

THE UNIQUE LAWRENCE¹

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The ubiquitous and much maligned originators of the "25¢ slide rule" are not all what they seem!



Why Lawrence?

It is easy to think that slide rule innovation and creativity in the 20th century was largely the domain of commercial greats like Nestler, Faber-Castell, Keuffel & Esser, etc. But like its maligned UK "counterpart" **Unique**, the ubiquitous Lawrence is wrongly and unfairly just seen as a "*pile 'em high and sell 'em cheap*"² maker of slide rules.

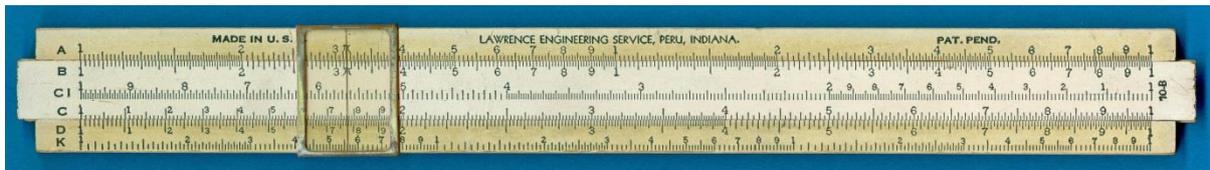


Fig. 1: classic Lawrence 25¢ painted Enhanced Mannheim 10-B

In so many ways the American *Lawrence Engineering Service* was a kindred spirit of the *Unique Instrument Company of Brighton Ltd.* Both makers had a charismatic founder and a colourful company history. Bruce Babcock's 1996 article in the *Journal of the Oughtred Society* (JOS) recounted the Lawrence company history. This article covers new and previously unreported revelations - the company's European roots, bitter family disputes, its unmatched cost control, the mystery behind the Lawrence model numbering and the many innovative and highly inventive slide rules Lawrence made.

European roots!

George Lee Lawrence, the founder of the Lawrence family slide rule business was born on 6th September, 1901. For many Europe-based collectors there is nothing more quintessentially American than a Lawrence-made slide rule. But it may surprise collectors on both sides of the Atlantic to learn that the Lawrence family are direct descendants of **John Philip Lorenz** (1727-1800) who emigrated to the States from Niederhausen, Prussia (now Western Germany) in 1748. So the company has traceable European rather than exclusive American roots.

George's father, **George Raymond Lawrence** (1868-1938), was born on his parents LaSalle County farm in Ottawa and is the great-great-grandson of his Prussian ancestor.

A decade after marrying Alice nee Herendeen (1861-1930) in 1890, George senior moved over 70 miles to Illinois' largest city: Chicago. George Lee and his 10-year older brother, Raymond Welcome, were both born in Chicago. In 1891 George senior opened the *Lawrence Portrait Studio*. He went on to build the largest known camera and develop an innovative process for flash photography. Later in life he started an aircraft company with partner Harry Lewis: *The Lawrence-Lewis Aeroplane Co*. The company built biplanes from 1913 to 1919. But he is best remembered as the world famous Chicago-based pioneer photographer who took remarkable aerial pictures with cameras slung under giant kites or large hydrogen-filled balloons.



Fig. 2: **George Raymond Lawrence's iconic aerial shot from 2000 feet of San Francisco in ruins after the earthquake in May 1906**

Lawrence "family" of companies

Like his UK counterpart, Burns Snodgrass (1881-1954) who founded **Unique**, Lee (he never used George – favouring his middle name) became an entrepreneur. His education was interrupted in 1909 when his mother Alice found out that his father had been having an affair and soon after they split up. It was so acrimonious that claims and counterclaims of kidnapping young Lee by both parents were first reported in the *Chicago Daily Tribune* newspaper on 17th February 1911. It was still newsworthy a year later when it featured in the *Oakland Tribune* in both the 31st March and 16th April editions. The divorce became final in 1913. In the same year Lee's father married Adele nee Page (1894-1962). The timing of his parents' bitter break-up might explain why there is no record of Lee ever gaining a college degree.

His father's success as a professional photographer and builder of biplanes was most probably behind the two Chicago-based businesses Lee started around 1930. Sadly no examples are known to have survived from the *Lawrence Slide Rule Company*. It made and sold photography related slide rules/charts. But a second business, *Lawrence Airplane Models*, flourished. The company sold a series of balsa wood kits of model planes of "unusual flying ability" – see Fig. 3. The kits, with impressive wing spans of 24 inches or more, included replicas of popular aeroplanes of the day such as the *Sopwith Camel*. The experience Lee gained cost-effectively manufacturing the many wooden parts need for such kits may well have paved the way for his later successful second attempt at manufacturing slide rules.

In 1935, five years after starting his Chicago-based businesses, Lee uprooted and moved over 160 miles south and out of state to Wabash, Indiana. This move may have been the result of an earlier marital breakup. Lee married the first of his eventual three wives in 1922. She was Ada nee Zimmer (1903-1975). Within two years the marriage was blessed with the birth of a son, Lee junior (1924-2012). Needless to say the marriage did not last and by 1929 Ada and her son had started a new life in Philadelphia.

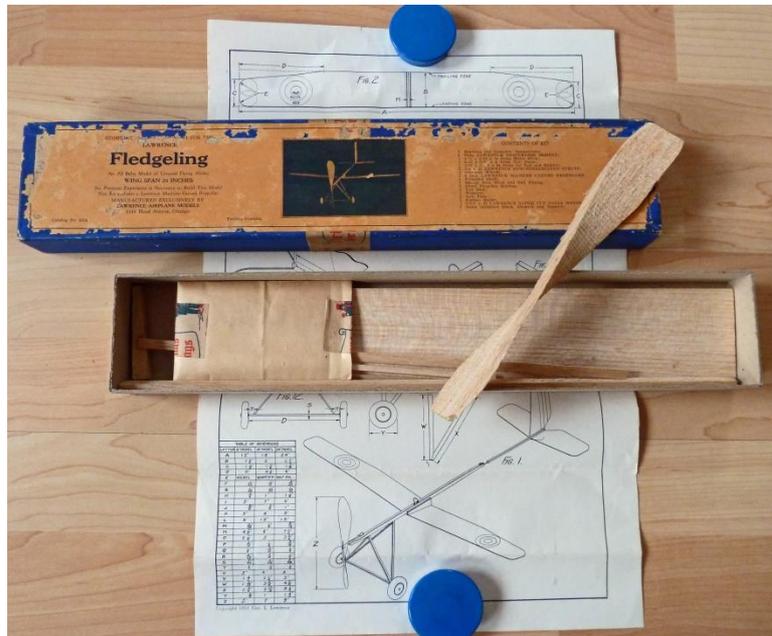


Fig. 3: **Boxed (15½ x 3 x 1¼ inch) kit © 1931 for building a "Fledgeling" – a model with a 24 inch wingspan requiring no previous model building**

In Wabash Lee founded *Lawrence Engineering Services* to make and sell slide rules. By now he was married to his second wife: Vivian nee Breyer (1915-1973). They met in Chicago but were married in Indiana in 1934. But Vivian did not immediately move with Lee to Wabash. She was ambitious and clever and, at first, may have been reluctant to leave Chicago. When she did eventually join him she took an active part in the business – particularly sales and promotion. Mike Konshak's "poster" succinctly summarises the evolutionary path of the Lawrence slide rule. But unlike some company success stories, this one revolves more around marriage and divorce than technology!

Flourishing sales is the most likely reason that three years after start-up the operation and the Lawrence family moved 13 miles west to larger premises in the neighbouring city of Peru. This accounts for either a Wabash or a Peru provenance being printed after the company name on all of their branded slide rules. Apart from adding plastic veneers in the late 1950s, this is the start of the most innovative era of the company. "PAT. PEND." can be found on many of the Wabash-made slide rules and on some later Peru-made models. But no corresponding registered patent exists. Like many other slide rule makers, Lee probably found it too time-consuming and too costly to get full patent protection – especially as the process involved annual renewal fees. It was more cost effective to make a patent application to get some initial protection and then let it lapse. However, apart from those credited to 3rd parties, a whole series of copyrighted designs are attributed to *Lawrence Engineering Services* from the mid-1940s onwards – see Tables 1 and 3.

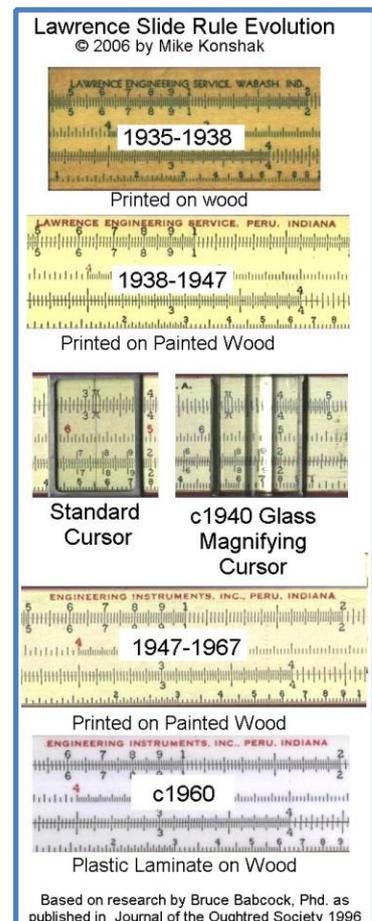


Fig. 4: **Lawrence slide rules through the years**³

Instigated by his second wife, Lee and Vivian were divorced in 1947. Vivian cited Miss Louise Huber, an old family friend, as co-respondent in the action. Lee always fiercely denied she was anything but a friend. But an inexplicable part of the divorce settlement was that Lee "let" the slide rule business go to his ex-wife. Directly afterwards Vivian's soon to be new husband, the Rev. Frank Bozarth, became President of the company and it was renamed: *Engineering Instruments Inc.* Twenty years later the business abruptly folded after a major fire on July 5th 1967 burnt everything down. Despite being insured, Frank Bozarth decided it was time to call it a day and the "Lawrence" family business stopped trading after being in business for 37 years.

A year after his divorce from Vivian Lee remarried for the third and last time to divorcee Nellie Donaldson nee Mowbray (1911-1990). They had met through the company as Nellie had previously been the wife of the sales manager at *Lawrence Engineering Services*. Having lost the slide rule business Lee threw his energies into a plastics company he had founded in 1945: *AGP Corporation*. Lee's initial interest in plastics stems from the high breakage/waste rate in making and shipping Lawrence glass cursors – especially the glass magnifying cursors for the *DeLuxe* version of the 10-B. Lee had bought his own plastic moulding machines so he could replace glass magnifying cursors with more durable and cheaper plastic versions. He clandestinely removed the machines when he realised he was going to lose the slide rule business to his second wife. This is borne out by no plastic magnifying cursor ever appearing on any of the models sold by *Engineering Services Inc.* But Lee's entrepreneurialism could not be dampened by family strife. With the *AGP Corporation* he ended up as the OEM manufacturer for many highly successful plastic toys. For example, the hit toy of the 1950s/1960s: "*Etch-a-Sketch*". In 1963 he became part-owner of another Peru-based company: *Precision Ceramics*. He died on 21st March, 1976 while on holiday with Nellie in the British Honduras. He is buried at the Mount Hope Cemetery in Peru, Indiana. Fourteen years later Nellie was laid to rest alongside him.

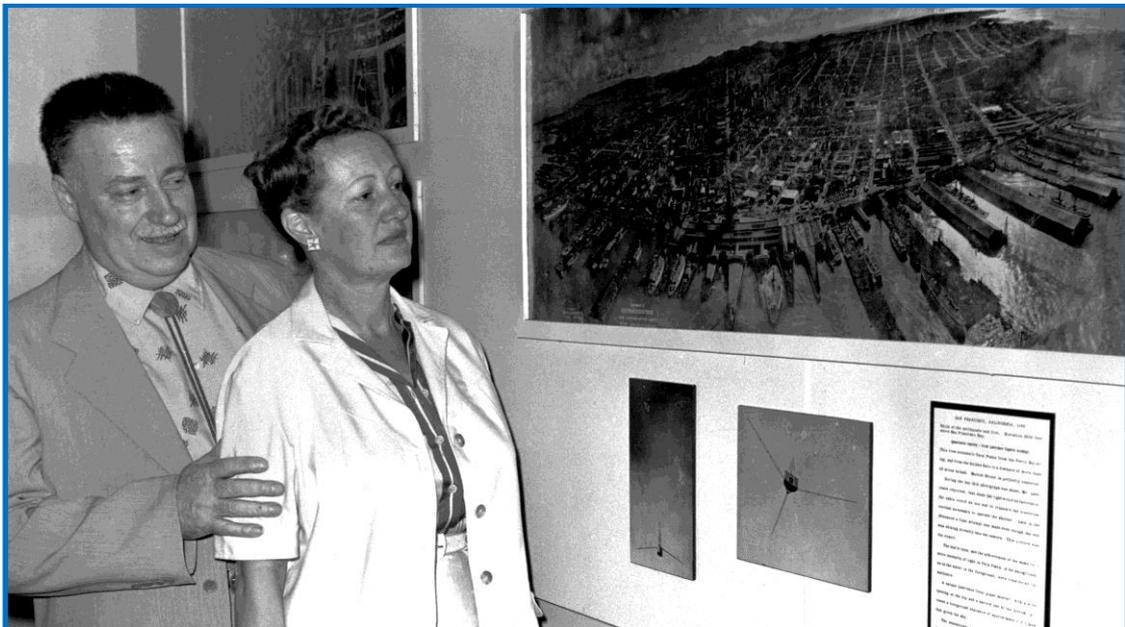


Fig. 5: **August 5th 1960: Lee and Nellie at the opening of "*Aerial Photography 1900-1910*" - an exhibition of his late father's work⁴**

Lawrence standard “blanks”

Margins for the originator of the **25¢**⁵ slide rule must have always been tight! In “money-of-the-day”, a comparable retail price now would be no more than \$4. Sadly because of the fire in 1967 there is no way of knowing for sure the shop floor set-up and working practices. However, after comparing over 50 different Lawrence/Engineering Instruments slide rules, phenomenal cost-efficiency stands out. In his working life Lee was considered a bit eccentric and short-tempered. But he was undoubtedly an “ideas man” with a sound engineering brain. For example, he inexpensively rejigged the working practices so that the company could go on to make many innovative slide rules. This leveraged the company out of their “*pile 'em high and sell 'em cheap*” niche market.

If Lee was the “ideas man” it was Ed Snyder, a long-standing employee, who usually turned them into something practical for the shop floor. It must have been soon after they started manufacturing in Wabash, that they hit on the idea to use standard wooden blanks. The company started by making two types of an 8-inch⁶ slide rule – a Mannheim and an Enhanced Mannheim (but without the trigonometric scales). The scales were printed in monochrome onto a solid frame wooden stock (see: Table 1). Later, for better contrast, the front face and sometimes the back of the slide were first painted white before the scales were added. Lawrence/Engineering Instruments ended up with an eclectic mix of model sizes. The portfolio included stock lengths of 5, 6, 7½, 8, 8½, 9, 10, 10½ and 12-inches. However, despite the variety of stock lengths, certain unique dimensions and characteristics never changed. Whether it was a Lawrence/Engineering Instruments branded slide rule, a specially commissioned themed slide rule or even an Original Equipment Maker (OEM) slide rule the:

- **width of the stock was always 1⅛ inch**
- **thickness of the stock was always 5/16 inch**
- **width of the slide was always 9/16 inch**
- **thickness of the slide was always 1/8 inch**
- **top and bottom side edges (never bevelled) always had tracks for a one-size cursor – even if one was not needed**
- **no scale was ever added to a side edge**
- **the back of the stock was never painted**
- **cursor (if needed) was always metal framed glass/plastic or all-plastic** (n.b. not all models came with or needed a cursor and for those that did come with a cursor, more than often it broke or was lost)

On some models the slide was left longer than the stock. Conversion tables or instructions were often printed on the back of the stock. Some even had a promotional advert for a 3rd party on the back. But the unique tooling dimensions and characteristics are always a sure-fire way of telling if a “look-alike” slide rule was made by Lawrence/Engineering Instruments or by someone else.

The uniformity of the dimensions suggests all models were milled from standard 12-inch solid frame blanks as the 10/10½-inch models were the most popular size. However, if a single-sized 12-inch blank created too much wastage, they may have opted for several different sized standard blanks – e.g. 12, 10/10½ and 6-inch⁶. To keep costs as low as possible the wooden blanks were probably milled from the readily available and inexpensive poplar trees - genus: *Populus*. However, not all the slide blanks were interchangeable. Most Lawrence/Engineering Instruments models were simplex models carrying no scales on the back of the slide. So for simpler rabbeting the rails along edges

of the slide are at the bottom. But some models did have scales on the back of the slide (see Table 2). For such models the rails were naturally centred.

Lawrence/Engineering Instruments made many different models that carried the company name – i.e. branded slide rules. But they made many more specially commissioned themed and Original Equipment Manufacturer (OEM) slide rules. However, identifying such unbranded slide rules can be tricky because the distinctive but unpatented Lawrence style was often copied.

Lawrence/Engineering Instruments branded slide rules

Previously published Lawrence related articles felt there was no rhyme or reason to the model numbering. Now having had the chance to examine first-hand almost all the branded Lawrence slide rules ever made, I have found a way of making sense of the cryptic model codes printed on the right-hand end of the slide. First it is important to realise that all the slide rules carrying a *Lawrence Engineering Services, Wabash/Peru* or *Engineering Services Inc., Peru* brand name belong to one of four distinct ranges:

1. **Imperial range with n[n]-x[x] alphanumeric model no.'s**
2. **Metric range with nn[n]-x[x] alphanumeric model no.'s**
3. **Set & Book range**
4. **Plain range with no model no.'s**

Most branded rules were part of the imperial range. The **n[n]** numerical prefix part of the model number is the length of the stock in inches – hence the name: “imperial range”. The first **x** alphabetical suffix is for all the different types within the range. The optional extra last character **[x]** was for different versions of the same type.

Model #	Type/Name (© yyyy)	Cursor	Scale layout/Use
8-A	Mannheim	Yes	A/B,C/D
8-B	Enhanced Mannheim	Yes	A/B,CI,C/D,K but <u>no</u> S,L,T
10-B & DeLuxe	Enhanced Mannheim (DeLuxe only on the box)	Yes Yes	A/B,CI,C/D,K but <u>no</u> S,L,T DeLuxe version = magnifying cursor
10-C	ENGRAVER'S AND PHOTOGRAPHER'S PROPORTION CALCULATOR	No	For area % up & down scaling (reduction/enlargement arrows point to results - no cursor needed)
10-D 10-Do	LUMBER CALCULATOR (© 1946)	No No	For lumber volume in board feet ⁷ (set thickness & width, result on “D” for given length – no cursor needed)
10-F	PRICING AND INVENTORY RULE (versions © 1945 and © 1946)	Yes	For discount or profit margin mark-up per gross/dozen/each in \$'s and value of stock in \$'s
10-G	CUTTING SPEED CALCULATOR (© 1946)	Yes	For recommended cutting speed in f.p.m. ⁸ for given drill speed & size
12-H	COPYFITTER (© 1946 but credited to Owen T. Taylor)	Yes	For font size and letter/word/line spacing in points and picas ⁹ when typesetting (also version in Table 3)
10-I	MODEL BUILDER'S SLIDE RULE (© 1947)	Yes	With the special tables on the back it scaled down railroads/trains

Model #	Type/Name (© yyyy)	Cursor	Scale layout/Use
			according to various railway gauge sizes to make replica size models
12-J	PRO-RATER (© 1948)	Yes	For calculating days between two dates and the pro-rata premium for a given number of days (pro-rata table to four decimal places on back)
9-K	MUSIC TRANSPOSER ¹⁰ (© 1947)	No	For constructing chords in any key & transposing one key to any other (red/blue dots – no cursor needed)
8-L	COPPER WIRE SELECTOR "Voltage Drop Calculator" (© 1946)	No	For minimum wire size in A.W.G. ¹¹ (set length & load, result on "D" for 440/220/110 voltage drop – no cursor needed)
10-N	PRINTER'S PROPORTION RULE (© 1946)	Yes	For moving between inches & picas ⁹ when printing/publishing
6-Op	FLASHRULE (© 1946)	No	For correct lens aperture per type of GE or Westinghouse flashbulbs.
6-Ow	FLASHRULE (© 1946)	No	Ditto but for WABASH flashbulbs (set film speed & lamp, result on "D" for distance – no cursor needed)

Table 1: **Imperial range of Lawrence/Engineering Instruments branded models**

As shown in the Appendix-A picture gallery, apart from the "everlasting" model 10-B, this range came out long before the Engineering Instruments Inc. era. But it remains a mystery why two letters in the model sequence were skipped – e.g. why has no type E or M ever turned up? Maybe they were prototypes that never made it to market.

The idea for the metric range came from fellow collector David Green. With one dubious exception, it covers all Lawrence/Engineering Instruments branded slide rules with model numbers that do not conform to the syntax of the imperial range. This time the **nn[n]** numerical prefix part of the model number refers to the length of the "D scale"¹² in millimetres rather than the length of the stock in inches - i.e. 250mm. Therefore the name: "metric range". The **x[x]** alphabetical suffix cryptically depicts the different types in the range. "BT" may stand for a model B from the imperial range and the I for the three extra trigonometric scales on the back of the slide. Likewise "V" may stand for veneered scales. The A on the "77A" could correspond to the name on the slide rule: "American Log-Log."

Model #	Type/Name (© yyyy)	Cursor	Scale layout/Construction
250-BT	Enhanced Mannheim	Yes	A/B, CI , C/D, K//S, L, T Front face and back of slide lacquered/painted
250-V	Enhanced Mannheim	Yes	A/B, CI , C/D, K//S, L, T Front face and back of slide veneered with hard white plastic

Model #	Type/Name (© yyyy)	Cursor	Scale layout/Construction
77A	Log-Log Decimal Trig	Yes	LL02,LL03,DF/CF,CIF,CI,C/D,LL3,LL2 //LL01,K,A/B,T,ST,S/D,L,LL1 Duplex all plastic (? OEM made rule)

Table 2: Metric range of Lawrence/Engineering Instruments branded models

Now the back of the slide was also part of the scale layout, a small clear plastic insert



was added into well of the stock at the right-hand end. With the hairline in the insert it was possible to set or read off results from using the trigonometric scales without having to reverse the slide. Also on many, but inexplicably not all 250-BT's, there is another 3-digit number printed under the slide on the left-hand end. Speculatively this might have been a batch or production-run number. The models in the metric range predominantly come from the post Lee Lawrence *Engineering Services Inc., Peru* era – see the Appendix-A picture gallery.

As shown by the only company-issued flyer I have ever been able to find, by the late 1950s more internationally orientated marketing and printing the scales on white plastic veneers to increase legibility were now part of the business philosophy.

Fig. 6: Front page of a 4-page marketing flyer from ca. 1958

By now the \$2.00 250-V was the top end model with the \$1.25 250-BT their “Students Special” and the old faithful 10-B reduced to being their 60¢ budget slide rule. Being all plastic, duplex and not conforming to the unique dimensions and characteristics of all Lawrence/Engineering Instruments made slide rules, the 77A is an oddity. It is, suspiciously, identical with the *Acu-Math* model 150 Duplex Log Log Deci Trig slide rule. I believe the 77A is an OEM slide rule made by *Acu-Math* for *Engineering Instruments Inc.* The front cover of the flyer also boasts two circular slide rule made of “vinylite”. Clearly by this time *Engineering Instruments Inc.* resold all-plastic slide rules and a wide assortment of drawing instruments – none of which they could have made in-house.

The set and book range shows how Lee forged new partnerships with other companies. Copyrighted in 1939 Lee first came up with the novel idea of marketing a toy: *the Lawrence Secret Code-Maker*.

Fig. 7: Code-Maker boxed set



The boxed set contained two (i.e. also one for your "best mate") identical 7½-inch *Secret Code-Maker* slide rules without cursors and a 16-page "*Make Your Own Secret Codes in a Flash*" instruction booklet. From the image on the box it was aimed at teenagers but intriguingly the image on the instruction booklet is of an adult. Perhaps Lee was trying to play to both the childhood "secret agent" fantasy and the prevailing WWII adult nervousness about secrecy? The A-Z, inverted Z-A and 5-cycle 0-9 scales make it easy to create or decode a Vigenère cipher¹³. This is a method of encrypting text messages with a simple one-step substitution, reversed substitution, mixed substitution or a more complex transposition code using a mixture of substitution methods. The Lawrence booklet incorporates and greatly extends a pamphlet written by W. St. John Maloney¹⁴ and copyrighted by the *Cole Corporation* of Chicago in 1939. Unlike other Lawrence slide rule guides¹⁵, this booklet is much more educational – including many code-related historical facts going back as far as the days of Julius Caesar. There were at least two variants of the code-maker. One was called: *The BEICH Secret Code-Maker*. This was an 8-inch⁶ Lawrence branded rule with a thin metal "fisheye" cursor and a simplified 4-page leaflet. It was part of a loyalty scheme and could be won by collecting Beich *Whiz*¹⁶ chocolate bar wrappers. So Lee was doing a "Willy Wonka" decades before Roald Dahl published "*Charlie and the Chocolate Factory*" in 1964 and Gene Wilder starred in the 1971 film of the book. The other version was the 6-inch⁶ *Dick Tracy Code-Maker*. Like the original 7½-inch⁶ model, the Dick Tracy version had no cursor. It came with a Dick Tracy emblazed simplified 4-page version of the booklet and was presumably marketed in cooperation with the "*Chicago Tribune New York News Syndicate*", the publishers of the comic strip book hero created by Chester Gould (1900-1985).

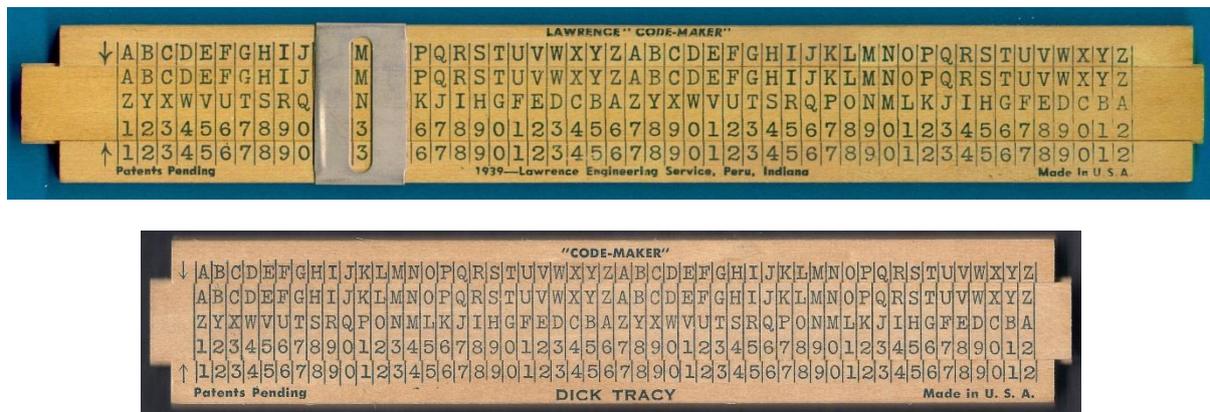


Fig. 8: **8-inch Beich and 6-inch Dick Tracy "Code-Maker's"**

In 1942 the Austin Publishing Company copyrighted an idea for a "teach yourself" workbook on how to use a slide rule. The US Letter sized hard-backed book came with a Lawrence DeLuxe (magnifying cursor) 10-B slide rule. The authors were Hobart H. Sommers, Harry Drell and T.W. Wallschlaeger and it was published by two companies. The *Grosset & Dunlap* version had a dirty orange and black cover and was published in New York (208 pages incl. Tables of Logarithms, Trigonometric Functions of Angles and the Answers). The *Wilcox & Follett Co.* edition had a dark-green and gold cover and was published in Chicago (same 208 pages but with an extra loose-leaf Answers addendum).

Much later, in 1961, *Lakeside Toys* brought out a *Draft-a-Plan Kit*TM. This large boxed drafting set came with a plastic electric-powered drawing slope, many drafting related aids and an Engineering Instruments Inc. made "5-B" pocket Enhanced Mannheim slide rule. The "*Drafting is Fun*" guidebook has a chapter on how to use the slide rule. Finally, in 1966, the *Cadillac Publishing Company* started publishing a 33-volume (7¼ x 10½ inch) *Self-Teaching Encyclopedia*. Volume 1 was "*Mathematics Made Simple*" and the publishers proudly sold it with a "free" model 10-B slide rule. Later, despite all the illustrated examples being based on the model 10-B, the company replaced it with a shorter (and cheaper) 6-inch⁶ version.

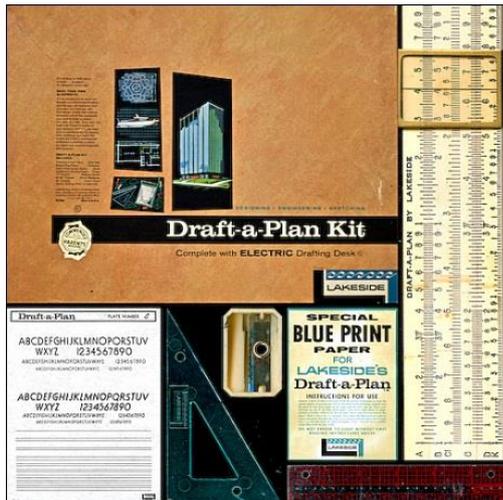


Fig. 9: **Lakeside *Draft-a-Plan Kit*TM set for a teenager**

The final plain range of branded slide rules is chronologically probably some of the last wood/painted slide rules Lawrence/Engineering Instruments sold. Apart from coming from the Peru factory, I can think of no good reason for leaving off a model number on any branded slide rule. Almost without exception, one did have "10-BK" on the box, all the branded slide rules without a model number are identical with one of the classic models – the 10-B or the later 250-BT. Maybe the model number was left off to give the slide rules fashionable cleaner lines for the "swinging sixties". An example is part of the Appendix-A picture gallery.

Lawrence/Engineering Instruments specially commissioned themed slide rules

Nearly all are unbranded and have no model number. Most have non-conventional scale layouts and are so innovative that almost all the designs were copyrighted. They came in various sizes (occasionally different sizes of the same model) and most, but not all, had a cursor.

It is easy to mistake many unbranded themed slide rule as being made by Lawrence/Engineering Instruments. But many are just "look-alikes" - similar in style but made by someone else. The listed examples all conform to the unique dimensions and characteristics of a Lawrence-made rule. However, any named model could easily have been commissioned by more companies/parties than those listed in the table.

Commissioned by (© yyyy)	Size ⁶	Model Name/Use
Lakeside Toys – Draft-A-Plan, Minneapolis (© 1961)	5"	Students <i>Learner</i> pocket slide rule – Enhanced Mannheim ("5-B" on box) with A/B,CI,C/D,K but no S,L,T
B.F. Grizzle, Washington and Terre Haute (8" version © 1941, 12" version © 1945)	8" & 12"	Gas Pipe Line Slide Rule for calculating the gas flow capacity/hour through a pipe of a given diameter
B.F. Grizzle, Washington and Terre Haute (© 1941)	8"	Gas Displacement Meter Calculator for calculating gas rates through displacement meters @ various pressures

Commissioned by (© yyyy)	Size ⁶	Model Name/Use
B.F. Grizzle , Washington (© 1941)	8"	Gas Low Pressure Line Flow Capacity Slide Rule for calculating the pressure drops for a given line flow & gas line size needed to deliver a given amount of gas
B.F. Grizzle , Washington (© 1944)	8"	Pipe Open Flow Capacity Slide Rule for calculating open flow rates based on pilot tube pressure readings
B.F. Grizzle , Washington (© 1939)	8"	Pipe Orifice Meter Calculating Rule for calculating the size of conduit/restriction needed to create a required pressure drop
B.F. Grizzle , Washington (© 1944)	8"	Water Line Capacity Slide Rule for calculating the friction loss in a section of pipe & head loss for a given pipe diameter, length & flow
Madison Manufacturing Company , Michigan (© 1947)	8"	Madison Speed Calculator for calculating drill & cutting speed for a given diameter
Thomas Specialities , California (© 1948)	8½"	Music Transposition for composing, transposing or creating harmonies
Massachusetts Institute of Technology (MIT) , Cambridge Radiation Laboratory – c1941 Roy C. Spencer	10"	Antenna Slide Rule (confidential and classified) for calculating radar antenna beam patterns - beam width, gain, etc.
Massachusetts Institute of Technology (MIT) , Cambridge High Voltage Laboratory – 1943 W.W. Buechener & E.A. Burrill Jr.	10"	Exposure Slide Rule (possibly for the US Navy in WWII) for calculating exposure times of super high-voltage steel penetrating X-rays of castings & munitions
C.V. Ore , Illinois (© 1955) (n.b.: Acu-Rule made an OEM plastic version of this rule)	10"	The S-M Slide Rule (DS/CI,C/D/DM) a <u>S</u> implified <u>M</u> ulti-purpose type of Enhanced Mannheim teaching rule supposedly making it easier to learn how to multiply/divide, etc
Canadian Radium & Uranium Corp. , New York (© 1942)	10"	Gamma-Ray Radiographic slide rule for commercial (steel) rather than medical use
Miller Motor Company , Illinois (© 1950)	10"	Air and Hydraulic Calculator (DIA,A/B,CI,C/D,GAL) for calculating flow rates through different sized pipes
Fun Incorporated , Illinois & Ideas Unlimited , California (© 1950)	6" & 10"	Poker Meter for 5/7 card stud or 5 card draw poker. Based on number and value of cards held, a colour code recommends the best play – "Get Out", "Stay" or "Raise"
PIC Walsh Freight Co. & Plaza Express Company Inc. (© 1939 M.T. Brockman)	9½"	Traffic Manager's Slide Rule for checking freight shipping charges or shipping rates or shipping truck/carload breaking points and calculating storage costs
US Army (DeYOE)	10"	Artillery Range Finding ("Graphic Table") for calculating how many guns and how many rounds of high explosive shells are

Commissioned by (© yyyy)	Size ⁶	Model Name/Use
		needed to be sure of hitting a target
Murphy & Murphy Inc. , Texas & Caprock Materials Co. , Texas & Warren E. Fennell , Indiana	10½"	Concrete Quantity Calculator for calculating cubic yards of concrete needed for or in a wall of certain dimensions
Tokheim Corporation , Indiana (© 1948)	12"	"K" Factor – using high & low outdoor temperatures and gallons of household fuel oil left, the K factor = days of supply left
Tenbrook Enterprises , Indiana	12"	L.P. Gas – for calculating the temperature correction (°F) needed when making bulk deliveries of propane
L.E. Waddington , (© 1947)	12"	Music & Music Acoustics for transposing chords, interval ratios, harmonic series, octaves and frequencies
Taylor Publishing Co , Ohio (© 1946 credited to Owen T. Taylor)	12"	Copyfitter for font size and letter/word/line spacing in points and picas ⁹ when typesetting (copy of the 12-H)
United States Aviation Underwriters Inc. , (© 1944 Albert J. Smith)	12"	Underwriters slide rule for calculating the risk duration (in days) for aviation related ventures (table on back has cancellation ratio's/days)
Pioneer (address unknown) & Adler Communications Laboratories , New York (© 1952 J.B. Epperson)	12"	Epperson TV Coverage Calculator for calculating VHF and UHF signal coverage based on a signal strength, FCC propagation curves and antenna height (UV/M and DB conversion table on back)
Radio Corporation of America (RCA) , New Jersey	12"	F.M. COVERAGE CALCULATOR for estimating (according to FCC propagation curves) coverage of FM radio stations according to the type of RCA radio antenna

Table 3: **Lawrence/Engineering Instruments unbranded specially commissioned themed slide rules**

As shown by the *Poker Meter*, *Traffic Manager's Slide Rule* and the *Concrete Quantity Calculator* entries, different companies often commissioned different sizes or different versions of the same themed slide rule. So this series proves, yet again, how Lawrence/Engineering Instruments successfully used their standard blanks to make an enormous variety of interesting and ground-breaking slide rules – often (re)selling the same design to multiple clients. An example of all the listed models can be found in the Appendix-B picture gallery.

Lawrence/Engineering Instruments OEM slide rules

By its nature this section is subjective and, in part, controversial. Lawrence/Engineering Instruments made OEM slide rules are, by definition, unbranded although some do have recognisable model numbers. One of the more easily made mistakes is to confuse them with certain early models from the St. Louis based *Festus/Acu-Rule Mfg. Co.* - in

particular their model 10-D. Because of the model numbering it is often mistaken for a Lawrence/Engineering Instruments 10-B. They are similar in size, have the same solid frame wooden construction and the same scale layout - an Enhanced Mannheim without the trigonometric S,L,T scales. But the telltale difference is that the Acu-Rule 10-D has a bevelled top edge inch scale – a feature never used on any Lawrence/Engineering Instruments slide rule.

Over the years it has been speculated that the budget-range models of some American commercial slide rule greats are OEM slide rules made by Lawrence/Engineering Instruments. The favourite nominations are:

- **Keuffel & Esser** model: N4058W
- **DIETZGEN** models: 1767/68/69P
- **POST** model: 1446-D
- **Charvoz-Roos** model: SR-31
- **A. Lietz Company** model: 2974N

All are Enhanced Mannheim’s and all are “Lawrence-like”. But only the **Charvoz-Roos SR-31** and the **Lietz 2974N** are OEM rules from Lawrence/Engineering Instruments - both rebadged 250-BT’s. The main OEM customers were businesses, government bodies and resellers of scientific or office/drawing equipment.

Made for:	Rebadged
DUPONT - Neoprene, Rubber Chemicals and Colors , Delaware	250-BT
U.S. Navy	250-BT
DU MONT , Ohio	250-BT 8-B
Burger Scientific Supplies , Boston	250-BT
W. M. Welch Scientific Company , Illinois	250-BT 250-V 10-B
NOBEMA Products Corp. , New York	10-B
PAULL INSTRUMENTS	10-B
LARCH , New York	10-B
Coyne Electrical School , Chicago	10-B
GENE LOEWY PRODUCTS , New York	10-B
ANCO PRODUCTS Co. , Ohio	8-B

Table 4: **Lawrence/Engineering Instruments “rebranded” OEM slide rules**

As in the past businesses often used such OEM slide rules as promotional gifts, many more unlisted examples undoubtedly exist. Nevertheless the listed examples do show how Lawrence/Engineering Instruments found yet another successful avenue to reuse/rebrand their popular Enhanced Mannheim and Mannheim type slide rules. The Charvoz-Roos, the Lietz and some of the examples listed in the table are part of the Appendix-B picture gallery.

Just toys or calculating aids for professionals?

The two most well-known models, the 10-B and the 250-BT, were their flagship "*pile 'em high and sell 'em cheap*" slide rules for everyday/school use and the budget market. But most of the other Lawrence/Engineering Instruments branded slide rules from the imperial range and all the specially commissioned themed slide rules are superb examples of innovation and inventiveness. But who were the target customers?

The *Secret Code-Maker* series and the 5-inch⁶ pocket slide rule in the *Draft-a-Plan Kit* were aimed at the teenager/toy market. The hobby market was the most likely target for the 10-I (MODEL BUILDER'S) and the 6-Op/w (FLASHRULE) models. The remaining models from the imperial range and nearly all the specially commissioned themed slide rules had a serious use and could have easily found their way into a tradesman's toolbox or onto a professional's desk. But the most convincing examples are the WWII war effort related specially commissioned Antenna and Exposure slide rules made for MIT. The design of the *Antenna Slide Rule* for calculating radar antenna beam patterns being considered so strategically important that both the British and American governments had it classified and kept it classified long after WWII had finished.

Slide rules from Lawrence/Engineering Instruments are often ridiculed because of their cheapness and basic construction. But perhaps without realising their provenance, many were used and appreciated by professionals from many, many trades and professions.

The Lawrence legacy

Family acrimony was the reason why "Lawrence" was purged from the company name after 1947. However, Lee Lawrence was the charismatic inspiration for the company's most inspired 1935-1947 era and the reason for the company's success and longevity.

It is certainly true that all Lawrence/Engineering Instruments slide rules were cheaply made when compared with the likes of K&E, Pickett & Eckel, Faber-Castell, Nestler, etc. They also probably never made it on to NASA's shortlist for slide rules to go on five of the Apollo missions. But this is like expecting an OPEL/General Motors family saloon to be built to the same engineering standards and build quality as a Mercedes-Benz S-class. So when only accuracy to a couple of decimal places was needed, Lawrence/Engineering Instruments produced fit-for-purpose slide rules for a price that no other manufacturer matched. Their low-cost was a unique advantage allowing the company to develop an impressive range of slide rules for the professional, hobby, toy and budget markets.

Unenlightened slide rules collectors may dismiss Lawrence/Engineering Instruments slide rules as "uninteresting" and not worth bothering with. In reality their esteemed peers could not match their low-cost business model and their ability to continually find new partners and avenues for new innovative slide rules. In the post Lee Lawrence years by moving to plastic veneered scales for the model 250-V shows Engineering Instruments Inc. wanted to embrace technological improvements. But this meant the 250-V ended up retailing for three times more than the original painted 10-B they were still selling.

Like **Unique**, Lawrence/Engineering Instruments slide rules are often maligned but for a modest investment any determined collector can find some amazing and colourful models that would certainly grace any slide rule collection. The Lawrence legacy is undoubtedly an unsurpassed portfolio of surprisingly innovative and inventive slide rules rightly earning it the accolade of: **"The Unique (Lee) Lawrence"**.

Acknowledgements

Without help this story would have been, at best, hopelessly incomplete. I need to thank:

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A special postscript mention should go to **Louis Block**. While researching his family history he discovered that his maternal grandmother, Ada Verbit nee Zimmer, was Lee Lawrence's first wife. This led him to my article. In late 2016 he contacted me. With the information he kindly shared I could correct and supplement aspects of the convoluted Lawrence family history as part of a major update to this article in 2017.

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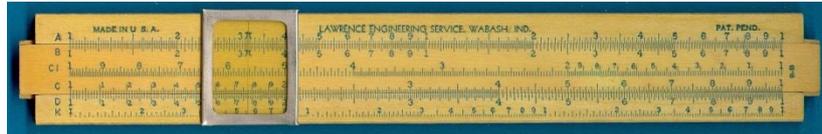
Appendix-A: Lawrence/Engineering Instruments branded slide rules

Imperial Range:

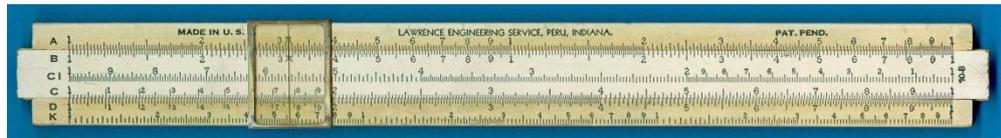
8-A



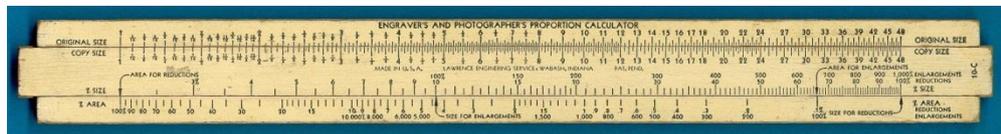
8-B



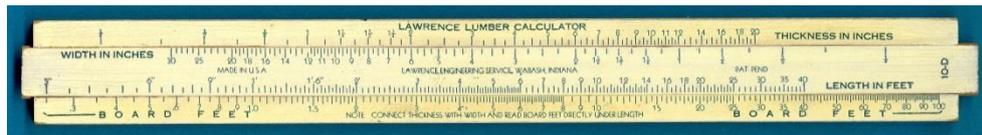
10-B



10-C



10-D



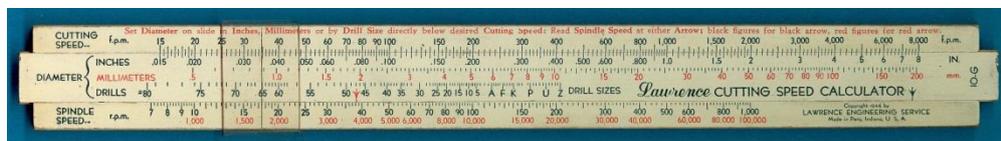
10-D0



10-F



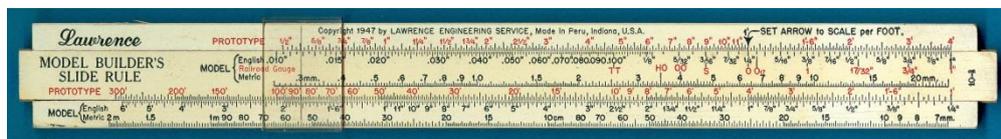
10-G



12-H



10-I



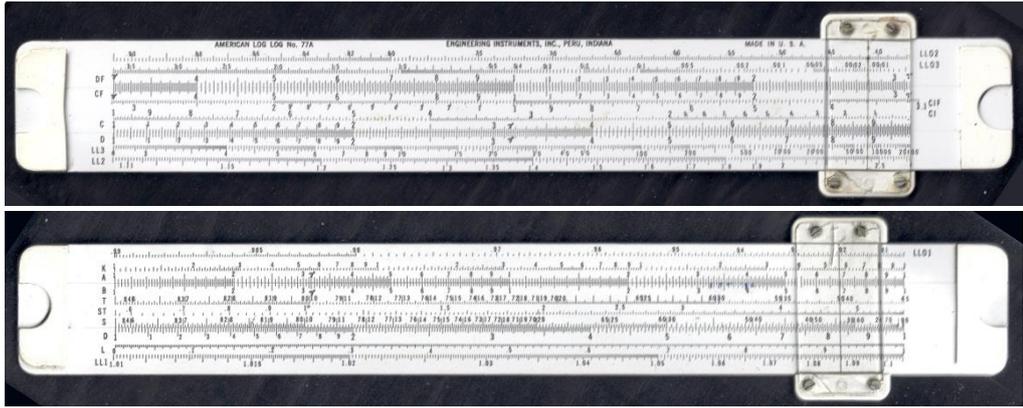
12-J

Lawrence PRO-RATER
One Year Premium (Red Scale)

Calendar showing months from JANUARY to DECEMBER with days of the month. Below the calendar is a table of premium rates for various amounts.

1.0027	13.6356	25.0685	37.1034	48.1342	61.1671	73.2000	85.2329	97.2658	109.2988	121.3315	133.3644	145.3973	157.4301	169.4628	181.4955	193.5282	205.5610	217.5937	229.6264	241.6591	253.6918	265.7245	277.7572	289.7899	301.8226	313.8553	325.8880	337.9207	349.9534	361.9861	374.0188	386.0515	398.0842	410.1169	422.1496	434.1823	446.2150	458.2477	470.2804	482.3131	494.3458	506.3785	518.4112	530.4439	542.4766	554.5093	566.5420	578.5747	590.6074	602.6401	614.6728	626.7055	638.7382	650.7709	662.8036	674.8363	686.8690	698.9017	710.9344	722.9671	734.9998	747.0325	759.0652	771.0979	783.1306	795.1633	807.1960	819.2287	831.2614	843.2941	855.3268	867.3595	879.3922	891.4249	903.4576	915.4903	927.5230	939.5557	951.5884	963.6211	975.6538	987.6865	999.7192	1011.7519	1023.7846	1035.8173	1047.8500	1059.8827	1071.9154	1083.9481	1095.9808	1108.0135	1120.0462	1132.0789	1144.1116	1156.1443	1168.1770	1180.2097	1192.2424	1204.2751	1216.3078	1228.3405	1240.3732	1252.4059	1264.4386	1276.4713	1288.5040	1300.5367	1312.5694	1324.6021	1336.6348	1348.6675	1360.7002	1372.7329	1384.7656	1396.7983	1408.8310	1420.8637	1432.8964	1444.9291	1456.9618	1468.9945	1481.0272	1493.0599	1505.0926	1517.1253	1529.1580	1541.1907	1553.2234	1565.2561	1577.2888	1589.3215	1601.3542	1613.3869	1625.4196	1637.4523	1649.4850	1661.5177	1673.5504	1685.5831	1697.6158	1709.6485	1721.6812	1733.7139	1745.7466	1757.7793	1769.8120	1781.8447	1793.8774	1805.9101	1817.9428	1829.9755	1842.0082	1854.0409	1866.0736	1878.1063	1890.1390	1902.1717	1914.2044	1926.2371	1938.2698	1950.3025	1962.3352	1974.3679	1986.4006	1998.4333	2010.4660	2022.4987	2034.5314	2046.5641	2058.5968	2070.6295	2082.6622	2094.6949	2106.7276	2118.7603	2130.7930	2142.8257	2154.8584	2166.8911	2178.9238	2190.9565	2202.9892	2215.0219	2227.0546	2239.0873	2251.1200	2263.1527	2275.1854	2287.2181	2299.2508	2311.2835	2323.3162	2335.3489	2347.3816	2359.4143	2371.4470	2383.4797	2395.5124	2407.5451	2419.5778	2431.6105	2443.6432	2455.6759	2467.7086	2479.7413	2491.7740	2503.8067	2515.8394	2527.8721	2539.9048	2551.9375	2563.9702	2576.0029	2588.0356	2600.0683	2612.1010	2624.1337	2636.1664	2648.1991	2660.2318	2672.2645	2684.2972	2696.3299	2708.3626	2720.3953	2732.4280	2744.4607	2756.4934	2768.5261	2780.5588	2792.5915	2804.6242	2816.6569	2828.6896	2840.7223	2852.7550	2864.7877	2876.8204	2888.8531	2900.8858	2912.9185	2924.9512	2936.9839	2949.0166	2961.0493	2973.0820	2985.1147	2997.1474	3009.1801	3021.2128	3033.2455	3045.2782	3057.3109	3069.3436	3081.3763	3093.4090	3105.4417	3117.4744	3129.5071	3141.5398	3153.5725	3165.6052	3177.6379	3189.6706	3201.7033	3213.7360	3225.7687	3237.8014	3249.8341	3261.8668	3273.8995	3285.9322	3297.9649	3310.0000	3322.0327	3334.0654	3346.0981	3358.1308	3370.1635	3382.1962	3394.2289	3406.2616	3418.2943	3430.3270	3442.3597	3454.3924	3466.4251	3478.4578	3490.4905	3502.5232	3514.5559	3526.5886	3538.6213	3550.6540	3562.6867	3574.7194	3586.7521	3598.7848	3610.8175	3622.8502	3634.8829	3646.9156	3658.9483	3670.9810	3683.0137	3695.0464	3707.0791	3719.1118	3731.1445	3743.1772	3755.2100	3767.2427	3779.2754	3791.3081	3803.3408	3815.3735	3827.4062	3839.4389	3851.4716	3863.5043	3875.5370	3887.5697	3899.6024	3911.6351	3923.6678	3935.7005	3947.7332	3959.7659	3971.7986	3983.8313	3995.8640	4007.8967	4019.9294	4031.9621	4043.9948	4056.0275	4068.0602	4080.0929	4092.1256	4104.1583	4116.1910	4128.2237	4140.2564	4152.2891	4164.3218	4176.3545	4188.3872	4200.4200	4212.4527	4224.4854	4236.5181	4248.5508	4260.5835	4272.6162	4284.6489	4296.6816	4308.7143	4320.7470	4332.7797	4344.8124	4356.8451	4368.8778	4380.9105	4392.9432	4404.9759	4417.0086	4429.0413	4441.0740	4453.1067	4465.1394	4477.1721	4489.2048	4501.2375	4513.2702	4525.3029	4537.3356	4549.3683	4561.4010	4573.4337	4585.4664	4597.4991	4609.5318	4621.5645	4633.5972	4645.6299	4657.6626	4669.6953	4681.7280	4693.7607	4705.7934	4717.8261	4729.8588	4741.8915	4753.9242	4765.9569	4777.9896	4790.0223	4802.0550	4814.0877	4826.1204	4838.1531	4850.1858	4862.2185	4874.2512	4886.2839	4898.3166	4910.3493	4922.3820	4934.4147	4946.4474	4958.4801	4970.5128	4982.5455	4994.5782	5006.6109	5018.6436	5030.6763	5042.7090	5054.7417	5066.7744	5078.8071	5090.8398	5102.8725	5114.9052	5126.9379	5138.9706	5151.0033	5163.0360	5175.0687	5187.1014	5199.1341	5211.1668	5223.1995	5235.2322	5247.2649	5259.2976	5271.3303	5283.3630	5295.3957	5307.4284	5319.4611	5331.4938	5343.5265	5355.5592	5367.5919	5379.6246	5391.6573	5403.6900	5415.7227	5427.7554	5439.7881	5451.8208	5463.8535	5475.8862	5487.9189	5499.9516	5511.9843	5524.0170	5536.0497	5548.0824	5560.1151	5572.1478	5584.1805	5596.2132	5608.2459	5620.2786	5632.3113	5644.3440	5656.3767	5668.4094	5680.4421	5692.4748	5704.5075	5716.5402	5728.5729	5740.6056	5752.6383	5764.6710	5776.7037	5788.7364	5800.7691	5812.8018	5824.8345	5836.8672	5848.8999	5860.9326	5872.9653	5884.9980	5897.0307	5909.0634	5921.0961	5933.1288	5945.1615	5957.1942	5969.2269	5981.2596	5993.2923	6005.3250	6017.3577	6029.3904	6041.4231	6053.4558	6065.4885	6077.5212	6089.5539	6101.5866	6113.6193	6125.6520	6137.6847	6149.7174	6161.7501	6173.7828	6185.8155	6197.8482	6209.8809	6221.9136	6233.9463	6245.9790	6258.0117	6270.0444	6282.0771	6294.1098	6306.1425	6318.1752	6330.2079	6342.2406	6354.2733	6366.3060	6378.3387	6390.3714	6402.4041	6414.4368	6426.4695	6438.5022	6450.5349	6462.5676	6474.6003	6486.6330	6498.6657	6510.6984	6522.7311	6534.7638	6546.7965	6558.8292	6570.8619	6582.8946	6594.9273	6606.9600	6618.9927	6631.0254	6643.0581	6655.0908	6667.1235	6679.1562	6691.1889	6703.2216	6715.2543	6727.2870	6739.3197	6751.3524	6763.3851	6775.4178	6787.4505	6799.4832	6811.5159	6823.5486	6835.5813	6847.6140	6859.6467	6871.6794	6883.7121	6895.7448	6907.7775	6919.8102	6931.8429	6943.8756	6955.9083	6967.9410	6979.9737	6992.0064	7004.0391	7016.0718	7028.1045	7040.1372	7052.1699	7064.2026	7076.2353	7088.2680	7100.3007	7112.3334	7124.3661	7136.3988	7148.4315	7160.4642	7172.4969	7184.5296	7196.5623	7208.5950	7220.6277	7232.6604	7244.6931	7256.7258	7268.7585	7280.7912	7292.8239	7304.8566	7316.8893	7328.9220	7340.9547	7352.9874	7365.0201	7377.0528	7389.0855	7401.1182	7413.1509	7425.1836	7437.2163	7449.2490	7461.2817	7473.3144	7485.3471	7497.3798	7509.4125	7521.4452	7533.4779	7545.5106	7557.5433	7569.5760	7581.6087	7593.6414	7605.6741	7617.7068	7629.7395	7641.7722	7653.8049	7665.8376	7677.8703	7689.9030	7701.9357	7713.9684	7725.9991	7738.0318	7750.0645	7762.0972	7774.1299	7786.1626	7798.1953	7810.2280	7822.2607	7834.2934	7846.3261	7858.3588	7870.3915	7882.4242	7894.4569	7906.4896	7918.5223	7930.5550	7942.5877	7954.6204	7966.6531	7978.6858	7990.7185	8002.7512	8014.7839	8026.8166	8038.8493	8050.8820	8062.9147	8074.9474	8086.9801	8099.0128	8111.0455	8123.0782	8135.1109	8147.1436	8159.1763	8171.2090	8183.2417	8195.2744	8207.3071	8219.3398	8231.3725	8243.4052	8255.4379	8267.4706	8279.5033	8291.5360	8303.5687	8315.6014	8327.6341	8339.6668	8351.6995	8363.7322	8375.7649	8387.7976	8399.8303	8411.8630	8423.8957	8435.9284	8447.9611	8459.9938	8472.0265	8484.0592	8496.0919	8508.1246	8520.1573	8532.1900	8544.2227	8556.2554	8568.2881	8580.3208	8592.3535	8604.3862	8616.4189	8628.4516	8640.4843	8652.5170	8664.5497	8676.5824	8688.6151	8700.6478	8712.6805	8724.7132	8736.7459	8748.7786	8760.8113	8772.8440	8784.8767	8796.9094	8808.9421	8820.9748	8833.0075	8845.0402	8857.0729	8869.1056	8881.1383	8893.1710	8905.2037	8917.2364	8929.2691	8941.3018	8953.3345	8965.3672	8977.3999	8989.4326	9001.4653	9013.4980	9025.5307	9037.5634	9049.5961	9061.6288	9073.6615	9085.6942	9097.7269	9109.7596	9121.7923	9133.8250	9145.8577	9157.8904	9169.9231	9181.9558	9193.9885	9206.0212	9218.0539	9230.0866	9242.1193	9254.1520	9266.1847	9278.2174	9290.2501	9302.2828	9314.3155	9326.3482	9338.3809	9350.4136	9362.4463	9374.4790	9386.5117	9398.5444	9410.5771	9422.6098	9434.6425	9446.6752	9458.7079	9470.7406	9482.7733	9494.8060	9506.8387	9518.8714	9530.9041	9542.9368	9554.9695	9566.9992	9579.0319	9591.0646	9603.0973	9615.1300	9627.1627	9639.1954	9651.2281	9663.2608	9675.2935	9687.3262	9699.3589	9711.3916	9723.4243	9735.4570	9747.4897	9759.5224	9771.5551	9783.5878	9795.6205	9807.6532	9819.6859	9831.7186	9843.7513	9855.7840	9867.8167	9879.8494	9891.8821	9903.9148	9915.9475	9927.9802	9939.9999	9952.0326	9964.0653	9976.0980	9988.1307	10000.1634	10012.1961	10024.2288	10036.2615	10048.2942	10060.3269	10072.3596	10084.3923	10096.4250	10108.4577	10120.4904	10132.5231	10144.5558	10156.5885	10168.6212	10180.6539	10192.6866	10204.7193	10216.7520	10228.7847	10240.8174	10252.8501	10264.8828	10276.9155	10288.9482	10300.9809	10313.0136	10325.0463	10337.0790	10349.1117	10361.1444	10373.1771	10385.2098	10397.2425	10409.2752	10421.3079	10433.3406	10445.3733	10457.4060	10469.4387	10481.4714	10493.5041	10505.5368	10517.5695	10529.6022	10541.6349	1
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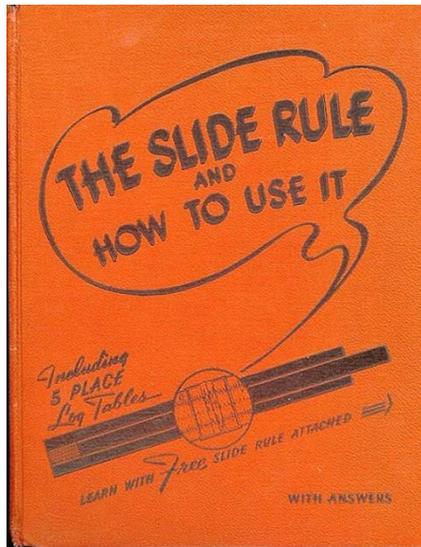


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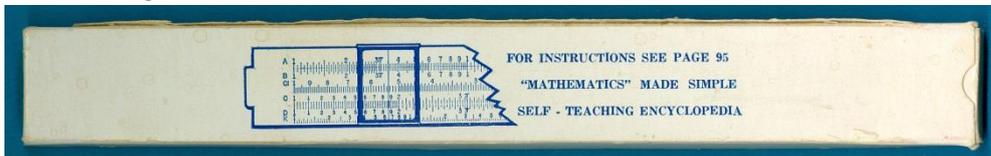
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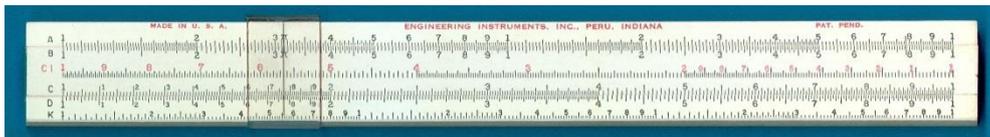
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Cadillac Publishing Co.



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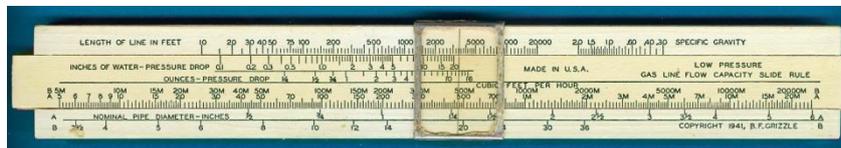
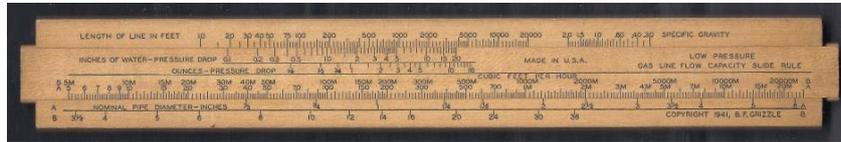
Appendix-B: Lawrence/Engineering Instruments unbranded slide rules

Specially Commissioned Themed slide rules:

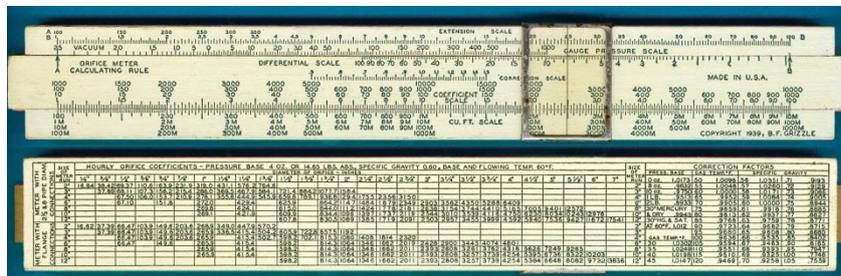
Students Learner



Gas



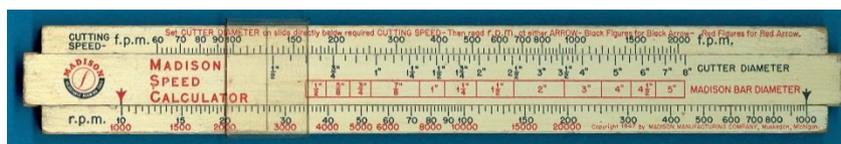
Pipe



Water



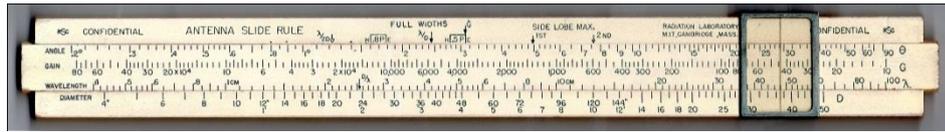
Cutting



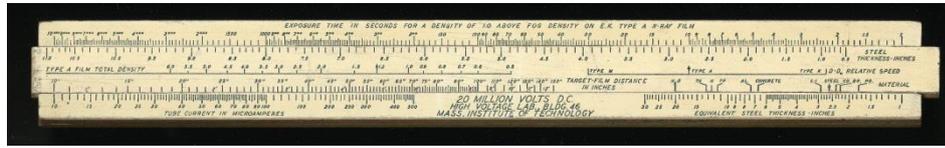
Music



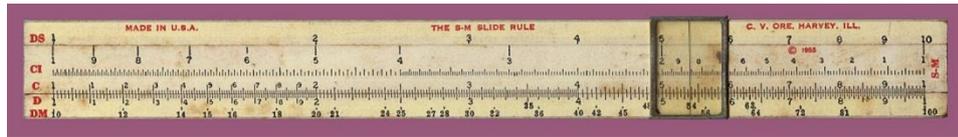
Antenna



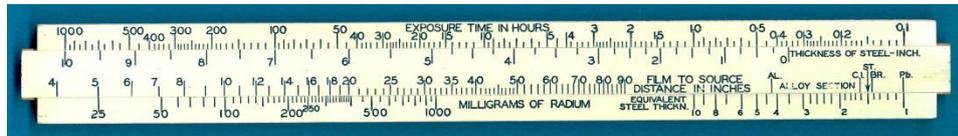
Exposure



S-M



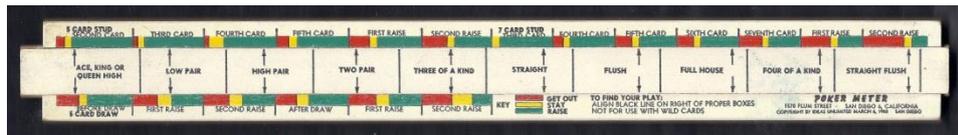
Gamma-Rays



Air/Hydraulic



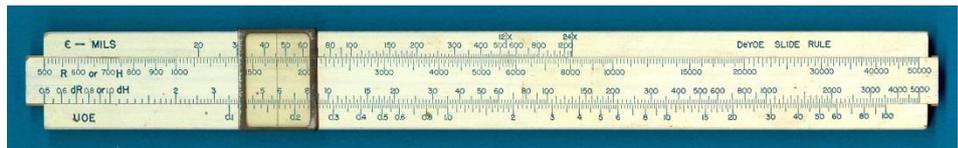
Poker



Traffic



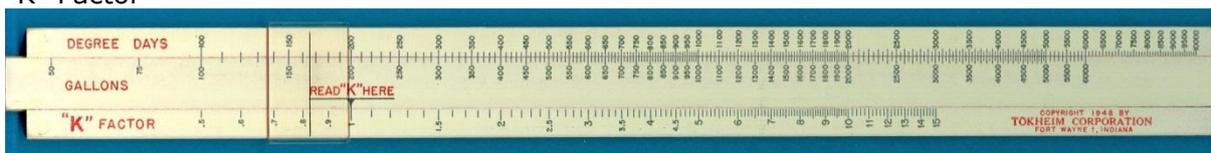
US Army



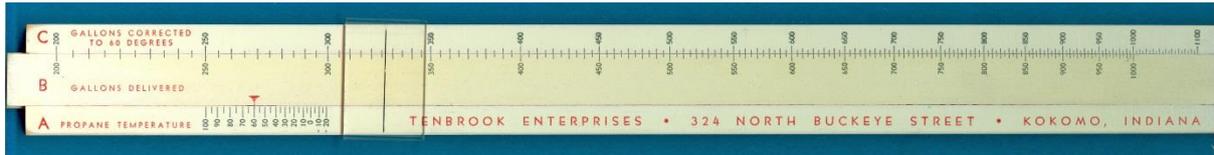
Concrete



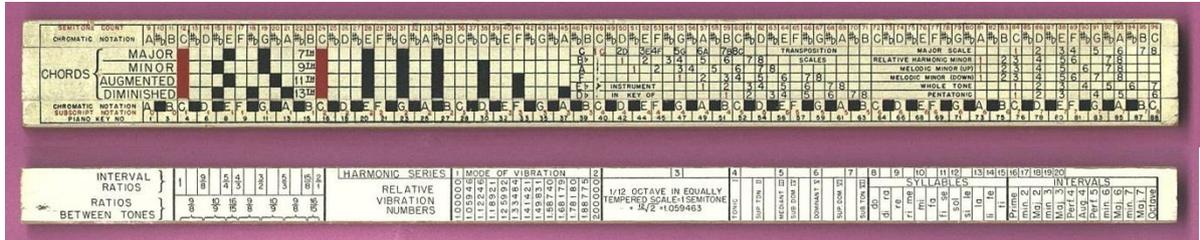
"K" Factor



L.P. Gas



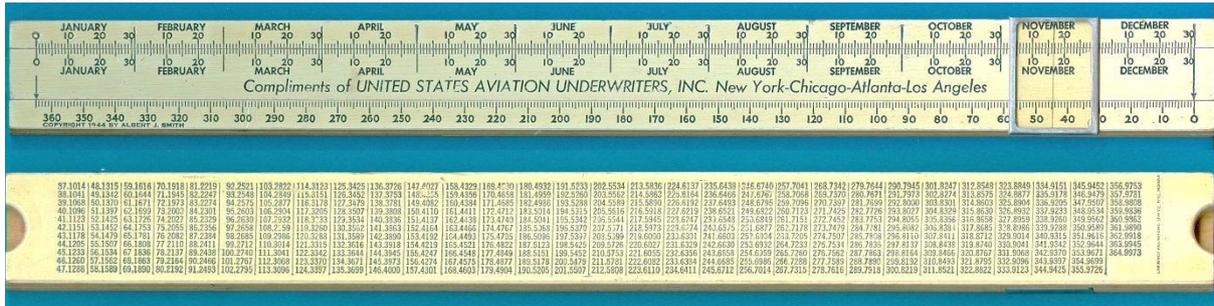
Music & Music Acoustics



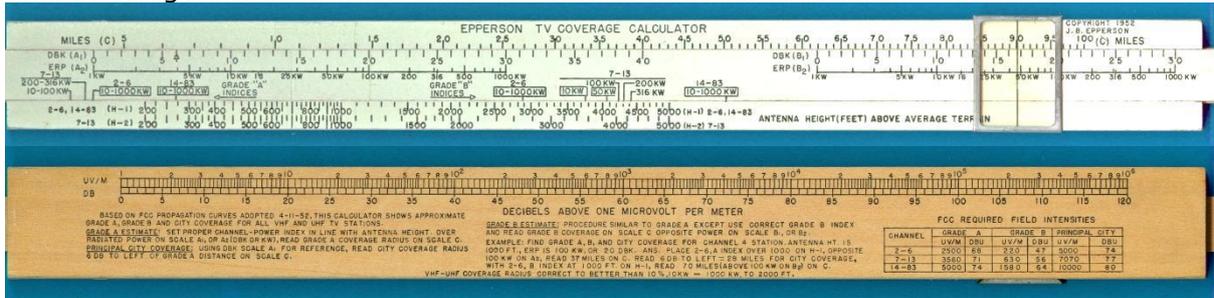
Typesetting



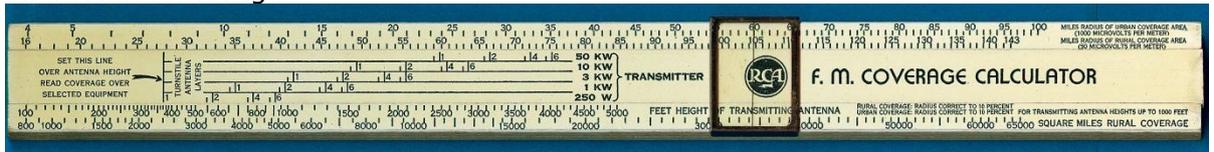
Underwriters



T.V. Coverage



F.M. Radio Coverage



Examples of "Rebranded" OEM slide rules:

Charvoz-Roos SR-31 (BT)



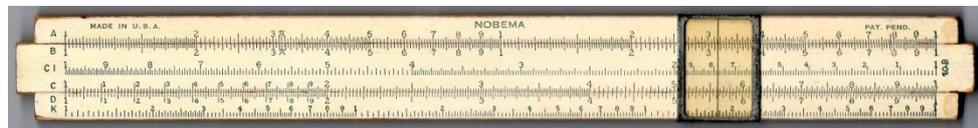
A. Lietz Company No. 2974N (BT)



ANCO



NOBEMA



US NAVY (BT)



¹ Revised and extended version of a paper first presented at the IM2011, Boston, USA.

² Motto attributed to Jack Cohen (1898–1979) founder of the supermarket chain: TESCO.

³ Source: ISRM.

⁴ Source: Chicago History Museum - negative number "ICHI 17490".

⁵ Astonishingly, when allowing for shipping costs, the pre WWII sales price in UK High Street retailer WOOLWORTHS for a Lawrence slide rule was 6d pre-decimal pence. In "money-of-the-day", the comparable retail price in 2011 would still be no more than £1.25 GBP or about €1.50 – clearly a "loss leader" of its day.

⁶ Physical length of the stock – the US still use imperial units for length, area, volume and mass.

⁷ Specialised unit of measure used for the volume of lumber in the US and Canada. It is the volume of a one-foot length of a board, one foot wide and one inch thick.

⁸ f.p.m. = feet per minute.

⁹ French, American & Anglo-Saxon versions exist -1 American pica = 0.166044 inch.

¹⁰ See JOS Vol. 15 No. 1: "Slide Rules Are ... Music To My Ears!", 2006, Pg 20.

¹¹ A.W.G. = American Wire Gauge.

¹² Convention adopted by many slide rule makers to quote the length of a full cycle main scale, usually the D scale, of their linear slide rules in flyers, catalogues, etc.

¹³ A coding method described by Giovan Battista Bellaso in his 1553 book: "*La cifra del. Sig. Giovan Battista Bellaso*". Later, in the 19th century, it was misattributed to Blaise de Vigenère and has since been incorrectly called the "Vigenère cipher".

¹⁴ A reputed writer of detective stories and a specialist in cryptography.

¹⁵ Early versions of the distinctive red and blue (orange and blue also existed) instruction guides were © 1939 to W. Stanley Marshall jr. and called: "*Stanley's Slide Rule Instructions*". Later in the same year Lawrence copyrighted their own version (but using the same colours) calling it "*The Quick and Easy Lawrence Slide Rule Instruction Book*".

¹⁶ Popular American 1920/30/40s chocolate "candy bar" made by Beich Co. of Bloomington, Illinois.