# George R. Stibitz's Film Slide Rule: a computing machine with logarithmic scales

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**Opening remarks**

The scope of this article precludes a detailed account of the many achievements and the astonishing inventiveness of American Dr. George Robert Stibitz (1904–1995). Instead we have chosen to highlight selected events from his working and family life that we think will help the reader get an idea of the extraordinary man behind the almost unknown but truly innovative Stibitz (Film) slide rule.

Although Stibitz's remarkable slide rule is unique it should be considered part of a group of 20 similar inventions. They were all patented in the period 1902 to 1950 – for details see the Addendum in JOS Plus. Interestingly all these similarly-minded inventors describe their inventions as: *"a slide rule calculating machine"*.

**Case history**

This is the story of a groundbreaking cross between a calculating machine and a slide rule. In 1941 George Stibitz, while working as a mathematician at Bell Laboratories (Bell Labs), was co-opted onto the US government's *"National Defense Research Committee (NDRC)"*. In 1944, in cooperation with the University of North Carolina, he developed and built the Film Slide Rule for the NDRC. By this time he was already a natural sciences graduate of Denison University, Union College, and Cornell University. But the secret to understanding how he came to invent his amazing slide rule is rooted in his astonishing career.

George Stibitz is considered "the Father of the Modern Digital Computer". In 1965, jointly with Konrad Zuse (1910–1995) from Germany, he was awarded the prestigious Harry H. Goode Memorial Award[1]. But his contribution is best summarised by the following citations:

- It remained for one of Bell Lab´s employees**,** Dr. George Stibitz, *"to serve as the catalyst to bring them together"* < said in conjunction with > *"The invention of the computer at Bell Laboratories, like its invention elsewhere, resulted from a convergence of technical skill, social need and talent. Those preconditions were there by the mid-1930´s"* [2].

- He was the inventor of the "Model K" (1937) – an early digital calculating machine using binary addition. In 1940 followed a Complex Number Calculator – Stibitz was: *"the pivotal figure who matched the requirements with the capabilities known to a switching engineer, the result of this marriage was the Complex Number Calculator"* [3].

- Under Stibitz's pioneering leadership, more than 30 different types of computers for various aims were devised at Bell (Telephone) Labs. Most were relay operated – optimised for calculating trajectories. They were superseded by electronic computers at the end of WW II.

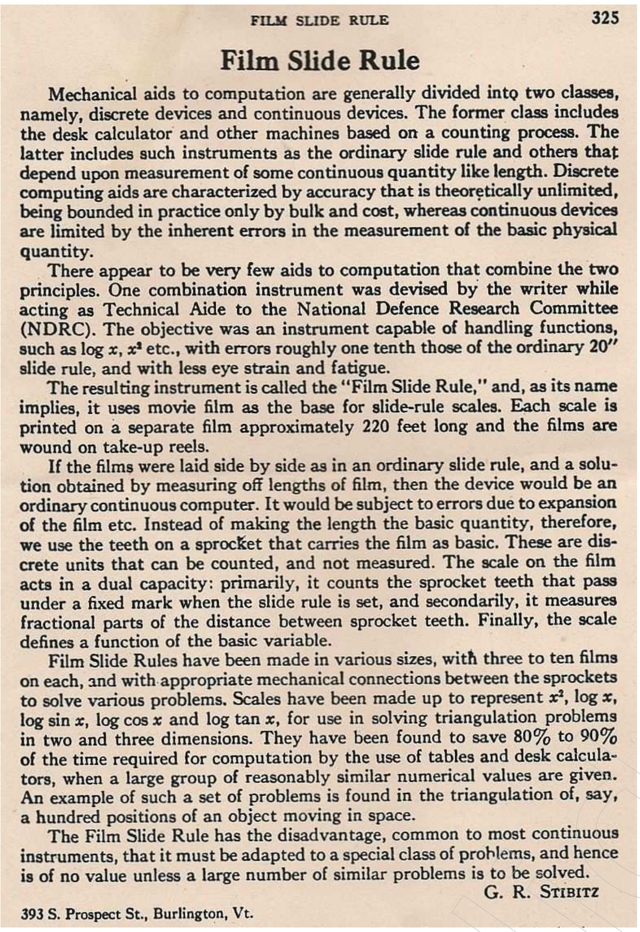
- In 1943 George Stibitz wrote: "As both are types of numerical calculator I see no reason why the relay system RDAPB (electromechanical computer) should enjoy less success than the ENIAC - Electronic Numerical Integrator and Computer. But I am sure the development time for the electronic system will take 6 times longer than the relay system" [4].
  In 1946 the legendary ENIAC was ready for use. The ENIAC University of Pennsylvania pioneers were John P. Eckert, John Mauchley, and Hermann H. Goldstine[5].

Returning to Stibitz's Film Slide Rule, it is scarcely known in the USA. Furthermore it seldom gets a mention or comes anywhere near the top of the returned results from a slide rule related Internet Google search. It was a special idea – in some ways it was an extension of the monopoly Bell Labs had at the time with computers but in this instance working with "logarithmic slide rule scales".

One reason it is little known and rarely cited is because it was developed for the military and used by the military for many years. It was in their interest to keep the existence of such machines secret. This is also probably the reason that, even in the new millennium and despite every effort by the authors, still little related information is in the public domain. A few references do exist[6]. For example: *"Invented Film Slide Rule for triangulation in fire control tests, 1943 - 45. Several units built for NDRC"* and *"During WW II Stibitz took a leave of absence from Bell Labs and joined Division 7 (Fire Control) of the NSRD, later the OSRD (Office of Scientific Research and Development). The Dynamic Tester, a device developed by Division 7 to test and guide the design of newly developed anti-aircraft gun control Directors, made great demands on the computers."*

By chance a short 1-page account written by Dr. George R. Stibitz and published by the American Mathematical Society in the 1947 October edition (Vol. 2 No. 20) of

*"Mathematical Tables and Other Aids to Computation"* caught the eye of the authors and was the incentive for writing this article.



FILM SLIDE RULE 325

## Film Slide Rule

Mechanical aids to computation are generally divided into two classes, namely, discrete devices and continuous devices. The former class includes the desk calculator and other machines based on a counting process. The latter includes such instruments as the ordinary slide rule and others that depend upon measurement of some continuous quantity like length. Discrete computing aids are characterized by accuracy that is theoretically unlimited, being bounded in practice only by bulk and cost, whereas continuous devices are limited by the inherent errors in the measurement of the basic physical quantity.

There appear to be very few aids to computation that combine the two principles. One combination instrument was devised by the writer while acting as Technical Aide to the National Defence Research Committee (NDRC). The objective was an instrument capable of handling functions, such as log $x$, $x^2$ etc., with errors roughly one tenth those of the ordinary 20″ slide rule, and with less eye strain and fatigue.

The resulting instrument is called the "Film Slide Rule," and, as its name implies, it uses movie film as the base for slide-rule scales. Each scale is printed on a separate film approximately 220 feet long and the films are wound on take-up reels.

If the films were laid side by side as in an ordinary slide rule, and a solution obtained by measuring off lengths of film, then the device would be an ordinary continuous computer. It would be subject to errors due to expansion of the film etc. Instead of making the length the basic quantity, therefore, we use the teeth on a sprocket that carries the film as basic. These are discrete units that can be counted, and not measured. The scale on the film acts in a dual capacity: primarily, it counts the sprocket teeth that pass under a fixed mark when the slide rule is set, and secondarily, it measures fractional parts of the distance between sprocket teeth. Finally, the scale defines a function of the basic variable.

Film Slide Rules have been made in various sizes, with three to ten films on each, and with appropriate mechanical connections between the sprockets to solve various problems. Scales have been made up to represent $x^2$, log $x$, log sin $x$, log cos $x$ and log tan $x$, for use in solving triangulation problems in two and three dimensions. They have been found to save 80% to 90% of the time required for computation by the use of tables and desk calculators, when a large group of reasonably similar numerical values are given. An example of such a set of problems is found in the triangulation of, say, a hundred positions of an object moving in space.

The Film Slide Rule has the disadvantage, common to most continuous instruments, that it must be adapted to a special class of problems, and hence is of no value unless a large number of similar problems is to be solved.

G. R. Stibitz

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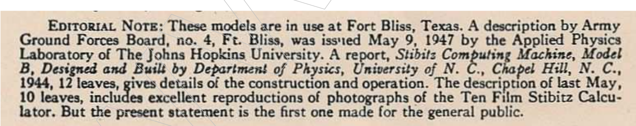
FIGURE 1.
First published news on the Film Slide Rule

In it Stibitz describes a computing instrument - a Film Slide Rule. He goes on to describe its origin, its use by the Army, how it was constructed and used, and its capabilities. By now Stibitz was working as a private consultant. Part of the description also recounts how it was the realisation of an extraordinary "slide rule idea". Stibitz was granted a patent for his invention on June 7th 1955 (US patent no. 2,710,142 - application date: 1946).

An "Editorial note" postscript at the end of the article helpfully states:



Editorial Note: These models are in use at Fort Bliss, Texas. A description by Army Ground Forces Board, no. 4, Ft. Bliss, was issued May 9, 1947 by the Applied Physics Laboratory of The Johns Hopkins University. A report, *Stibitz Computing Machine, Model B, Designed and Built by Department of Physics, University of N. C., Chapel Hill, N. C.,* 1944, 12 leaves, gives details of the construction and operation. The description of last May, 10 leaves, includes excellent reproductions of photographs of the Ten Film Stibitz Calculator. But the present statement is the first one made for the general public.

FIGURE 2.
Postscript explaining extra details and the existence of a Stibitz Calculator

So it can be assumed that the first Film Slide Rules were only for military use. But by 1947 Stibitz must have got his invention declassified as he could now, for the first time, announce the existence of his Film Slide Rule to peers and interested parties in a recognised trade publication.

**Description of the Stibitz Film Slide Rule**
(from the patent specification).

The first statements of the patent specification are:
"The present invention relates to slide rules and particularly *to that type of slide rule in which the scales are marked on movable filmstrips.* (sic)
More particularly the invention relates to a film slide rule having a plurality *of item entering scales and one or more result scales.*
In the past all film slide rules of which I am aware required the reading of the result from one of the item entering scales and thus necessitated the return of the scales to a zero referent point prior to each performance of a computation on the rule. By my present invention the necessity for resetting the scales to zero is obviated and, consequently, the rule is much more advantageous to use than any of those previously suggested."

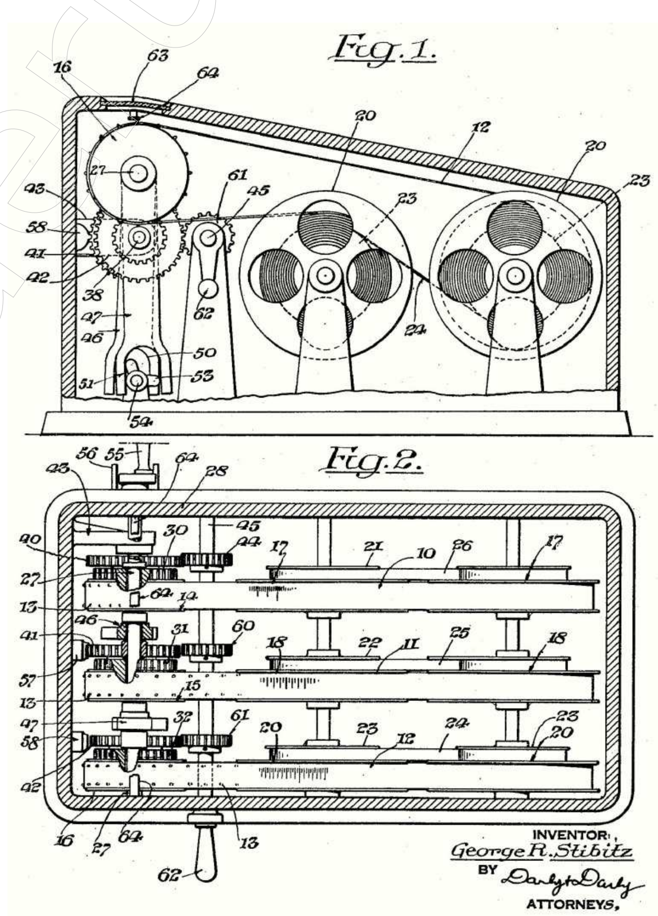



FIGURE 3.
Patent drawing of Stibitz's first Film Slide Rule

It is the final part of the specification that highlights what distinguishes Stibitz's invention from prior or similar patents. By eliminating the need to reset the scales to "zero" or return to a starting position, Stibitz is describing the simultaneous use of multiple scales i.e., a continuous strip of film. Furthermore the scales are part of a drive mechanism capable of working with or independently of one another. This meant they could be linked during a calculation or different values on the scales be locked as "constants" for use in a calculation.

Despite a major effort, the best and only picture of the Film Slide Rule is the one shown in the patent description. Possibly the military overtones kept (and continue to keep) any images from being released and stopped any built examples of the Film Slide Rule making it into a suitable museum collection.

**How did the Film Slide Rule work?**

Sadly it is difficult to judge how accurate the Film Slide Rule was. Speculatively, and going by the length of the film roll scales, results were probably accurate to 5 or even more digits.

What follows, based on the patent description, is a worked example for a five-film machine particularly applicable to the solution of trigonometric problems. By changing the cam arrangement and the scales, various other problems could also be solved.

Let us consider a trigonometric example taken from the patent. We start with a right-angled triangle with side A and adjacent angle ß.

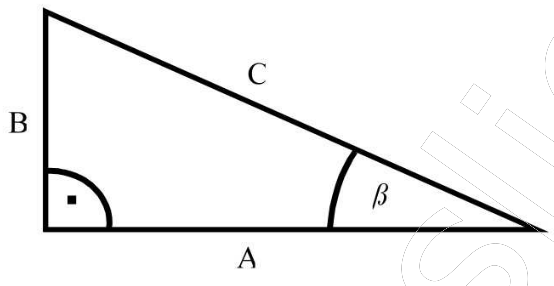



FIGURE 4.
Trigonometric example problem

Formulas to be considered:

$$C = A/\cos ß \rightarrow \log C = \log A - \log \cos ß$$
$$B = A * \sin ß/\cos ß = A * \tan ß \rightarrow \log B = \log A + \log \sin ß - \log \cos ß$$

The task is to calculate the length of side B opposite to angle ß and the length of the hypotenuse C.

For this kind of calculations the following scales are used within the machine (in the patent the scales a), b), c), d), and e) are named 10, 11, 12, 70, 71):

a) logarithmic scale 200 to 20000

b) logarithmic scale 200 to 20000

c) logarithmic scale 200 to 20000

d) log sine scale 0.56250 to 900 (given by unit mil, where 1mil = 1/6400 of 360°)

e) log cosine scale 1.68750 to 89.43750 (given by unit mil again)

The different scales are connected to a camshaft. The camshaft controls which scales will move simultaneously during operations, where the other scales will stay in their recent positions. For the above mentioned trigonometric problem three different camshaft positions are used:

I. Scales b) and d) will move
Scales a), c), and e) will not move

II. Scales a), b), and c) will move
Scales d) and e) will not move

III. Scales a) and e) will move
Scales b), c), and d) will not move

Now we can start the calculating operations itself. Set all the scales to the starting position. (n.b.: not mentioned in the patent description). Afterwards follow the three operations given in Table 1.

TABLE 1.
Three cam positions and their corresponding working

| | | | Cumulative distances moved on single scales | | | | |
|---|---|---|---|---|---|---|---|
| Shift to camshaft position | Scale operation | Moved distance during operation | Scale a) log | Scale b) log | Scale c) log | Scale d) log sine | Scale e) log cosine |
| **I.** b) and d) move | Move scale d) to ß | log sin ß | *No movement* | log sin ß | *No movement* | log sin ß | *No movement* |
| **III.** a) and e) move | Move scale e) to ß | log cos ß | log cos ß | *No movement* | *No movement* | *No movement* | log cos ß |
| **II.** a), b) and c) move | Move scale a) to A | log A - log cos ß | log A | log A - log cos ß + log sin ß | log A - log cos ß | *No movement* | *No movement* |
| **Final scale readings** | | | A | B = A*sin ß / cos ß = A*tan ß | C = A / cos ß | ß | ß |

**George Stibitz - the man**

Most of his professional life is well known and can be found via the Internet (see References). We also touched on it in recounting the story of his Film Slide Rule. Therefore we (only) cite some dates courtesy of stibitz.denison.edu/bio.html:

*"Born in York, Pennsylvania, Stibitz attended Moraine Park, an experimental school in Dayton, Ohio, and graduated from Denison University in 1926 with a Ph.B. in Applied Mathematics. (Ph.B. is often mistakenly written as Ph.D.) He received an M.S. from Union College in 1927 and a Ph.D. in physics from Cornell in 1930. Stibitz joined Bell Telephone Laboratories in 1930 and served as a mathematical consultant. From 1940 to 1945 he was on loan to the U.S. Office of Scientific Research and Development.*
*Following World War II, he was an independent consultant in applied mathematics for various government and industrial agencies. In 1964 he joined the Department of Physiology at Dartmouth Medical School as a research associate.*
*He then worked primarily on applications of physics, mathematics, and computers to biophysical systems. He became a professor in 1966 and professor emeritus in 1970."*

He died highly honoured in 1995 [7].

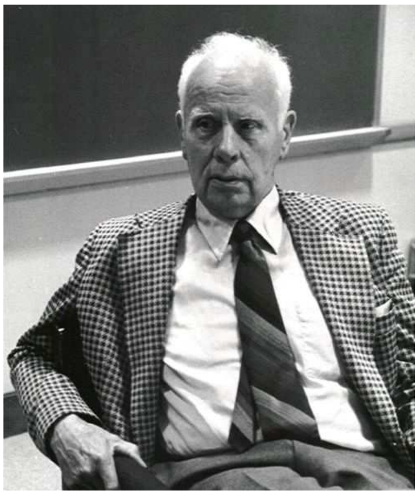


FIGURE 5.
George Robert Stibitz
(for more pictures see: stibitz.denison.edu/photos.html )

George R. Stibitz was born on April $30^{th}$ 1904 in York, Pennsylvania. He married Dorothea nee Lamson and they had two daughters: Mary and Martha. From Martha[8] (the younger sister) we learnt that George Stibitz built their first family house in 1929 when he was out of full-time work. It was the time of the Great Depression. He only worked four days a week. So he went on to build furniture for the house. In fact the kitchen table he made was also the "workshop bench" on which he built his first "breadboard" computer K.

FIGURE 6.
Stibitz house built in 1929

FIGURE 7.
Stibitz family (from left to right): George, daughters Mary & Martha, wife Dorothea

In her recollections Martha cannot remember her father's Film Slide Rule but she did provide details of his projects from home and in particular the building of the model K. The prototype was put together in the kitchen of his house, and therefore named K - an amusing story that can be found in most biographies of Stibitz.
*"Stibitz gathered a conglomeration of old relays, batteries, torch bulbs, wires, tin strips and sat down at his kitchen table in 1937 to fiddle"* [9]. Martha could answer one question related to her father building a Film Slide Rule model: *"he was a good mechanic and he made models of all his computers"*.

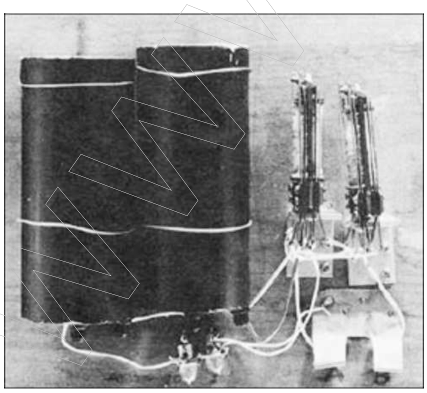


Figure 8.
Model K[9]

To sum up the man it would be wrong to see George Stibitz as just a consummate computer scientist and accomplished biomathematician. This would be overlooking the many aspects of his character which endeared him to his colleagues. He had a delightful sense of humour. Coupled with intolerance for bureaucratic bumbling and pomposity, the result is a humour-loving family man who despite his brilliance, always kept his feet firmly on the ground.

## Conclusion

George R. Stibitz was special. He was a prolific inventor and won many prestigious honours and awards. He is often rightly cited as: *"The father of the modern digital computer"*. But he was also a family man and greatly enjoyed family life.
Before reading this article many slide rule collectors may not have felt any affinity with George Stibitz. They should have as in his day Stibitz was one of a very few academics that bridged the analogue and digital worlds. But perhaps more poignantly he felt that the rash search for digital solutions in the 1930/40s abruptly stopped investment in analogue-based technology long before its full potential had been exploited.
Sadly the military overtones associated with the Stibitz Film Slide Rule probably stopped it (and still does) getting the recognition and publicity it rightly deserved. Nevertheless it is a fitting epitaph that the end of the analogue slide rule came too soon and before its usefulness and many applications could be fully matched by anything digital.

NOTE: An Addendum in JOS Plus gives the full text and drawings of Stibitz's patent no. 2,710,142, and lists (with descriptions) all the patents comparable with the Stibitz Film Slide Rule.

## Acknowledgements

It will come as no surprise that when such a remarkable invention has been "lost" for so long we needed help in fitting together all the pieces of the puzzle. In particular we owe a sincere word of thanks to:

- Martha Stibitz Banerjee: the younger daughter of George and Dorothea Stibitz.
  Early on in our research we tentatively contacted Martha to tell her about our plans. From the beginning she was enthusiastic about the idea to publish an article about her father's "forgotten" invention. When information was hard to come by her continued support motivated us. She also unselfishly shared memories and images relevant to us of her father's work and their family life.
- Paul E. Ceruzzi: Chair, Division of Space History National Air & Space Museum.
  Martha suggested we contacted Paul. He kindly provided many useful leads and tips for us to follow. He also alerted us to the online version of his book *Reckoners*. This was to prove invaluable to our research.
- Dr. Detlef Zerfowski: co-author of: *"A.W. Faber Model 366 – System Schumacher"* (JOS Vol.13,

No.2).Once again Detlef proved a great help and source of information. He pointed out relevant patent information and provided some useful computer history insights.

- Prof. Dr. Joachim Fischer and Dr. Detlef Zerfowski: both were instrumental in understanding and preparing a working example of how to use of the Film Slide Rule.
- Eugen Paulin/Dr.-Ing. E.h.Günter Kugel/Trevor Catlow: friends and fellow collectors. All three experts provided valuable intellectual insights, helpful advice and encouragement.
- Todd Feil: responsible for the Denison University online tribute to George R. Stibitz. As George R. Stibitz was an illustrious past graduate of the university, Todd compiled and published a web-based tribute to him on the Denison University website. Importantly for us when we contacted him he was able to put us in contact with Martha Stibitz Banerjee.
- Peggy A. Kidwell: Curator of Mathematics at the Smithsonian Institute. In response to our enquiry Peggy helpfully provided us with information and an image of the Paisley Calculator in their collection.

**Notes**

1. Zerfowski, Detlef (private correspondence) and Glade, Heinz (pg. 132-134):
George Stibitz and Konrad Zuse followed their ideas from 1937/38. Zuse´s basic Z1 (program controlled mechanical computer) was improved by the electromechanical relay controlled computer (Z2). Developments came to a head in 1941 with the model Z3 – with more than 2600 relays. The program was loaded using eight-tracked punched tape. Model Z3 performed 15 - 20 additions/sec or one multiplication in 4 – 5 seconds. This Z3 was destroyed by a 1943 bomb attack on Berlin but Zuse had foreseen a model Z4 which outlasted WWII.
(Martha Stibitz Banjeree mentions that her father got back and stayed in contact with Zuse after the War).
2. Ceruzzi, Paul E.: RECKONERS pg. 0074.
3. Ceruzzi, Paul E.: RECKONERS pg. 0075.
4. Paturi, Felix R.: *"Chronik der Technik"*, pg. 460 (translated from German).
5. Glade, Heinz, *"Am Anfang stand der Abakus"*, pg. 128.
6. Stibitz, George R.: curriculum vitae, projects.
7. PH.D., SC.D., ED.D, and other doctoral degrees (WI honorary). He also he held 38 patents.
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8. Stibitz, George R.: *"Film Slide Rule"*, Mathematics of Computation, American Society of Mathematics, Vol. 2, No. 20, ISSN 1088-6842(e) ISSN 0025-5718(p), Pg 325-325, 1947.

9. WIKIPEDIA: the free on-line encyclopaedia, entry for George Stibitz, http://en.wikipedia.org/wiki/George_Stibitz , 2011.

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12. http://www.kerryr.net/pioneers.stibitz.htm

13. Glade, Heinz-Manteuffel, Karl: *"Am Anfang stand der Abacus"*, Kulturgeschichte der Rechengeräte, Urania-Verlag, Leipzig Jena Berlin, 1973.

14. De Man, Andries: *"Electric Slide Rules"*, Mededelingen en Informatie voor verzamelaars van historische Rekeninstrumenten (MIR), magazine of the Dutch KRING, No. 48, Pg. 22, August 2008.

15. Meyer zur Capellen, W.: *" Mathematische Instrumente"*, 3. erg. Auflage, Akademische Verlagsgesellschaft Geest & Portig K-G, Leipzig, 1949.

16. Paturi, Felix R. *"Chronik der Technik"*, Chronik Verlag, Dortmund, 1988.