The Flynn Universal Trigonometric Combination Semi-Circular Slide Rule – Protractor – Sine Table – Angle Formula Finder

Edwin J. Chamberlain, PE

Introduction

The name given to the Flynn semi-circular slide rule (Figure 1) is a mouthful: *Universal Trigonometric Combination Semi-Circular Slide Rule – Protractor – Sine Table – Angle Formula Finder* (Figure 2). This calculating device features a semi-circular slide rule along with a protractor, a semicircular table of sines, cosines, tangents and cotangents, and formulas for solving triangles. All of these features are printed on one side of two thin disks made of Celluloid®, one of the first thermoplastics.

George Ryan Flynn patented his slide rule in 1922[1]. He states in his patent that:

> This device is especially useful for students . . . and for surveyors, mechanical engineers, and others who have occasion to figuring out mathematical problems.

He noted that

> most of the calculating devices [scales on his invention] are of semi-circular form, and therefore can be read without turning [the disk].

He also claimed that he was the first to devise a semi-circular slide rule and that his slide rule would fit in the pocket of the user.

Flynn is not quite correct about being the first to design a semi-circular slide rule. In a past Journal of the Oughtred Society, Rudowski[2] described a semi-circular slide rule developed by D. Joh. Matthaei Biler in Germany in 1696, some 226 years before Flynn's semi-circular slide rule. Biler called his instrument "*Instrumentum Mathematicum Universale".*

Moreover, Flynn was not the only maker of a semi-circular slide rule to make the claim of being first. In 1943, more than 20 years after Flynn developed his semi-circular slide rule in the US, Walter Hiltpold[3] described a semi-circular slide rule that he developed in Switzerland and claimed that his was the first with this format. Hiltpold also made claims similar to Flynn's for compactness and ease of use (Wirz[4]).

Two other semi-circular slide rules were designed later (c.1960) by a New York engineer named Frankenfield and sold under the ARC Engineer's label. Frankenfield was aware of the Flynn device; he cited the Flynn patent in his patent application. I will first describe a little about the Biler, Hiltpold, and Frankenfield semi-circular slide rules, then more about the Flynn device.

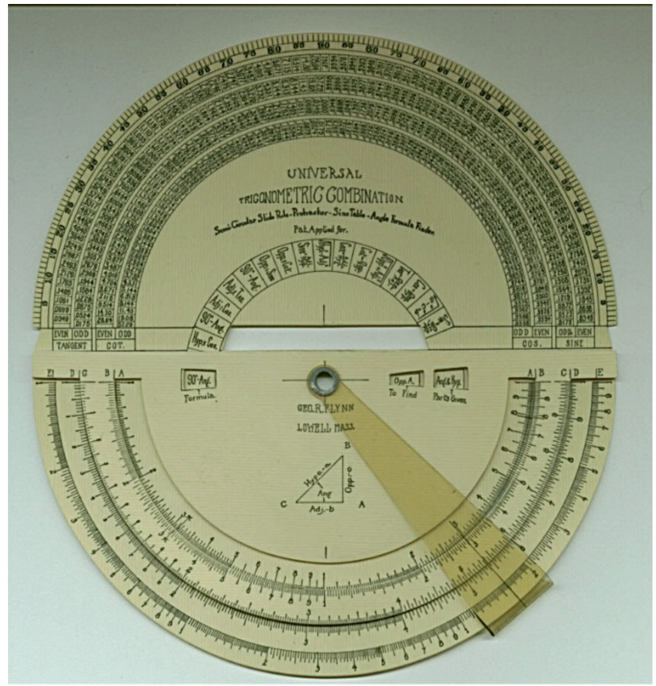

FIGURE 1. The Flynn "Universal Trigonometric Combination Semi-Circular Slide Rule Protractor – Sine Table – Angle Formula Finder"

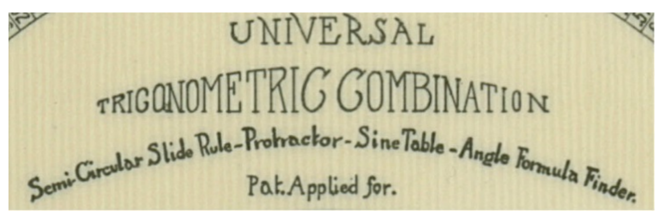

FIGURE 2. Detail of the Flynn Semi-Circular Device Showing the Impressive Name (my collection)

Other Semi-Circular Slide Rules

The Biler *Instrumentum Mathematicum Universale*

Because there are no known examples of the Biler (Figure 3) instrument, whether any were made is uncertain. However, Rudowski suggested that a working example could easily be made by printing out a copy of the Biler on paper or cardstock. The Biler slide rule had four scales: a pair of 2-cycle number scales, and tangent & sin scales. One more linear scale about the outer rim allowed the device to be used as a protractor. The outer four scales rotate about an inner number scale. The hairline is made of a silk thread that pivots on the radius center of the device. The user, perhaps, holds the thread in tension at the outside edge of the device when making calculations, because it is not attached there.

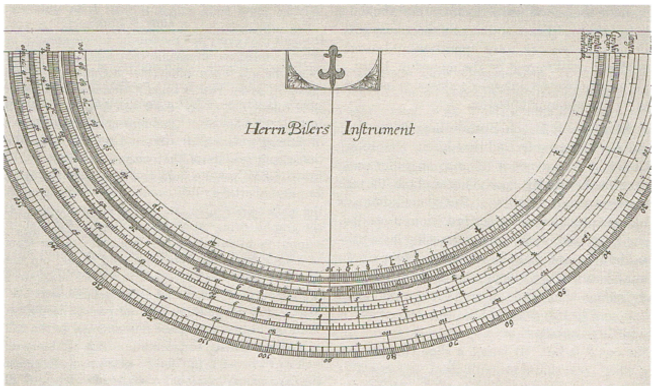

FIGURE 3. Biler's Semi-Circular Slide Rule, 1696
(after Rudowski, 2006)

The Hiltpold Kreisnomograph

In Hiltpold's patent, he described two different sized semicircular slide rules: one with a 10 cm radius and one with a 15 cm radius. Wirz[4] reported the salient details in 1988. The Hiltpold semi-circular slide rule is two sided, made up of a set of stacked plastic plates and a pair of linked transparent cursors – one on either side. The front outer plate is transparent and the inner plate is opaque. Scales are engraved on both the inner and outer plates. The inner plate scales align with the outer plate scales and are visible through the outer plate. The familiar calculating scales on the front of the smaller plate (Figure 4) are: A/B, C/D, L, 360°. The A, D, and L scales marked on the outer transparent plate, and the B, CI, and D scales marked on the inner opaque plate. The scales: K, S, T, and ST are all marked on the back plate. The ganged front and back cursors facilitate relating of the scales on the back to the scales on the front. Close to the center on the front side is a 360° scale for using the device as a protractor. The larger version of the Hiltpold semicircular slide rule also has CI, 400 degree, and (three) LL scales.

The ARC Engineer's Semi-Circular Slide Rules

Two semi-circular slide rules were patented[6] by Andrew Frankenfield, a New York engineer in 1961. One, the ARC Engineer's slide rule, model ADF 103 (Figure 5) lays out conventional engineer's slide rules scales (D, L, DI, S, T, ST, K, R, LL3, LL2, LL1, LL01, LL02, LL03, TH, SH2, SH1, LL0, LL00) on a 8.3 cm radius aluminum semi-circular disk. The other model, the ARC Extended slide rule (Figure 6), has L, S, T, and a 10 m long scale in 25 semicircular sections. Frankenfield designed, manufactured, and sold these slide rules under the ADF Products name for a few years beginning in 1959. I know of no examples, except for two models provided to me by Andrew Frankenfield.

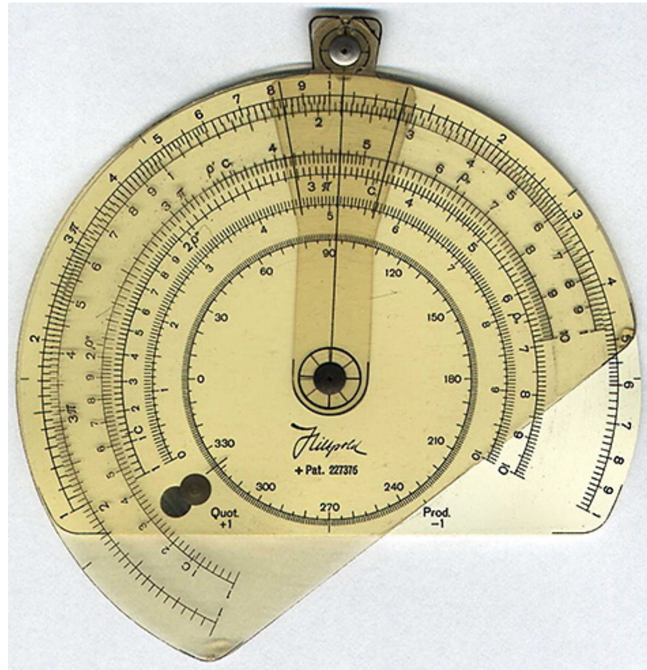

FIGURE 4. Reverse side of Hiltpold's Semi-Circular Slide Rule[5]

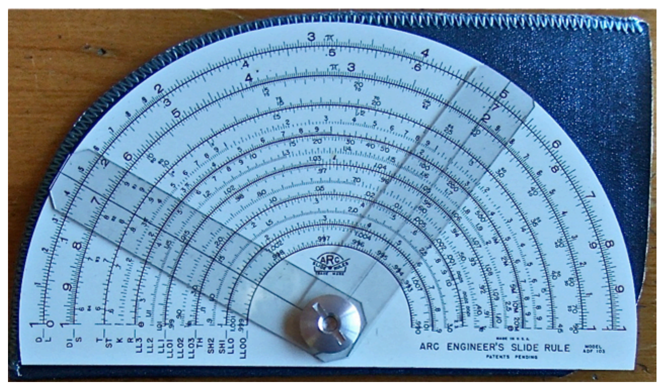

FIGURE 5. Frankenfield's ARC Engineer's slide rule, Model ADF 103 (my collection)

The Flynn Universal Semi-Circular Slide Rule

The Flynn slide rule (Figure 1) is made of thin (1.3mm) Celluloid® with simulated ivory grain. The maker's name is printed in very small print (font size smaller than 2 points) on the reverse side – "Whitehead, Hoag & Co., Newark, NJ" (Figure 7). The slide rule is signed "George R. Flynn, Lowell Mass." on the front (Figure 8). The Flynn rule consists of a nearly circular base disk about 14 cm in diameter, a semi-circular top disk arranged on the lower half of the base disk, and a single transparent cursor (Figure 1). The base disk has tangent, cotangent, sine, and cosine tables arranged in concentric semi-circular bands along with a protractor scale on the base disc's upper half (Figure 9). Formulas for solving triangles are arranged in a circular band in the central region of the disk, and the A, B, C, D, and E scales are arranged in circular bands on the lower half of the device. The top semi-circular disk rotates about the center of the base disk to facilitate calculations.

The semi-circular disk and the cursor both pivot on a single metal rivet. Window openings (Figures 8, 10, & 11) in the semi-circular disk facilitate the working of the angle finder and the slide rule scales. The features of the Flynn calculator are more completely described in the following paragraphs.

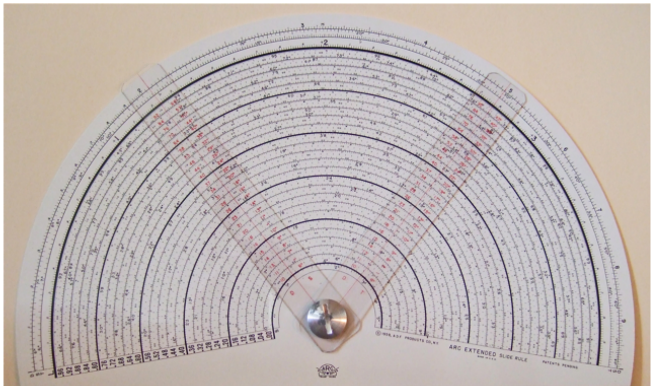

FIGURE 6. Frankenfield's ARC Extended slide rule
(my collection)

The Semi-Circular Slide Rule Component

The semi-circular slide rule has five calculating scales arranged on concentric arcs on the lower half of the device. These scales are arranged (from the inside to the outside) in the following order: A/B, C/D, E (Figure 11). Scales A and B are 2-decade number calculating scales, C and D are single decade calculating scales, and E is a 3-decade number scale – the cube scale. The A, D, and E scales are printed on the lower half of the circular base disk and the B and C scales are printed on the semicircular top disk, which rotates about the rivet and acts as the slide. The A, D, and E scales show through semi-circular openings in the pivoting disk. The C and D scales are about 17.6 cm long. They appear finely divided, with 320 gradations over their complete length, the same as for the C and D scales on a common 25 cm (10 in) slide rule. Calculations with the Flynn semi-circular slide rule are made in the conventional manner.

The Protractor Component

The outside edge of the upper half of the circular base disk is graduated for measuring angles (Figure 9) in a way similar to that of an ordinary protractor. Gradations are marked for every degree, and the angles are labeled from 0 to 90 in both directions at five-degree intervals. A cutout window, just above the pivot point of the semi-circular slide rule, allows the protractor to be centered at the apex of angles for angle measurements and layouts.

The Trigonometry Table

The trigonometry table (Figure 9) contains 4-digit entries for all angles between 0 and 90 degrees at 1-degree intervals. The tangent and cotangent columns run in concentric circular columns in the upper left quadrant, and the sine and cosine columns run along in concentric circular columns in the upper right quadrant. Note the neat hand numbering and the close spacing of the numbers. This was done by a very skilled draftsman.

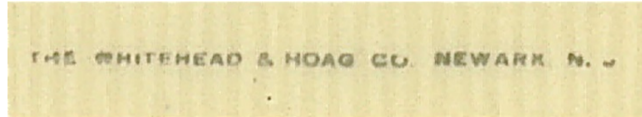

FIGURE 7. Detail Showing "The Whitehead & Hoag Co. Newark N,J." Marking

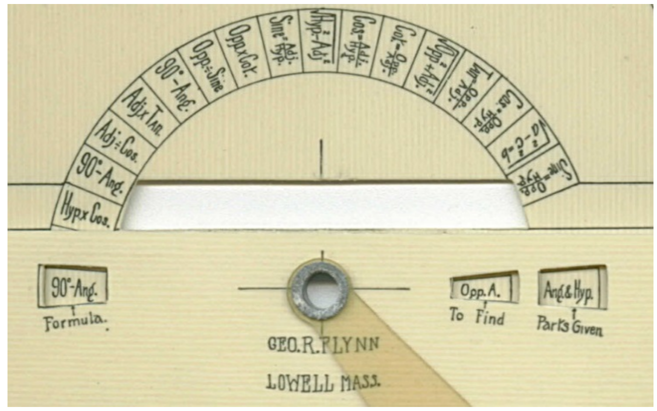

FIGURE 8. Detail Showing the Formulas for Solving Triangles Feature and the Geo. R. Flynn, Lowell, Mass Signature

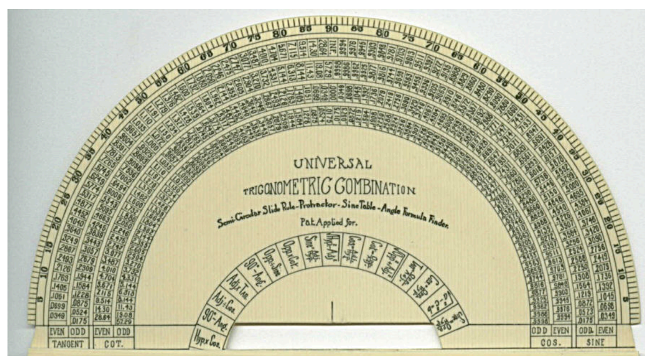

FIGURE 9. The Upper Half of the Flynn Device Showing the Protractor Scales

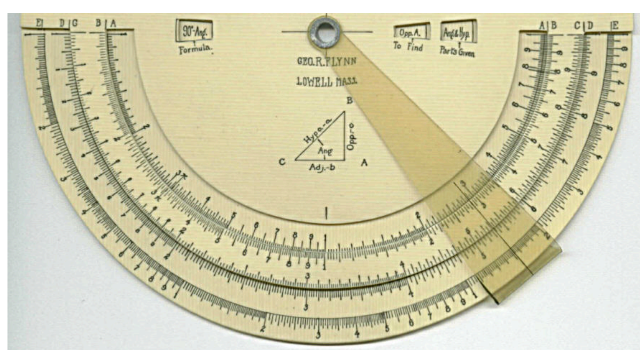

FIGURE 10. The Lower Half of the Flynn Device Showing the Semi-Circular Slide Rule

The Angle Formula Finder Component

The formula finder component in the lower half of the device has three windows (Figure 12) in the semi-circular rotating disk, labeled: a) *Formula*; b) *To Find*; and c) *Parts Given*. This feature of the Flynn calculating device is used to find one part (angle or side length) of a right triangle, given two other parts. The formulas and parts are printed on the circular base disk and viewed through the windows on the semi-circular disk. Different formulas and parts are viewed by rotating the semi-circular disk. Thirty-six different formulas are given, along with a reference diagram labeled with the various parts of a right triangle (Figure 12). Most of these formulas are trivial to the graduate engineer or mathematician, but these formulas could have proven valuable to the less accomplished student.

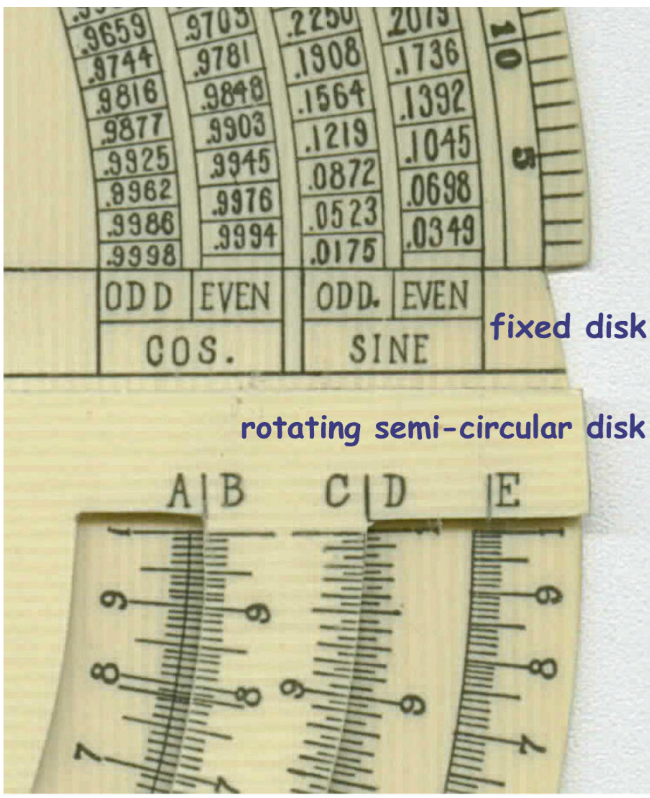

FIGURE 11. Detail Showing Cos & Sine Tables

Claims made in the Flynn Patent

The claims made in the patent relate to the circular form with semi-circular scales, the layout of the scales, the cutout windows for viewing slide rule scales, the slots enabling the use as a protractor and reading angle formulae, and the transparent cursor with a hairline. The patent does not suggest dimensions, except for the claim that the slide rule fits in a pocket. However, the actual slide rule in my collection is too large (14 cm diameter) to fit in most pockets today, but perhaps it could fit in the large coat pockets favored by technicians in Flynn's time.

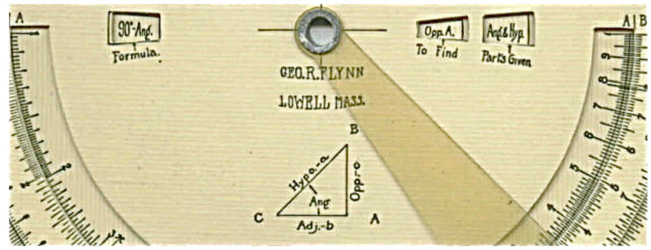

FIGURE 12. Detail Showing the Reference Diagram for the "Angle Formula Finder" Feature

Some Further Observations

The lettering and artwork on the Flynn device appear to have been done by hand (see Figures 8 & 9 for examples), perhaps on a master sheet of drawing vellum, and then transferred by a printing process such as *screen-printing* to the Celluloid®. All of the 240 entries for the trigonometric functions are in hand written script, and the words *trigonometric combination* (Figure 2) are in a highly stylized print of varying letter height. Much of the rest of the lettering is in script. The example of the Flynn calculator in my collection appears much like the drawings in the patent, including the style of the printing. My version is marked *Pat. Applied for*, so it might have been made before the patent grant date of August 22, 1922, but after the patent application date of April 8, 1921.

The Flynn calculator came in a very nice soft leather case marked *"UNIVERSAL TRIGONOMETRIC-COMBINATION"* in gold stamped letters (Figure 13). The case and the calculator make a very nice display piece. I have them mounted in a shadow-box-like picture frame (Figure 14). The slide rule and leather case are held in place with fine fishing line. I have mounted other slide rules for display in a similar way. Details of how I do this may be the subject of a future paper.

Both the Flynn calculator and its patent indicate that George R. Flynn was from Lowell, Massachusetts, at the time of the patent and making of the slide rule. Lowell is not too far from my home in New Hampshire, so I traveled to Lowell to learn more about George Flynn. Lowell was an industrial town in Flynn's time. The town is located just south of the New Hampshire border, about 25 miles northwest of Boston. One might think that Flynn was an engineer or draftsman with a record of technical contributions to this industrial town. However, after considerable sleuthing I only found that he was a 24-year old junior high school teacher when he invented his slide rule. He was probably a math teacher, but I was not able to find this out for certain.

The Flynn calculator appears to be scarce. As a regular follower of eBay slide rule offerings, I have seen only two other examples in the past 15 years – one in 1998 and the other in 2000. None appear in Rod Lovett's e-Bay Slide Rule Search[7] covering the past 14 years (1999 to 2013). The *Flynn Universal Trigonometric Combination Semi-Circular Slide Rule – Protractor – Sine Table – Angle Formula Finder* may have had a limited production life. Few have entered slide rule collections. My purchase was made at an antiques shop in southern New Hampshire a few miles from Lowell, Massachusetts where Flynn lived.

FIGURE 13. The Leather Case for the Flynn Calculator Labeled in Gold "UNIVERSAL TRIGONOMETRIC-COMBINATION"

FIGURE 14. The Flynn Calculator and Leather Case Mounted in a Frame for Display

A Bit of Conjecture

The reader should note that three of the five known semi-circular slide rules have the protractor feature. Is this by coincidence, or did the shape of the common protractor give light to the idea of a semi-circular slide rule? Furthermore, is that the word *universal* is used in the names of both the Biler and the Flynn semi-circular slide rules another coincidence? Probably so, as there is no evidence that Flynn knew of Biler's work. Flynn thought that he was the first to come up with that idea. That both thought the *universality* of their devices was that they could be used as both technical drawing and calculating instruments is probable.

An Aside on Celluloid®

I have another measuring device made by Whitehead, Hoag & Co, also made of thin Celluloid® plastic. Whitehead, Hoag & Co., the maker of the Flynn device, was well known in the early 20th century for its plastic novelties such as advertising pieces, campaign buttons and pins, trade cards, etc. made from Celluloid®. Celluloid® is a plastic made by reacting cellulose with nitric acid to form cellulose nitrate (nitrocellulose). This plastic and other plastics made from cellulose acetate (CA) were the forerunners of modern plastics. Celluloid® and CA were sometimes formed with grain, much like the Flynn calculator, to have the look of ivory.

Cellulose nitrate polymers were the first plastic laminates on wooden slide rules. Celluloid® provided high contrast scale surfaces, and was a great improvement over natural wood surfaces for reading scale markings. This type of plastic is unstable. This instability was probably responsible for "cursor rot" in early K&E cursor bars, for warping of the thin plastic slide rules made by K&E and others, and for the shrinkage of plastic laminated scale surfaces. I have in my collection a 20-inch long K&E Mannheim slide rule with a scale surface marked by *alligator* cracking of the laminate surface, much like an asphalt highway pavement cracks when the pavement ages and is subject to environmental and wheel loading stresses (my civil engineering profession is showing through here). That cracking in the Celluloid® laminate probably occurred because of shrinking during the aging process, the laminate adjacent to the cracks being held fast to the wooden body of the slide rule by adhesive. I also have an early Richardson metal framed slide rule where the Celluloid® laminate scale strips have shrunk differentially – resulting in paired scales that no longer match in length. Many of the early German slide rules have screws or pins (in addition to an adhesive) fixing the laminate in place to limit the shrinkage.

Cellulose nitrate, of course, was a major ingredient of explosives. The demand for cellulose nitrate during World War II for the making of explosives and munitions limited the supply for domestic purposes. This and other demands led to the development of modern, more stable, plastics for slide rule laminates, and eventually to slide rules made of solid plastic.

References

1. Flynn, George Ryan, *Calculating Device,* US Patent, No. 1,426,829, patented August 22, 1922.
2. Rudowski, Werner H., *How well known were slide rules in Germany, Austria and Switzerland before the second half of the 19th century?,* Journal of the Oughtred Society, 15:2, 2006, pages 42-49.
3. Hiltpold, Walter, *Kreisnomograph.* Hauptpatent, Schweizerische Patentschrif, no.228237, 15 August 1943.
4. Wirz, Paul, *The semi-circular slide rules of Walter Hiltpold,* proceedings of The 4th International Meeting of Slide Rule Collectors, Huttwil, Switzerland, 14-16 October, 1988, pages 59-62.
5. Oughtred Society web site, JOS Rarities Gallery; http://osgalleries.org/os/fulldetails.cgi?match=341
6. Frankenfield, Arthur D., *Two-Dimension Slide Rule*, US Patent No. 2,998, 916, September 5, 1961.
7. Rod Lovett's E-Bay Slide Rule Search; http://sliderules.lovett.com/srsearch.html

New Exhibition Opens: "The Schuitema Collection"

David Rance

Fate can sometimes be cruel. Sadly, after a long illness, renowned Dutch collector and author IJzebrand Schuitema (1929-2013) died two months before an exhibition dedicated to his famous collection opened in Bonn, Germany.

Legacy of the "Champion Collector"

A spur of the moment buy in a flea market in 1984 was the catalyst for IJzebrand's collection. Not being a man for "half measures", he then spent 30 odd years compiling a slide rule collection, whose quality and diversity had few peers in Europe or possibly the rest of the world. Sadly, some family tragedies and increasing personal health issues forced IJzebrand to face the question every collector dreads, *What will happen to my collection when I am gone?* In IJzebrand's case, this was a loaded question because he was determined that his collection would not be broken up.

Arithmeum Saved the Day

When he approached the leading technical museums in Holland, surprisingly they showed little or no interest in the collection. Alternatives, like opening a private museum, proved infeasible. Then a fellow collector reminded IJzebrand that the Arithmeum museum in Bonn, Germany, had a rich history in mathematics and calculating. Discussions followed, and IJzebrand soon realised he had found a sympathetic and grateful home for his entire collection[1].

Therefore, in 2008, as part of a major international removal exercise, IJzebrand's collection of over 3000 slide rules and an extensive library of associated books and documentation were relocated to Bonn.

A Mountain to Climb

Cataloguing and archiving is the lifeblood of any museum. However, I suspect the Arithmeum has never had so many new items arrive on the same day, therefore, to know where to start must have been difficult for the museum staff and volunteers! They took literally years to examine and meticulously record every item. However, in 2012, the cataloguing was completed and plans could be made for the Arithmeum to stage a special exhibition dedicated to "The Schuitema Collection".

FIGURE 1. IJzebrand's Collection 1999

FIGURE 2. Arithmeum

Such exhibitions typically take more than a year to plan and set up. The Arithmeum also called on the specialist help of two leading German slide rule experts and collectors, Peter Holland and Werner Rudowski. They helped shape the themes running through the exhibition and provided much of the explanatory information for the specially prepared exhibition catalogue.