in) and large (120-in) "extended" gridiron slide rules. An example is shown in Figure 4.

Cherry's gridiron slide rule (1880) took a little different form. According to Pickworth [48], the Cherry Calculator had segmented scales laid out in a series of parallel lines on the base. The lines were laid out on a slight bias (Fig. 5) so that the end of a segment line is at the same elevation as the beginning of the next segment line. If the lines were laid out on a sheet of paper and wrapped around a cylinder of appropriate diameter, a helix scale much like one on the Fuller cylindrical slide rule would be formed. A matching set of lines was laid out on a transparent sheet that functioned as a slide. Each of the four corners of the base and transparent slide scale sets had index marks. These index marks and the biased scale segments facilitate the calculations. The advantage of this arrangement is that there was no need to repeat parts of scale segments.

Towards the end of the 19th century, the Swiss company Billeter (c1890) also made gridiron slide rules—unlike the Cherry model—that had the scale segments in parallel lines running straight across the tablet. The base scales were repeated. The glass slide had paper scale strips glued to the underside of the glass. According to Joss [34], the Billeter Rechentafel came in four sizes: 0.5, 1, 4, and 8m in scale length, with the scale broken into four, eight, and ten segments for the first three sizes. The details are not known for the largest 8m model.

Printed graphic tables are another class of long-scale logarithmic calculating devices. They are similar to gridiron slide rules, but do not have sliding pieces. Cajori [9] reported that in 1846 Lon Lalanne designed a *Tableau Graphique*, that may have been the first graphic table of calculating line segments. However, Cajori does not give sufficient detail to be sure. Later in the late 1800s, Loewe [39] published his *Rechenscalen für numerisches und graphisches Rechnen* in Germany. The segments run vertically in Loewe's graphic calculating table in fifty segments, on five pages, for a total long-scale length of about 10m. A pair of dividers is used to facilitate the calculations. Details were reported by Holland [24]. Holland also reported that Anton Tichy [66] published the book *Graphische Logarithmen-Taflen* in Austria in 1897, but gave no details.

Figure 4. Dixon's Combined Circular, Spiral, Multi-Index Slide Rule, ca.1882—Science Museum/Science & Society Picture Library, London [59]

The Science Museum in London has a third spiral slide rule [59] (Fig. 4) in its collection, one made by Dixon in 1882. Dixon's Combined Circular, Spiral, Multi-Index Slide Rule and Four Figures Logarithmic Decimals Scale Table is mounted in a wooden frame. It has single-cycle number and common logarithm scales on an outer ring, and a ten-spiral 421cm long scale running outwards from near the center of the paper scale surface. Three brass indicators facilitate the calculations. Pickworth [48] and Cajori [9] also mention spiral slide rules by Schuermann (c1896) and Fearnley (c1900), but give no details.

Figure 5. Calculigraphe pocket watch slide rule—author's collection

The first pocket watch-style circular slide rule with a segmented long scale—the Boucher or Calculigraphe (Fig. 5)—was designed by Henri Chatelain in France in the 1870s [27]. It had a 30cm long scale made up on three-concentric rings. The Calculigraphe was made or sold by several different engineering instrument specialists, including: Keuffel & Esser [35] and Dietzgen [16] in the US; W.F. Stanley, "Manlove, Alliott & Fryer", and J.F. Steward in The UK; J-B Rehan and Pedos S.A. in Switzerland; and Henri Chatelain and others in France [26]. Models are known to be marked H-C, F-C., A.F., E.D. Co., Stanley, Manlove, "Manlove, and Alliott & Fryer", and K&E Co. The example in my collection is marked H-C, and came with a K&E instruction pamphlet labeled: "Boucher Calculators (Calculigraphs.)—Keuffel & Esser Co.—127 Fulton Street, New York". Another pocket watch slide rule with a segmented long scale that appeared in the late 1800s is the

Mechanical Engineer. This pocket calculator has two concentric ring segments, and came in several sizes, including models with 17 and 24cm scale lengths. Examples are known with and without the Mechanical Engineer marking. One example is marked "SWISS" [15], lending a clue to the country of origin. The Mechanical Engineer was sold by W.F. Stanley, The Scientific Publishing Co, and others.

The first mention of a cylindrical slide rule that I found in Cajori's history [9] (other than Delamain's fantasy "Great Cylinder" is one attributed to Hoyau (1816) in France. However, no details are given. According to Cajori, both J.D. Everett (a Scottish 19th century maker of slide rules), MacFarlane (c1842) and Amédée Mannheim (the most influential of French slide rule designers in the 19th century) also designed cylindrical slide rules. However, we do not have any details for these either.

Arguably, one of the most innovative long-scale designs was the helix scale laid out on a cylinder. The most widely known of this type of slide rule was the Fuller "Calculator" made by Stanley of London, and invented by George Fuller in 1878. The Fuller "Calculator" has a scale length of almost 12.8m that winds around a 7.6cm diameter cylinder—20 times. Two brass index pointers facilitate the calculations. It came in several different models. It was well described by Feely and Schure [22] in a previous volume of the *JOS*. Fuller may also have designed a "Midget" model having a scale length of about 5.08m.

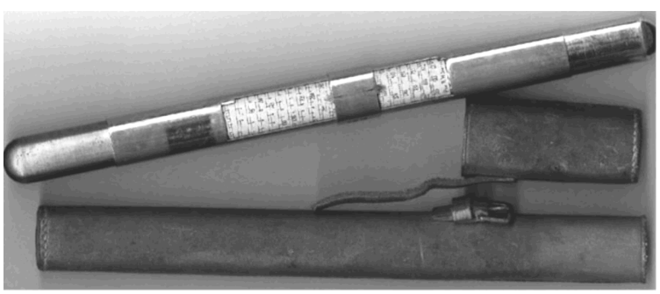

Figure 6. R.H. Smith cylindrical slide rule—courtesy The Gemmary [65]

According to Cajori [9], other cylindrical slide rules with helical scales were also designed by Mannheim, MacFarlane, Everett, G.H. Darwin, and Prof. R.H. Smith from the middle to the late 18th century. Little is known about the Mannheim, MacFarlane, Everett, and Darwin devices. However, several examples of the Smith Calculator are known with scale lengths of 102 and 107cm. See Figure 6, for example.

Another innovative development in long-scale technology in the US was the cylindrical slide rule patented by an American civil engineer, Edwin Thacher [21], in 1881. Thacher broke a double calculating scale into 40 segments, each 46cm long, and each repeating half of the preceding scale. The cylinder slides inside a sleeve of 20 parallel rods, each having two sections of the double scale (matching two sections on the cylinder). The effective length of the Thacher long-scale is 9.14m. Thacher cylindrical slide rules were made in England until c1900. Thereafter, they were made by Keuffel & Esser in the United States. The Thacher cylindrical slide rule has been the subject of numerous papers in the *JOS*.

Two other makers of cylindrical slide rules got their start at the end of the 19th century: the Swiss companies Daemen-Schmid (1896)—which later became Loga—and Billeter (1886). These companies were most active in the 20th Century. Their cylindrical slide rules will be discussed in a later chapter.

One other long-scale slide rule innovation reported by Cajori [9] takes the form of a tape that is taken up on a spool or spools. The idea is to place the logarithmic line upon a pair of continuous metallic tape, wound from one roller or spool upon another, as in instruments by Darwin (1875) and Tower (1885). Cajori provides no details for these makers. A later version of this type of slide rule was developed by J.R. Paisley [20] in 1939 (Fig. 7). Another was patented by Silvio Masera in 1902 [32].

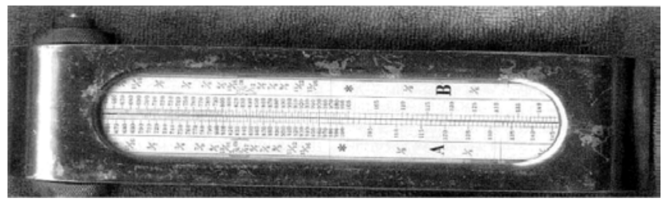

Figure 7. Paisley tape Calculator—[20]

Long-Scale Slide Rules in the 20th Century

Important sources for details on long-scale slide rules in the more recent history were the wonderful books on slide rules by Peter Hopp [26] and Dieter von Jezierski [69]. Other sources included offerings from many other slide rule collectors and my own collection of slide rules. These are the long-scale slide rules that the collector has the greatest chance of finding. In this section, I have broken the discussion down for the various formats of slide rules. Tables I and II summarize the results.

Slide Rules with Linear Formats

This category focus primarily on segmented scale linear slide rules, and does not cover slide rules with single-segment 50cm scales as there are just too many to consider here. However, there are two single-segment straight slide rules with scales longer than 50cm that deserve mentioning. One of the first (c1904) in the 20th century that comes to mind is the Scofield-Thacher Engineer's slide rule [56]. It has several scales designed for the structural engineer, including a 56cm long single-cycle calculating scale. Another is the Nestler Reitz, made in the 1930s, that had a single-segment scale with a length of 1m [26 & 69].

One more long-scale slide rule that deserves recognition is the "Texas Magnum" slide rule constructed by Skip Solberg and Jay Francis [63] in an aircraft hangar on February 28, 2001. It is 107m long in one segment, having a precision of nearly six digits. While this slide rule was not intended for commercial production, it is recognized by the Guinness Book of Records as the longest slide rule ever made.

In the 20th century, slide rule makers introduced several new linear slide rules with segmented calculating scales. For instance, the Nestler [69] Precision #27/9 (also listed as 27/a) model was a 50cm slide rule with a pair of calculating scales broken into two segments, each 50cm in length. The first segment runs from 100 to the square root of 1000, and the second segment runs from the square root of 1000 to 1000. There are a pair of 1st segments at the upper margin of the slide and a pair of 2nd segments at the lower margin of the slide. The effect of this arrangement was to give a calculating scale of 100cm length. The Nestler Precision slide rule also came in 15cm and 25cm scale lengths, having calculating scale lengths of 30 and 50cm, respectively. Table 1 shows that other slide rules with two-segment scales were made (or sold) by Wichmann, Unique, Dennert & Pape, Faber-Castell, Dietzgen, Roos, and Favor.

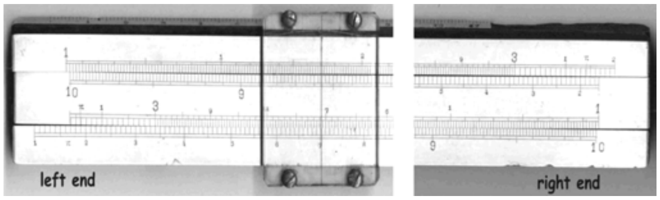

Figure 8. Post Ritow "Long" slide rule—author's collection

In my collection (Fig. 8), I have a 50cm (German made) Post slide rule with a pair of 100cm scales, each made up of two segments—half of each pair on the stators and half on the slide. This slide rule is interesting because the half scale sections on the slide are inverted—something like the CI scale on a modern slide rule. In 1910, Pickworth [48] described a similar slide rule and named it the "Long" slide rule. The example in my collection has the Dennert & Pape patented screw adjustment system for regulating slide friction. A German patent was issued for this system in 1903, so the "long" scale slide rule mentioned by Pickworth and the example in my collection could be the same, with the German maker, perhaps, being Dennert & Pape. Post may have sold this as a Ritow model #1466 slide rule [45, 51], which was listed in Frederick Post catalogs in the 1920s. Dennert & Pape showed similar models with 25 and 50cm scale lengths in their 1910 catalog [70].

The 25cm Unique Pioneer Long-scale [6] and the 50cm Hemmi #201 [19] slide rules take the segmented scale innovation to another level. Both of these slide rules break the calculating scales into four pieces each, the resulting scale length being 100cm for the Unique Pioneer and 200cm for the Hemmi #201. The C scale is broken into four equal length segments on the slide and four matching D-scale segments on the lower stator. For this case, the number of digits that can be resolved is further improved to about four. However, it begins to get a bit tricky in deciding on which scale to read the result. One either calculates the approximate result in one's head, or resorts to making a calculation with a normal pair of C and D scales before using the segmented C and D scales.

The Hemmi #200 [69] is a 41cm duplex slide rule that breaks the scale into even more segments. It breaks the C and D scales into six sections each, giving an effective 244cm scale length. As for the Hemmi #201, one must be adept at calculating the approximate result in one's head, or resort to a normal set of calculating scales to get the approximate result, so that one knows on which scale to read the result.

Gridiron Slide Rules

As we have learned, the earliest of the gridiron slide rules found was the ten-segment, 305cm total length, slide rule attributed to William Nicholson (c1797) [9].

The Hannyngton "Extended" gridiron slide rule (Fig. 9), which was first made in the late 1800s, continued to be sold into the 1920s. Cherry's gridiron "Calculator" was also sold into the early 1900s (Fig. 10). Proell's gridiron "Pocket Calculator" appeared at the turn of the 20th century. It was similar to the Cherry Calculator, except that the scales on the sliding part (clear celluloid) run from right to left, much like the inverse scale on a common slide rule. Multiplication is accomplished by placing a needle to fix the position of intermediate results in multiple calculation problems. Index marks on the fixed lower card enable square and cube roots to be extracted.

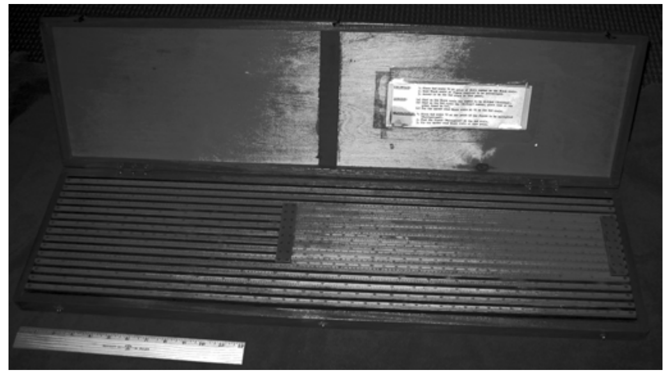

Figure 9. Hannyington's gridiron slide rule—courtesy of Bob DeCesaris [14]

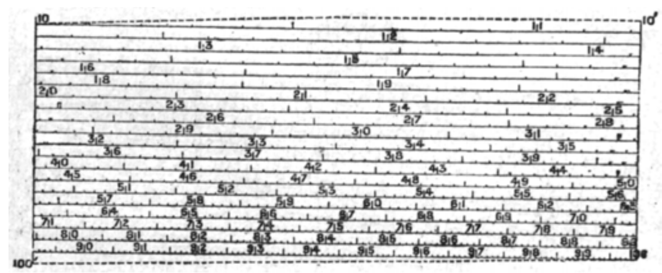

Figure 10. Cherry's gridiron slide rule—from Pickworth [47].

An instruction manual issued in 1909 by the Kolesch Co. [47] listed a gridiron slide rule called the "Calculigraph" or "Australian Slide Rule". It was printed on cardboard. The scales are printed on 13cm. x 28cm. "cardboard" in two ranks of 22 parallel segments to form a two-cycle calculating scale. A sliding transparent "bridge" with a one-cycle segmented scale is used to make the calculations. The scale length was about 5.5m. According to the advertising material, this slide rule had a max error = 1 in 5000, or nearly five digits precision.

The Gilson Slide Rule Company is better known for its circular slide rules, but it appears that very early in this company's existence (ca. 1915) it sold a linear pocket gridiron slide rule that broke the calculating scales into 14 sections. An advertisement in the instruction manual [50] for the Richardson Direct Reading slide rule shows the Gilson "Pocket Slide Rule" having 14-section calculating scales for a total scale length of about 178cm. The scales are printed on "heavy water-proof Bristol," a cardboard-like material. The price was 50 cents. The only mention of this slide rule that I have been able to find is in the Richardson and Clark instruction manual. It is uncertain if any copies have survived.

The Cooper (20-segments, 250cm length) is an interesting variant of a gridiron slide rule sold in the early 1900s. This slide rule was described in detail in an article by Bennett [7]. A single 20-section scale was laid out on a white celluloid sheet laminated to a mahogany board, with the scale on 20 parallel lines, each about 13cm long. The four corners of the block of scales are marked with special indicator marks labeled with the number 100. A separate clear celluloid sheet with matching indicator slides over the calculating scale. The calculations are made using the appropriate corner indicator mark and a weighted pointer that freely slides over the clear celluloid sheet.

Hopp [26] mentioned that Gladstone's "Cross Gauge" was much like the Everett gridiron, but gives no details other than it had a scale length of greater than 10m. It was sold in the 1920s. Two other gridiron slide rules available in the 20th century have come to my attention. One is the Marotti "Lagartabla" gridiron. This appears to be of Eastern European origin. It has a 27-segment base (repeating) scale printed on a metal sheet, and a 14-section sliding metal piece with slots to reveal the scale beneath it. The scale length is about 240cm. One was sold at auction at IM2000 [28]. Unfortunately, I was not alert enough during this auction to prevail. The other gridiron slide rule, the "Logaritmal" (Fig. 11) was designed by Vaclav Jelinek. Reinhard Atzbach [3] reported details for the Logaritmal on his Internet site, including download images for construction of this gridiron slide rule. It breaks the scale into ten segments, having a total length of 1.5m.

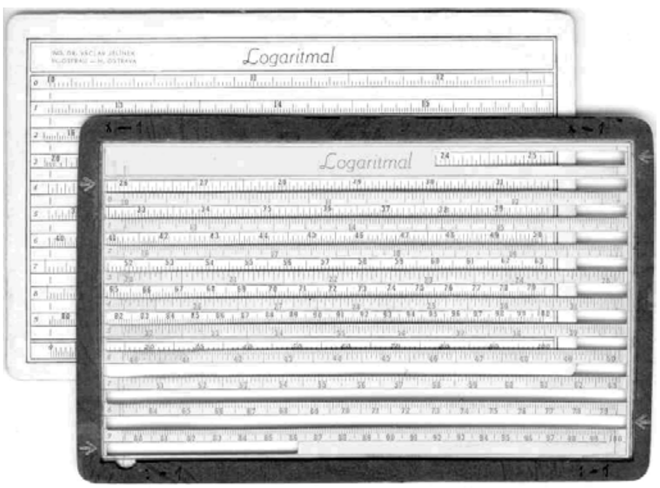

Figure 11. Logaritmal gridiron slide rule—from Richard Atzbach [3].

Slide Rules with Sawtooth Formats

One more interesting idea that surfaced in the 20th century to improve slide rule precision was the incorporation a 'vernier' into the calculating scale by a kind of sawtooth arrangement. Babcock [4] reported on two different approaches. One by A.N. Lurie developed in 1910 used diagonal lines drawn from the bottom of one scale division to the top of the next. This diagonal line, in combination with a series of horizontal crossbars on the cursor, allows the user to divide the space between the divisions into ten parts. Lurie applied his method to an ordinary 25cm Mannheim slide rule, but Richardson employed a similar concept to a gridiron type scale. Richardson (c1918) used a method designed by Yu Wang, whereby a kind of tent or triangle is laid out between gradations. In Yu's design, five parallel horizontal lines are drawn within the triangle. The reading of the cursor hairline is then determined by where it crosses the point of intersection of one of the horizontal lines and one of the diagonal lines. This same concept was employed on the Appoullot "Logz" circular slide rule [55], but in this case the "tent" between gradations is formed by ten short lines drawn normal to the scale direction. In this case, the tent is located in the space outside of the calculating ring where there is more room. The Appoullot slide rule is also interesting because it incorporates a spiral scale.

Charts and Table 'Slide Rules'

The Goodchild and the LaCroix and Ragot calculating charts [12] are interesting variations of the gridiron type slide rule, but without a sliding piece. The Goodchild Mathematical Chart and its accessory triangular (tallying) rule were sold by K&E [36] for a short time in the early 1900s. The chart broke the number scale down into 100 parallel segments on a single folded card stock sheet. The total scale length is over 16m. Each line is numbered at the beginning and end with the first two digits of the mantissa. The balance of the logarithm is represented by the distance along the segment. Every fifth gradation along the segment is labeled with the number represented in the logarithmic scale by the particular segment and distance. The triangular tallying scale acts like a bridge to enable the calculations. One side has scales and a slide to add (or subtract) the first two digits of the mantissa of the numbers in the operation. This gives the initial two digits of the line on which the result will be found. The other two sides each have a series of equally spaced gradations and very short slides that are used as index markers to keep track of the distance of the reading from the left edge of the column. Figure 12 shows the triangular rule on a reproduction of the Goodchild chart. A few of the Triangular Rules are known, but I have been unable to find an original copy of the Goodchild chart.

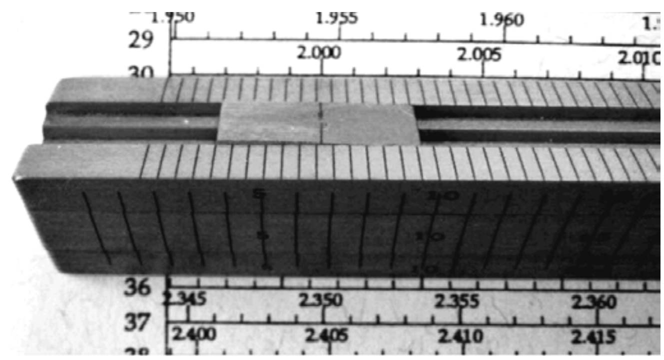

Figure 12. Goodchild tallying rule—author's collection.

The LaCroix and Ragot Graphic Table [37] is a very long (111m) five-place graphical table form of a gridiron slide rule. The table is laid out in 1000 lines over 40 pages in a book format. This graphical table is used much like a table of logarithms, the operations being done by adding (or subtracting) logs of numbers in the normal way. It cannot be used with a pair of dividers or tallying rule because the scale segments are not divided into equal lengths. The advantage of this table is that it is much more compact than a conventional 5-place table of logarithms.

Another printed graphic table that I acquired recently is one printed on a rule by C. Dumesnil, the "Régle Universelle Déposée". It has a 2m long scale laid out on eight parallel segments on paper on the front and back of a boxwood rule. It appears that one uses dividers to make the calculations. I have seen two examples of this rule; one was in an ornate brass souvenir case for a Paris Exposition. The example in my collection (Fig.13) is signed "Médaille A L'Exposition Universelle de 1900".

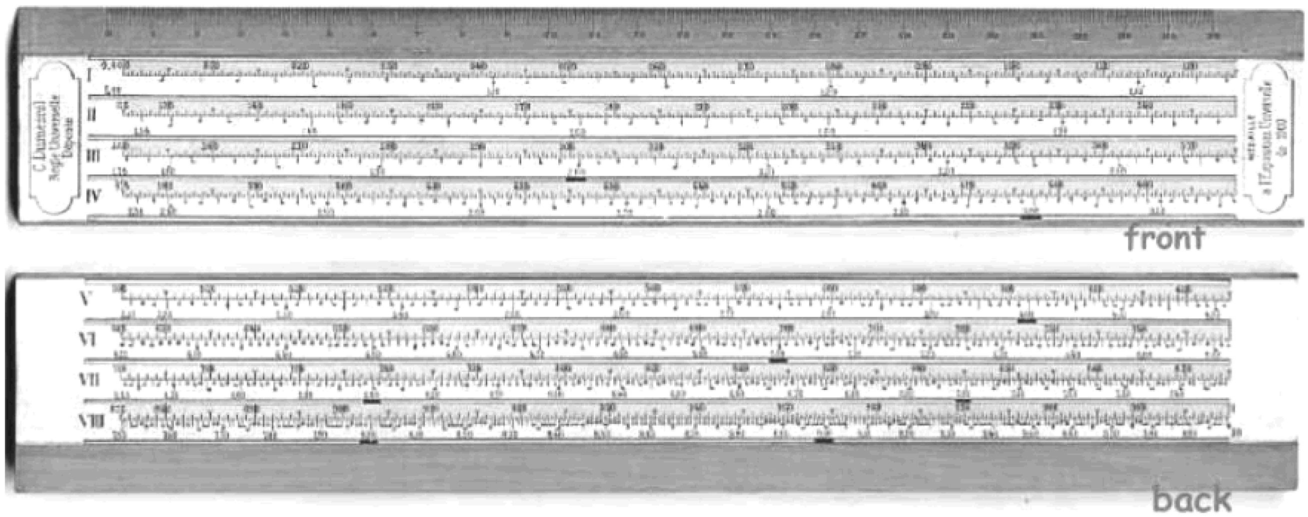

Figure 13. Dumesnil, the “Régle Universelle Déposée”—author’s collection

One other chart type slide rule deserves attention. The *MacMillan Table Slide Rule* [5, 12] is unique among slide rules in that it takes the form of a table of discrete logarithms, not an analog scale of logarithms. There are four tables laid out on card stock, one each for number, logarithm, sine, and tangent operations. Each table has two-cycles of data in a 201-line by 20-column format. The calculations are performed using card stock slides, which have a matching format but with only half the width.

One more possible graphic chart type logarithmic calculator produced in the 20th century, the Knowles “Calculating Scale”, was reported by Cajori [9]. It is uncertain if this was of the graphic chart type or a gridiron calculator.

Circular Slide Rules with Circular Scales

Figure 14. Tröger 1m Rechenscheibe—author’s collection.

Following the innovations of the earliest slide rule makers, many different makers of circular slide rules emerged in the 1900s. Table II shows a few examples of circular slide rules with long-scales, including single-ring circular slide rules with long scale lengths from about 50cm (German Norma Graphia 190) up to about 1m (East German Tröger) (Fig. 14). The popular Gilson Binary and Atlas (made in the US) circular slide rules had long-scale lengths of about 64cm on their perimeters. None of the circular slide rules of the 20th century had long (single-ring) scales approaching the lengths (1.4 to 1.5m) of the 18th century Scott and Clairault circular slide rules.

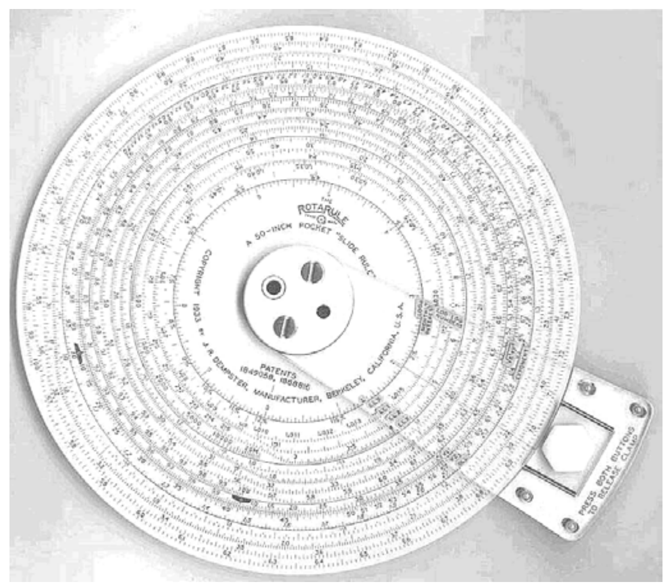

Figure 15. Dempster RotaRule—author’s collection.

Circular Slide Rules with Segmented Concentric Ring Scales

The Boucher (Calculigraphe) continued to be available into the first quarter of the 20th century. It had a segmented three-ring scale with a length of about 30cm. In the early 1900s, K&E introduced another pocket watch style circular slide rule with a segmented three-ring scale—the Sperry [44]. It had a scale length of about 32cm. In the second and third quarters of the 20th century, Fowler [27] produced three different long-scale slide rules with segmented ring scales. They were the “Long scale” (6-ring, 76cm), the “Long Scale Magnum” (6-ring, 127cm), and the “Jubilee Magnum Extra Long Scale”

(11-ring, 185cm). These slide rules were very popular in England and many examples are in collections. The Dempster RotaRule [61] was one of the most complex of the concentric segmented-ring circular slide rules. First made in the 1930s, it had many of the scales common to the log log duplex slide rule, in addition to a 4-ring, 127cm long scale (see Figure 15). Pickett and Boykin [64] made copies of the RotaRule in the 1960s. In the 1960s, the British company, Unique, also showed a concentric segmented ring circular slide rule in their catalogs, the "Dial Calculator" [26], a 5-ring, 127cm long scale. The longest scale concentric ring circular slide rule that I found reference to was the Sexton "Omnimetre #6 (Companion)" [2] circular slide rule. It had 20 concentric rings and a scale length of about 411cm. It dated to the early 1900s. No examples are known to me.

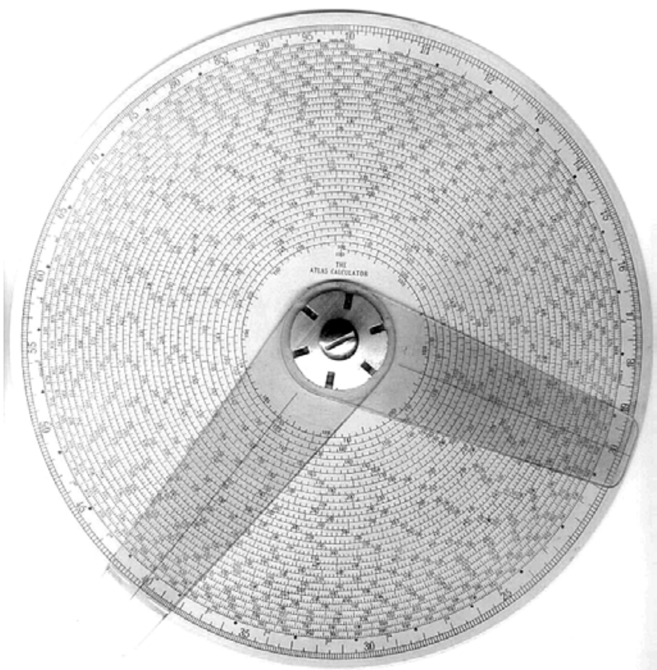

Figure 16. Gilson Atlas (21cm dia disk)—author's collection.

Circular Slide Rules with Spiral Scales

Several new circular spiral slide rules appeared in the 20th century. The Gilson Atlas was probably the most widely known make of this type of slide rule in the United States. It came in three different versions [1]. The standard Gilson Atlas slide rule had a scale length of about 10.7m. The spiral winds 25 revolutions on the 21cm diameter disk. The Atlas has an extra ring at the outer edge of the disk that contains one complete calculating scale. One first makes the calculation on this outer ring to obtain the result to three to four digits, and then repeats the calculation on the spiral scale to get the result to about five digits. The precision of the readings is nearly the same at both ends of the scale. This is the result of the increasing diameter of each winding. This advantage is more pronounced on spiral scales with large diameters and large numbers of windings. Gilson also made two early versions of the Atlas, one sometimes referred to as the "square" Atlas and the other a smaller diameter version (Fig. 16) of the square Atlas, that had 30 windings, and scale lengths of nearly 14m and 11.9m, respectively. The Gilson Atlas slide rules could resolve calculations to about five digits. The square Atlas has a scale length even longer than the scale lengths of the Fuller and Thacher cylindrical slide rules.

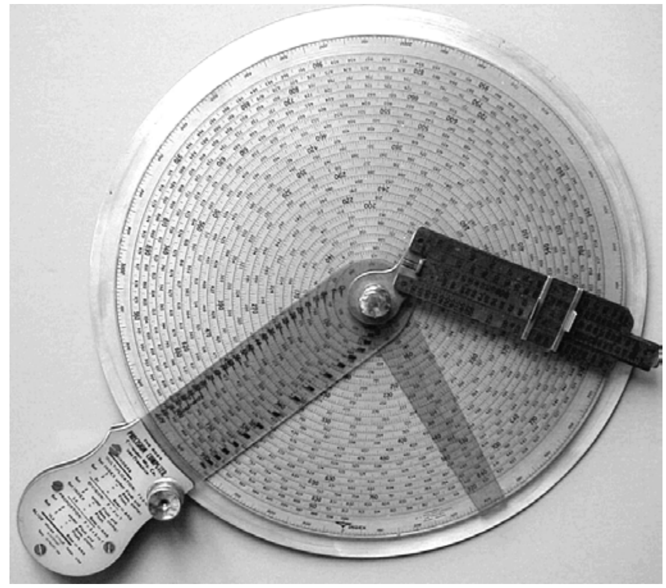

Figure 17. Ross Precision Computer—author's collection.

The lesser-known "Ross Precision Computer" (Fig. 17) has a spiral calculating scale, much like that of the common Atlas slide rule. It has 25 windings, and the scale length is 9.14m. It can be read to about the same precision as the Atlas. The Ross, however, has a unique feature. It has a rectilinear slide rule attached to a radial arm that rotates on the center pivot point. One first makes the calculation on the straight slide rule, and then on the spiral scale using two celluloid indicators. The position of the cursor on the straight slide rule lines up with the appropriate winding on the spiral scale to obtain the result. Examples of the Ross slide rule are quite scarce—with maybe 10 to 20 copies in collections. Many of these are in poor condition because of the unstable metals used in their manufacture. I gathered details from an example in my collection that is made of stainless steel and brass.

Others, including the Appoullot "Logz" [55], Logomat "V & G Nr.816" [54], Alro "Commercial" [53] and Concise "M.V. Douglas" [43] spiral slide rules have shorter scale lengths and fewer windings than the Atlas and Ross slide rules. Like the Ross slide rule, examples of these models are scarce.

The Appoullot Logz (Fig. 18), made in the 1920s in France, deserves a special mention for its artistic qualities. It has three number scales, one each with one, two, and three windings. It also has a vernier scale for obtaining more precise readings from the one-revolution scale. While the two- and three- revolution scales are primarily for determining roots and powers, they can also be used for multiplication and division. As far as is known, the Appoullot Logz came in two sizes, the T2 being about 14cm in diameter, and having scale lengths of about 32, 42 and 63cm, and the T3 and T4 models being about 20cm in diameter, and having scale lengths of about 45, 60, and 90cm.

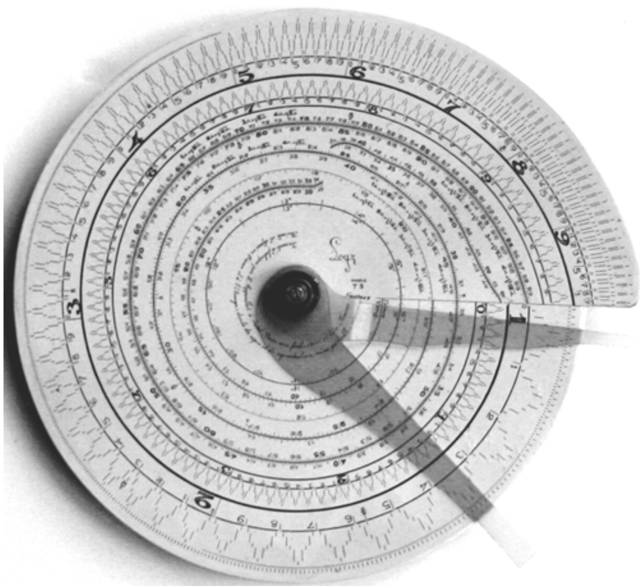

Figure 18. Appoullot Logz—author's collection.

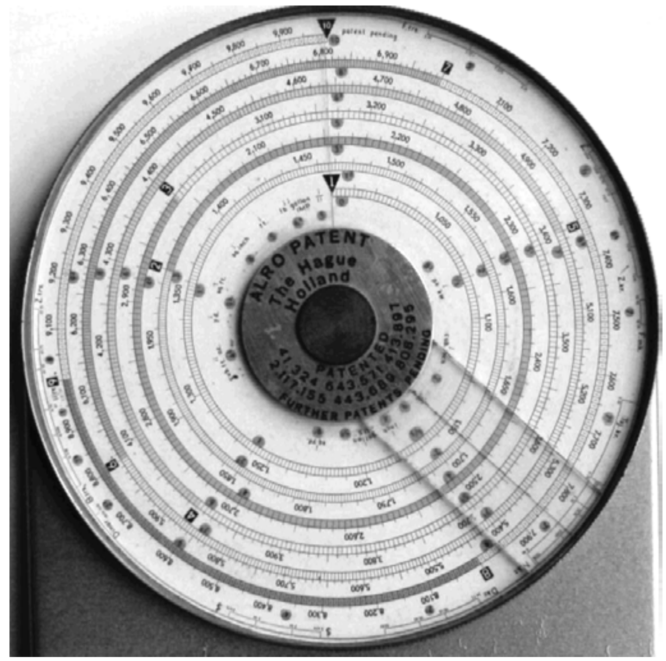

Figure 20. Alro Commercial slide rule—author's collection.

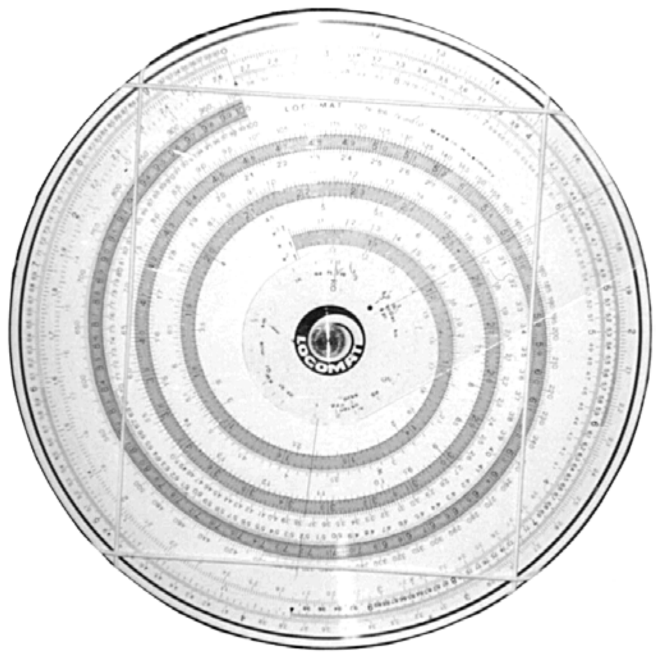

Figure 19. Logomat V&G Nr.816—from [52].

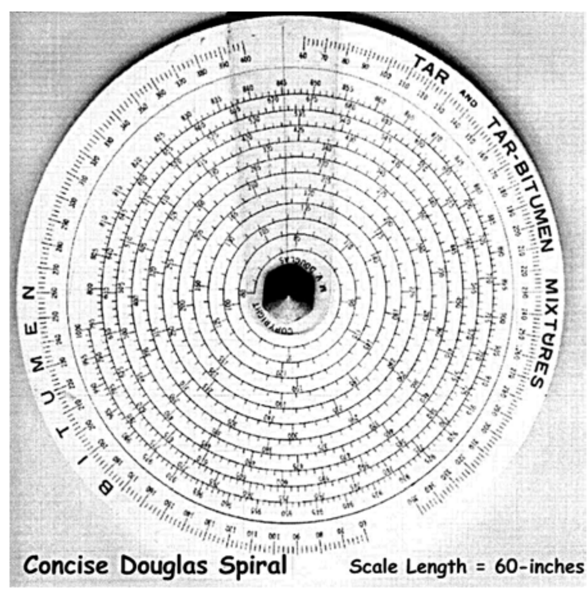

Figure 21. Concise M.V. Douglas spiral slide rule—courtesy of Michael O'Leary [43].

The Logomat spiral slide rules were made in the 1970s, and came in numerous models and spiral scale lengths. The Logomat V & G Nr.816 model (Fig. 19) had the longest spiral scale—with a length of 110cm over three windings. Other Logomat models had scale lengths ranging from about 20cm to 60cm. Details are shown in Table II.

The Alro Commercial slide rule (Fig.20) had a scale length of 150cm over six windings, while the Concise M V Douglas (Fig. 21) had a scale length of 152cm over ten windings.

One other spiral slide rule has only recently come to my attention—the Felsenthal Altitude Correction Computer (Fig. 22). It was used during WWII for making in flight true-altitude calculations. It has one spiral scale that can be used, with some difficulty, for multiplication and division. The scale runs from 700 to 50,000 for more than five revolutions. The portion of the scale running from 1,000 to 10,000 runs for about 2.7 spirals and has a length of about 60cm. Old stock of this slide rule is still being sold.

Cylindrical Slide Rules with Helical Scales

The Fuller helix "Calculator" gained its popularity in the 20th century, and is one of the most widely known of the cylindrical slide rules made. Stanley of London started making them in the 1880s, and continued making them right up until the electronic pocket calculator brought an end to slide rule use in the early 1970s. More than 14,000 were made [22]. The Fuller has a scale that winds around the cylinder 20 times to give a total scale length of about 12.7m. One can resolve the readings to a precision of five digits at the left index and 4.5 digits at the right index, not quite as good as for the Gilson 'square' Atlas, but a little better than the common Gilson Atlas slide rule. Dobie, an Australian company, may have produced Fullers under license to Stanley, the maker of Fuller calculators in the 1970s. Frederick Post Co., an American supplier of engineer's products, listed a cylindrical slide rule with a 12.7m long helix scale (the same length as the Fuller) in their catalogs in the 1920s under the Ritow line of slide rules [49]. It is described as being about 7.6cm diameter and 30cm long, with a 12.3m helical scale, and a magnifying glass to improve accuracy. However, no examples of the Ritow cylindrical slide rule are known.

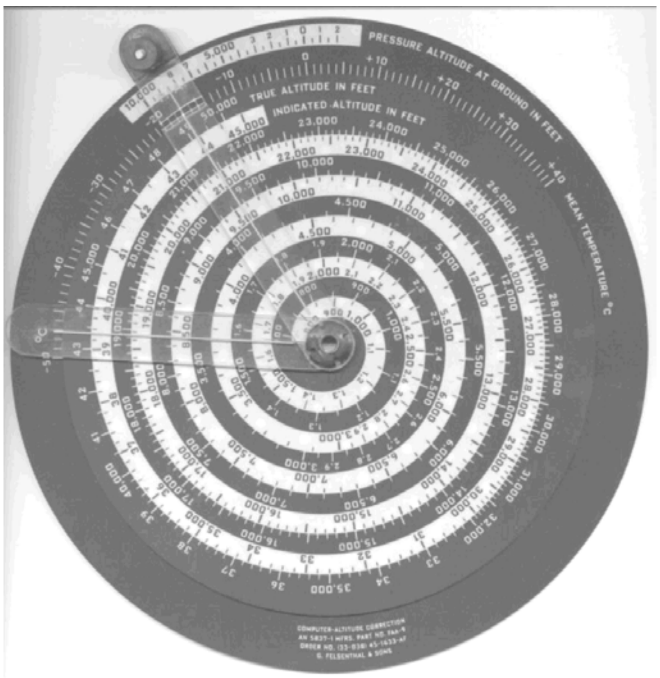

Figure 22. Felsenthal Altitude Correction calculator—author's collection.

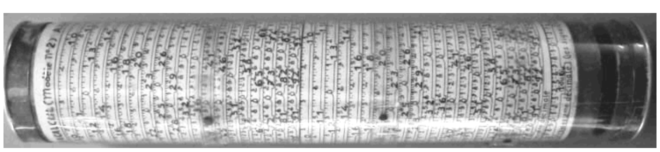

Figure 23. Lafay Helice a Calcul—author's collection.

Other production cylindrical slide rules with helix scales include the well-known Otis King pocket cylindrical slide rule, and the less common R.H. Smith Calculator. The Otis King model 'K' has one double scale with 40 windings and a second single-log-cycle scale with 20 windings about a 2.5cm diameter cylinder [25]. A sliding cursor sleeve facilitates the calculations. The Otis King scale length is about 1.7m, and it can be read with a precision of about four digits. Examples of the Otis King are very common. They were made from the 1920s right up until the early 1970s. They are, perhaps, the first of the cylindrical slide rules to make it into a collection.

The R.H. Smith Calculator (Fig. 8) was described by Weinstock [72]. A description of this cylindrical slide rule also appears in the 11th edition (1910) of Pickworth's [48] book. Weinstock's R.H. Smith slide rule has a cylinder diameter of about 1.3cm and a scale length of about 1m, which contrasts to the 1.9cm diameter cylinder and 1.3m scale length reported in the Pickworth book. The cursors are also different for these two models, the Weinstock version having two brass rods, much like the Fuller cylindrical slide rule, whereas the Pickworth version has an actual sliding cursor something like that of the Otis King, only much shorter. Examples of the R.H. Smith Calculator are scarce.

I have one other cylindrical slide rule with a spiral calculating scale in my collection that deserves mention. It is marked "Helice a Calcul—No.2", and was made by A. Lafay of Neuville S/Saone in France (ca 1930). The spiral scale winds 50 times around a 4cm diameter tube to give a total scale length of about 2.5m and a precision of four digits. A sliding celluloid sleeve and three celluloid cursors facilitate the calculations. Figure 23 shows the Lafay slide rule. My friend, Sigismond Kmiecik, sent me information [38] on other LaFay Helice à Calcul models, including models No.1 and No.2bis. Model No.1 is a smaller version with ten windings and a scale length of 85cm. Model No.2bis has half the number of windings as my No.2, with double the space between windings for "writing personal coefficients". No examples of Models 1 and 2bis are known in collections.

Andrew Davie [13] showed a picture of a "model calculating cylinder" cylindrical slide rule designed by the Russian, Alexander Schukarev ca.1910 that has a design like the Lafay cylindrical slide rule. It appears to have about 80 windings. No other details for this slide rule are available.

Cylindrical Slide Rules with Linear Segment Scales

The most widely known of the cylindrical slide rules with linear segment scales in the US is the Thacher Calculator patented by Edwin Thacher in 1881, and sold by K&E starting in the late 1800s. As described earlier, the Thacher is essentially a 9.14m long-scale gridiron slide rule in a cylindrical format. The Thacher slide rule was made from the 1880s right up into the 1940s. Many examples of this slide rule are known to collectors, as nearly 8,000 were made.

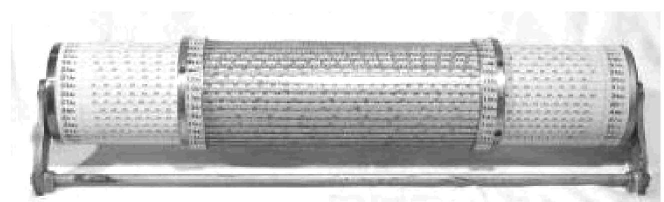

Figure 24. Loga 7.5m Rechenwalze—author's collection.

The Loga Rechenwalze (and its Swiss and German cousins) was the most widely known cylindrical slide rule in continental Europe. The Loga cylindrical slide rule is similar to the Thacher in its operation, except that the cylinder is fixed and the segmented scales are on a sleeve sliding on the cylinder. The sliding sleeve has a length about half that of the cylinder, and the segments on it make up a single scale. Each segment on the cylinder repeats half of the previous segment to facilitate the calculations. This is a Swiss-made calculator that has its origins in the late 1800s under the brand name Daemen-Schmid, becoming Loga in 1915 [32]. It came in many different diameters and long scale lengths—including lengths of 1.2, 2, 2.4, 7.5, 10, 15, and 24 meters [33]. Figure 24 shows a 7.5m Loga Rechenwalze in my collection. The 24m Loga has the longest scale length of any slide rule that I reviewed (other than the printed tables).

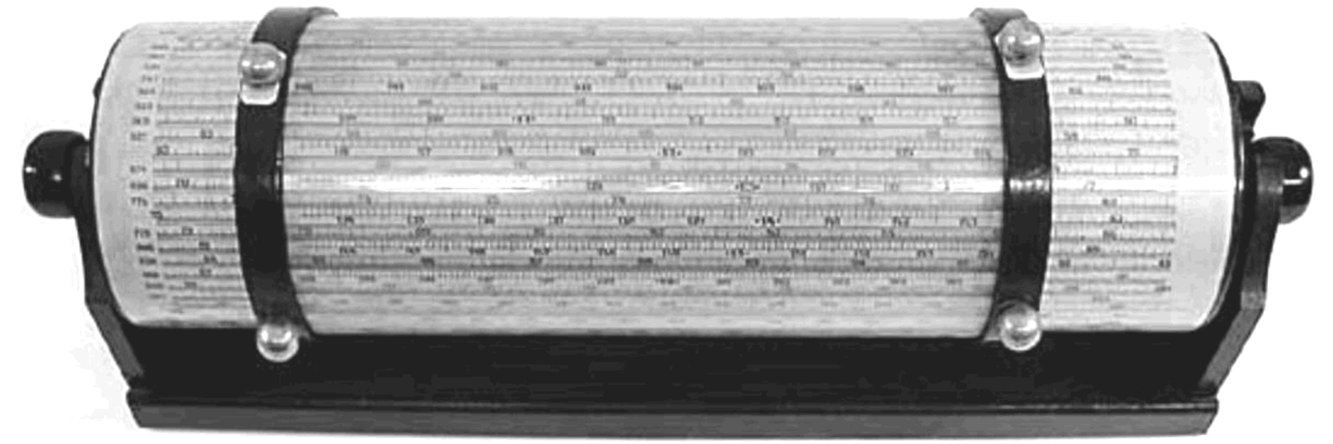

Figure 25. Tröger 7.37m rechenwalze—from Werner H. Schmidt's Internet site [23].

The company Billeter started making cylindrical slide rules in 1888, earlier than Daemen-Schmid [32]. Members of the Billeter family became involved in the National Cylindrical Slide Rule Ltd. in about 1917, when the company Billiter was dissolved. Billeter was known to have made cylindrical slide rules (similar to the Daemen-Schmid/Loga rechenwalzen) with 2m and 10m long scale lengths. National made cylindrical slide rules with long scale lengths of 8, 10, and 16 meters [33].

Similar cylindrical slide rules were also marketed by Nestler, a German maker of slide rules. Joss [33] lists a 1.6m Nestler rechenwalze, and von Jezierski [69] lists two additional models, with 3.75 and 12.5m long-scale lengths. I have examples of the latter two models in my collection.

The East German company Tröger made two different cylindrical slide rule models [67] with scale lengths of 5- and 25- Bavarian feet (1.46 and 7.37m). Tröger's DRGMs for cylindrical slide rules were granted in the early 1920s, but it is uncertain just when they started making cylindrical slide rules. The Tröger rechenwalzen (example in Fig. 25) have unique scale arrangements. The segments on the cylinder repeat twice, and those on the sliding sleeve repeat once, in contrast to the arrangement on the Loga, National, and Nestler models where the scales on the cylinder repeat just once and those on the sleeve do not repeat. While many examples of the Loga and Nestler rechenwalzen are known, few Tröger cylindrical slide rules have made it into collections.

One other cylindrical slide rule of this type was brought to my attention by Rodger Shepherd [60]. That is the Japanese Kooler Calculator by Muto Giken. It is a modern version (perhaps 1960s) with 50 double-scale segments laid out longitudinally on a 1.85-inch-diameter by 11.5-inch-long tube. The sliding sleeve has three ring-indicators (like the Lafay Helice à Calcul) with hairlines rather than a set of calculating scales. The effective scale length is about 4.9m.

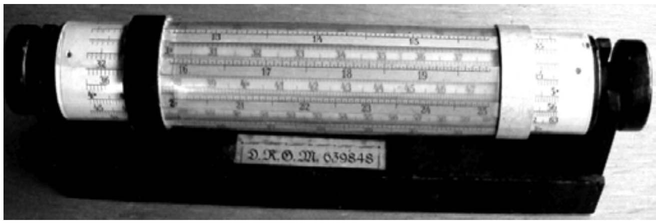

Figure 26. 1.5meter cylindrical slide rule (unknown maker)—author's collection.

Joss [33] also mentions: the 2-meter "Reciloga" made by Edmund Schneider of Munich, Germany; the 14.4-meter "Numa" rechenwalze of unknown Swiss origins; and some "no name" cylindrical slide rules. I have one "no-name" cylindrical slide rule in my collection (Fig. 26) that has an identical scale arrangement to the 1.46m Tröger. It is marked with the German registration number DRGM 639848.

Hopp [26] mentions one other cylindrical slide rule sold by Reiss, but gives no details. It may have been from one of the above makers, and relabeled under the Reiss name.

Tape Slide Rules

The only long-scale slide rule that I found with a tape format was one copyrighted by Paisley in 1939. This slide rule has two continuous scales placed on side-by-side ribbons that wrap around spools at each end of the device. The scales are read through a window in the case. The Paisley slide rule was briefly described by Feely [20]. The scales on the ribbons are positioned relative to each other by turning knurled knobs at one end of the device. The Paisley "Calculator" (Fig. 9) has a scale length of about 50cm. Also, according to Hopp [26], The German slide rule maker/reseller Wichmann listed a measuring tape slide rule, with a scale length of 50cm, in their catalog in 1938. No details are available, but it could be a relabeled Paisley Calculator. One other tape slide rule was mentioned by Joss [32]. It was attributed to Silvio Masera, Winterthur: "Rechenstab mit Endlosband", from a 1902 German patent, but it is not known if examples were produced.

Some Observations and Conclusions

Long-scale slide rules evolved from the beginnings of slide rule technology in the 1600s, well into the 20th century. The longest-scale production slide rules were the spiral and cylindrical types. The 24-meter Loga cylindrical slide rule was the longest production slide rule made. In my earlier report on long-scale slide rules [11], I showed that the 24-meter Loga could provide results to about five digits. The longest spiral scale slide rule made was the Gilson "square" Atlas. It had a scale length of about 14 meters, and could also give results to about five digits.

The spiral scale slide rules had several distinct advantages over the cylindrical slide rules. They were more compact and could fit in a desk drawer rather than on a desktop. They were also obviously less expensive and complicated to produce. The spiral slide rule was also more precise at the right end of the scale because of the expansion of the scale as the diameter increases. For example, the precision on the "square" Atlas spiral slide rule is about the same at both ends, whereas for the Loga cylindrical slide rule, it is about one-half digit less at the right end. Furthermore, the spiral slide rules are easier to use. One wonders why so much effort was put into developing and producing cylindrical slide rules given the great advantages of the spiral slide rule and its early invention.

I should have liked to include more pictures of long-scale slide rules in this paper. However, to save space, I have not included pictures of the Thacher, Fuller, Otis King, Fowlers, etc. because they have been often reported on and are found in many collections.

Finally, I recommend that, when in London, you should see two very early spiral slide rules on display at the Science Museum. The Sutton and Brown slide rules date to the earliest period of slide rule making. The amount of detail in the working of the spiral scales on these slide rules is remarkable. When examining these slide rules, one can almost feel the touch of William Oughtred, the inventor of the long-scale spiral slide rule.

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Table Ia. Long Scale Slide Rules with Straight Formats

Maker	Model	Configuration	Approx. Date	Effective Scale Length cm	Data Source
SINGLE SCALES (scale length > 50-cm)		**Segments**			
Delamoriniere	Regle a calcul - 1.2m	1	1863	c50 to 60	Hopp [26] & Cajori [9]
Scofield	Engineer's Slide Rule	1	c1905	60	Schure [55]
W. & S. Jones (also Adams)	Robertson slide rule (sliding Gunter)	1	c1775	ca.72	Otnes[45] & Cajori
Ward, John	2 to 3 ft. long slide rules	1	c1707	61-91	Cajori[10]
Hoare	none	1	c1915	100	Otnes [45]
Nestler	Reitz model #24R	1	c1937	100	Hopp[26]
Delaveleye	Regle a calcul - 2.3m	1	1863	c115	Hopp[26]
Lambert, Johan	4 ft. scales	1	1770s	c130	Cajori[10]
SEGMENTED SCALES		**Segments**			
Favor, Ruhl & Co.	M -D 7" Dual 10-5"	2	1940s	25	Chamberlain
Faber-Castell	Novo-Duplex #62/83 & 63/83N	2	1960s	25	von Jezierski [69]
Roos	Dual 10", 5"	2	1940s	25	Chamberlain
Nestler	Precision #27/1	2	c1915	30	von Jezierski [69]
Tavernier-Gravet	50-cm long scale on 25-cm slide rule	2	c1870s	50	Manley [40]
Nestler	Prazision No.27 & 0270	2	c1910	50	von Jezierski [69]
Dietzgen	Log Log Decimal Trig #1741	2	1960	50	Chamberlain
Faber-Castell	Columbus #3/42, #342, #3/42/342	2	1930	50	von Jezierski [69]
Faber-Castell	Novo-Duplex #2-83 & #2-83N	2	1960	50	von Jezierski [69]
Dennert & Pape	Verbesserter Einskala-Rechenstab Nr.10	2	c1910	50	von Jezierski [71]
Dennert & Pape	Präzisions-Kubus-Rechenstab	2	c1910	50	von Jezierski [71]
Unique	10/20 Precision	2	1960	51	Hopp[26]
Unique	Dualistic High-Speed	2	1960s	51	Hopp[26]
Kolesh	2761 Nestler prasicion	2	c1915	100	Otnes [45]
Nestler	Precision #27/9 & #27/a	2	c1915	100	von Jezierski [69]
Long	The 'Long' slide rule	2	c1910	100	Pickworth [48]
Post	Post Ritow Manifold #1466?	2	1925 - 1931	100	Chamberlain
Dennert & Pape	Verbesserter Einskala-Rechenstab Nr.11	2	c1910	100	von Jezierski [71]
Tavernier-Gravet	Lallemand	2	late 1800s	100	von Jezierski [70]
Whichmann	100-cm long scale on 50-cm slide rule	2	c1960s	100	Bready [8]
Unique	Pioneer Long Scale	4	1960s	112	Barnes [6]
Anderson	Improved Slide rule	4	1910 to 1920	120	Chamberlain
Hemmi	#201	4	1960s	200	Feazel [19]
Hemmi	#200	6	1930s	240	von Jezierski [69]
Hassler	Geodedic slide rule	10 @ 2-cycle	c1850	305	NIST [42]
Nicholson	Segmented slide rule scale	10 @ 2-cycle	1787	305	Cajori[9]
Horner	Segmented slide rule scale?	several	c1650	?	Cajori[9]
Scherer	Logarithmisch-graphische Rechentafel	?	c1860s	?	Cajori[9]
Péraux, E.	Échelle Logarithmique	2	c1860s	?	Cajori[9]
Mannheim	Side-by-side segmented scales	2	c1850s	?	von Jezierski [69]

Table Ib. Long Scale Slide Rules with Straight Formats

Maker	Model	Configuration	Approx. Date	Effective Scale Length cm	Data Source
GRIDIRON SCALES		**Segments**			
Billeter	Rechentafel - 0.5m	4	c1890	50	Joss [34]
Billeter	Rechentafel - 1m	8	c1890	100	Joss[34]
Aston & Mander	Hannyngton's - small Extended (60")	5	c1880s	159	De Cesaris [14]
Jelinek	Logaritmal	10	c1943	150	Atzbach [3]
Gilson	Pocket Slide Rule	14	c1915	178	Richardson & Clark [50]
Marotti	Lagartabla Gridiron	14	1900s	ca.250	IM2000 [28]
Cooper	100-Inch	20	c1900	254	Bennett [7]
Nicholson	Long scale	10	1797	305	Cajori [9]
Aston & Mander	Hannyngton's - large Extended (120")	8	1880s	318	De Cesaris [14]
Billeter	Rechentafel - 4m	10	c1890	400	Joss[34]
Cherry's	Calculator	20	1880	508	Pickworth [48] & Cajori [9]
Calculigraph	Australian Slide Rule	22	c1909	549	Petri-Palmedo [47]
Billeter	Rechentafel - 8m	?	1887	800	Joss[34]
Gladstone's	Cross Gauge (like Everett gridiron)	?	1923	10.8m	Hopp [26]
Clairault, Jean	Gridiron = 1500 French ft.	?	1720	500m ?	Cajori [9]
Scherer	Rechentafel	?	1892	?	Hopp [26]
Proell	Proell's Rechentafel	20	1901	?	Cajori [9] & Pickworth [48]
Everett	Universal Proportion Table Gridiron	?	1866	?	Cajori [9] & Pickworth [48]
Evans, Dr. J.D.	Gridiron scale	?	1866	?	Hopp [26]
SAW TOOTH SCALES		**Segments**			
Lurie	Precision	1	ca. 1910	50.8	Babcock [4]
Richardson	Pyramid #1898	20	ca. 1915	508	Babcock [4]
CHARTS / TABLES / GUNTER's LINES		**Segments**			
Merrifield	24-inch Gunter Rule	1	1850s	30.5	Chamberlain
Donn	Improved 'Gunter' Navigation Scale	1	c1850	61	Chamberlain
Forster	Gunter Rule (6ft. long double scale)	1	1632	91.4	Cajori [10]
C. Dumesnil	Graphic Table Rule	8	c1900	200	Chamberlain
MacMillan	Table Slide Rule	20	1925 to 1930	na	Ballantine [5]
Loewe	Rechenscalen	50	1893	10m	Holland [24]
Goodchild	Mathematical Chart	100	c1902	16.5m	K& E [36]
LaCroix and Ragot	Graphic Table book	1000	c1930	111m	La Croix & Ragot [37]
Lalanne	Tableau Graphique	?	c1846	?	Cajori [9]
Tichy	Graphische Logarithment-Tafeln	?	1897	?	Holland [24] & Tichy [66]
Knowles	Calculating scale	?	c1903	?	Cajori [9]

Table IIa. Long Scale Slide Rules with Circular, Cylindrical and Band or Tape Formats

Maker	Model	Long Scale Configuration	Approx. Date	Effective Scale Length cm	Data Source
CIRCULAR with CIRCULAR SCALES		**Circles**			
Nystrom	Nystrom's Calculator	1	c1850	36	Miller [41]
Norma	Grafia 190 Rechenschiebe	1	c1970	50	van Herwijnen [68]
Russian	CTM Military	1	1970	55	van Herwijnen [68]
Scott, Benjamin	18" dia. circular slide rule	1	1733	58	Cajori [9]
Gilson	Binary & Atlas	1	1930s to 1960s	64	Aldinger & Chamberlain [1]
Fuller/Palmer	Computing Scale	1	1844 to 1870s	67	Feazel [18]
Troeger	no.1 (37/393/6004)	1	c1930s	72	Troeger [67]
East German	Military	1	c1970s	75	van Herwijnen [68]
Loga	75T (disk about 12 in dia.)	1	c1950s	75	Joss[32]
Oughtred (Elias Allen)	12.5" dia. disk"	1	c1632	76	JOS[29]
Gilson	'Square' Atlas	1	1920s	78	Aldinger & Chamberlain [1]
Troger	No.1a (for persons with poor eyesight)	1	c1930s	100	Chamberlain
Scott	18" diameter circular slide rule	1	1723 & 1733	ca.140	Hopp[26]
Clairault, J.B	21" cardboard circular slide rule	1	1727	ca.150	Hopp[26]
CIRCULAR with CONCENTRIC CIRCULAR SCALES		**Circles**			
The Scientific Pub. Co. & etc.	The Mechanical Engineer	2	c1900	17	De Cesaris [15]
unknown Swiss company	The Mechanical Engineer	2	c1900	24	De Cesaris [15]
Henri Chatelain & others	Boucher (Calculigraphe)	3	1870s to 1920s	30	Chamberlain & Hopp [27]
K& E	Sperry	3 (hybrid)	1904 to 1940	32	Otnes [44]
Fowler	Long Scale	6	1920s to 1970s	76	Hopp [27]
Delamain	Two-disk with concentric circle long scales	4	1632	ca.112 - 140	Cajori [9]
Pickett	110ES (copy of RotaRule)	4 (hybrid)	1960	127	Shepherd [61]
Dempster, J.R.	RotaRule - Model AA	4 (hybrid)	1930	127	Shepherd [61]
Boykin Products	Copy of RotaRule	4 (hybrid)	1950	127	Stanley [64]
Unique	Dial Calculator	5	1930s ?	127	Hopp[26]
Fowler	Long Scale Magnum	6	1940s to 1970s	127	Hopp [27]
Fowler	Jubilee Mag. Extra Long Scale	11	1940s to 1970s	185	Hopp [27]
Sexton's	Omnimetre #6 (Companion)	20	c1900	411	Alteneder [2]
Biler	Concentric semicircle scale	?	1696	?	Cajori [9]

Table IIb. Long Scale Slide Rules with Circular, Cylindrical and Band or Tape Formats

Maker	Model	Long Scale Configuration	Approx. Date	Effective Scale Length cm	Data Source
CIRCULAR with SPIRAL SCALES		**Spirals**			
Logomat	3307	2	ca.1970s	20	van Herwijnen [68]
Logomat	Pfiffikus 1703	2	ca.1970s	24	van Herwijnen [68]
Logomat	Pfiffikus Passavant 2001	3	ca.1970s	34	van Herwijnen [68]
Logomat	1300/1301	2	ca.1970s	38	van Herwijnen [68]
Logomat	2300	2	ca.1970s	40	van Herwijnen [68]
Logomat	Mini-2000	3	ca.1970s	60	van Herwijnen [68]
Felsenthal	Altitude Correction Computer	2.7	1940s	60	Chamberlain
Appoullot	Logz T2	2 & 3	1920	42 & 63 (est)	Schuitema [55]
Appoullot	Logz T3 & T4	2 & 3	1920	60 & 90	Schuitema [55]
Logomat	816 (V & G)	3	ca.1970s	110	Schuitema [54]
Facini	Spiral	4	ca.1714	122	JOS [31]
ALRO	1010 Commercial	6	ca.1940	150	Schuitema [53]
Concise	M.V. Douglas	10	1960	152	O'Leary [43]
John Brown	Spiral slide rule	5	c1660	213	Science Museum [57]
Sutton (Oughtred)	Spiral slide rule	5	1663	280	Science Museum [58]
Dixon	Combined Spiral Multi-Index Slide Rule	10	1882	421	Science Museum [59]
Adams	12" dia. spiral sr w/10 windings	10	1748	ca.500	Hopp[26]
Ross	Precision Computer	25	1920	914	Chamberlain
Gilson	Atlas - Type III	25	1930	1067	Aldinger & Chamberlain [1]
Gilson	Atlas - Type II	30	1931	1186	Aldinger & Chamberlain [1]
Nicholoson	Spiral	10	c1797	1250	Cajori [9]
Gilson	Atlas - Type I (square)	30	1920	1400	Aldinger & Chamberlain [1]
Brown, John	Spiral slide rule	10	c1660	?	Hopp[26]
Brown, John	Spiral slide rule	20	c1660	?	Hopp[26]
Brown, Thomas	Spiral slide rule	?	1631	?	Hopp[26]
Fearnly	Universal Calculator	?	c1900	?	Pickworth [47]
Milburn, William	Spiral slide rule	?	c1650	?	Cajori [9] & Hopp [26]
Schuermann	Calculating Instrument	?	c1896	?	Pickworth [48]

Table IIc. Long Scale Slide Rules with Circular, Cylindrical and Band or Tape Formats

Maker	Model	Long Scale Configuration	Approx. Date	Effective Scale Length cm	Data Source
CYLINDRICAL with HELIX SCALES		**Revolutions**			
LaFay	Helice a Calcul #1	20	1930?	85	Chamberlain
J.H. Steward	R.H.Smith Calculator	?	c1906 - 1915	102	Weinstock [72]
LaFay	Helice a Calcul #2bis	25	1930?	125	Chamberlain
J.H. Steward	R.H.Smith Calculator	20	c1906 - 1915	127	Pickworth [48]
Otis King	Model “L”	20	1920 to 1970	168	Hopp [25]
Otis King	Model “K” (w/ log scale)	20	1920 to 1970	168	Hopp [25]
LaFay	Helice a Calcul #2	50	1930?	250	Chamberlain
Stanley	‘Midget’ (200”)	?	c1879	508	Feely & Schure [22]
Stanley	Fuller Model #1	20	1878 to 1960	1270	Chamberlain
Stanley	Fuller Model #2A (w/ sine scales)	20	1878 to 1960	1270	Hopp[26]
Stanley	Fuller Model #2B (w/ log & sine scales)	20	1878 to 1960	1270	Hopp[26]
Stanley	Fuller Model #3 - Bakewell Stadia	20	1878 to 1960	1270	Hopp[26]
Dobie (Austrialia)	Collins Brown tubular calculator	20	c1960	1270	Hopp[26]
Post	Model #1475 Ritow Cylindrical	20	1925 to 1927	1270?	Ross & Hume [51]
MacFarlane	Cylindrical slide rule	?	1842	?	Hopp[26]
Mannheim	Régle á Calcul Cylindrique	?	1854	?	Hopp[26]
Mannheim	Régle á Calcul Cylindrique (wooden)	?	1871	?	Hopp[26]
Mannheim	Régle á Calcul Cylindrique (metal)	?	1873	?	Hopp[26]
Schukarev	Cylindrical slide rule	80?	1910	?	Davie [13]
Everett	Cylindrical slide rule	?	1866	?	Hopp[26]
Darwin	Spiral slide rule	?	c1875	?	Cajori[9]

Table IId. Long Scale Slide Rules with Circular, Cylindrical and Band or Tape Formats

Maker	Model	Long Scale Configuration	Approx. Date	Effective Scale Length cm	Data Source
CYLINDRICAL with SEGMENT SCALES		**Segments**			
Daemen-Schmid / Loga	Loga Cylindrical 1.2 m	20	started in 1896	120	Joss [33]
Trogger	No.4 - small format (5 Bavarian feet)	10 / 20	c1920s	147	Joss [33] & Troeger [67]
no name (Troeger?)	Cylindrical slide rule 1.5m	10 / 20	c1920s	147	Chamberlain
Nestler	Cylindrical Calculator 1.6m	16	1922-1937	160	Joss [33]
no name	Cylindrical slide rule 1.6m	16	?	160	Joss [33]
Billeter	Cylindrical slide rule	16	started in 1888	200	Joss [33]
Daemen-Schmid / Loga	Loga Cylindrical 2 m	20	started in 1896	200	Joss [33]
Schneider, Edmund - Munich	Reciloga 2m	15	?	200	Joss [33]
Daemen-Schmid / Loga	Loga Rechenwalz 2.4 m	20	started in 1896	240	Joss [33]
Nestler	Cylindrical Calculator	?	1922-1937	375	von Jezierski [69]
Muto Giken	Kooler Calculator	50	1960	491	Shepherd [60]
Trogger	No.3 - large format	32 / 64	patented 1908	737	Troeger [67]
no name (Troeger?)	Cylindrical slide rule 7.37m	32 / 64	c1930s ?	737	Joss [33]
Daemen-Schmid / Loga	Loga Rechenwalz 7.5 m	40	started in 1896	750	Joss [33]
National	Cylindrical slide rule 8m	40	started in 1916	800	Joss [33]
Thacher	Cylindrical Slide Rule	40	1883 to 1940	914	Feely & Schure [21]
Billeter	Cylindrical slide rule	?	started in 1888	1000	Joss [33]
Daemen-Schmid / Loga	Loga Rechenwalz 10m	50	started in 1896	1000	Joss [33]
National	Cylindrical slide rule 10m	50	started in 1916	1000	Joss [33]
Daemen-Schmid / Loga	Universal 12m	?	started in 1896	1200	Joss [33]
Nestler	Ronda III	?	1922-1937	1250	Hopp [26] & von Jezierski [69]
Numa	Cylindrical slide rule 14.4m	50	?	1440	Joss [33]
Daemen-Schmid / Loga	Loga 15-meter	60	started in 1896	1500	Joss [33]
Billeter	Cylindrical slide rule 16m	?	started in 1888	1600	Joss [33]
National	Cylindrical slide rule 16m	80	started in 1916	1600	Joss [33]
Daemen-Schmid	Loga Cylindrical 24 m	80	started in 1896	2400	Joss [33]
Reiss	Cylindrical	?	c1950s ?	?	Hopp [26]
MacFarlane	Cylindrical (scale type uncertain)	?	c1842	?	Cajori [9]
Hoyau	Boîtes á calculer (type uncertain)	?	c1816	?	Cajori [9]
CYLINDRICAL with RING SCALES		**Rings**			
Delamain	Great Cylinder - one-yard diameter	10 or more	c1632	ca.30m	Cajori [10]
TAPE and BAND SLIDE RULES		**Bands**			
Paisley	Calculator, Model A (band slide rule)	2	c1939	50.8	Feely [20]
Wichmann	Rechen-Bandmass	2	c1939	50.0	Hopp [26]
Darwin	Metalic Tapes	?	1875	?	Cajori [9]
Tower	Metalic Tapes	?	1885	?	Cajori [9]
Silvio Masera	Rechenstab mit Endlosband	?	1902 patent	?	Joss [32]