ELEKTRO RULES

Their use and scales

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Introduction

Of the speciality rules, perhaps the most ubiquitous is the “Elektro” rule, almost every manufacturer of slide rules produced an Elektro rule. This paper examines the design of such rules and poses a few questions on the layout of the scales and their overall usefulness.

Definition of an “Elektro” Rule

A rule to aid the electrical engineer in solving specific problems. It is usually a rule with the scales of the standard Rietz system, supplemented with Log Log scales, motor/dynamo efficiency scales and a scale for voltage drop calculation. The calculations are normally limited to power system frequencies i.e. 0 (Direct Current) to a few hundred Hertz (Hz). Slide rules designed for Electronic engineering do exist; their main forte is the calculation of impedance of circuit elements in the higher frequency ranges i.e. 0.1 to 100 MHz. This paper concerns the rules that were primarily used in electrical engineering and not electronic engineering.

Electrical Engineering Problems they where intended to solve

The first “Elektro” slide rules were primarily designed to perform two types of calculations:

- Efficiency of motors and dynamos
- Voltage loss in cables

For motors and generators (dynamos) the efficiency was, in the case of a motor, the ratio of the mechanical energy output divided by the electrical energy input. In the case of a generator, it was the ratio of the mechanical energy input divided by the electrical energy output.
The calculation was basically very simple apart from the fact that the units of energy were different, HP (horsepower) for mechanical energy and KW (kilowatts) for electrical energy.
The calculation of voltage loss in cables was not that much more complicated.
The voltage loss was given by Ohms law:

$V = I * R$ (Volts = current (amps) * resistance (ohms))

The resistance was given by:

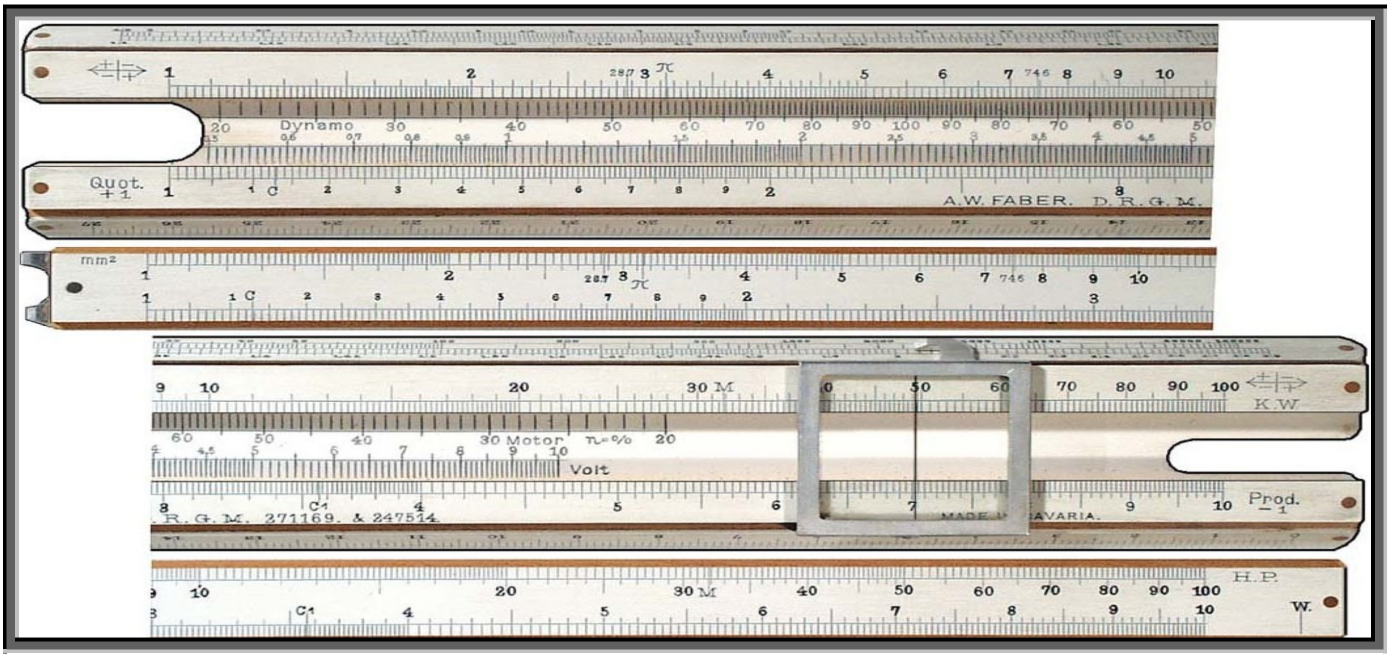
$R = L * \frac{\delta}{A}$ (Resistance (ohms) = length (m) * resistivity (ohm-metre) / sectional area (m^2))

But as usual in the real world, different countries and cultures use many different measurement units which invariably add a few complicating factors that require some explanation.
There were at least two different units for horsepower. The Imperial system, used in the British Commonwealth countries and the US, was based on the required energy to lift a 550 pound weight through 1 foot in one second and was equivalent to 746 watts. The second, used in mainly in Continental Europe i.e. users of the metric system, was based on the energy to lift 75 kilograms through 1 metre in 1 second and was equivalent to 736 (or even 735) watts. The latter marks are usually shown as PS on

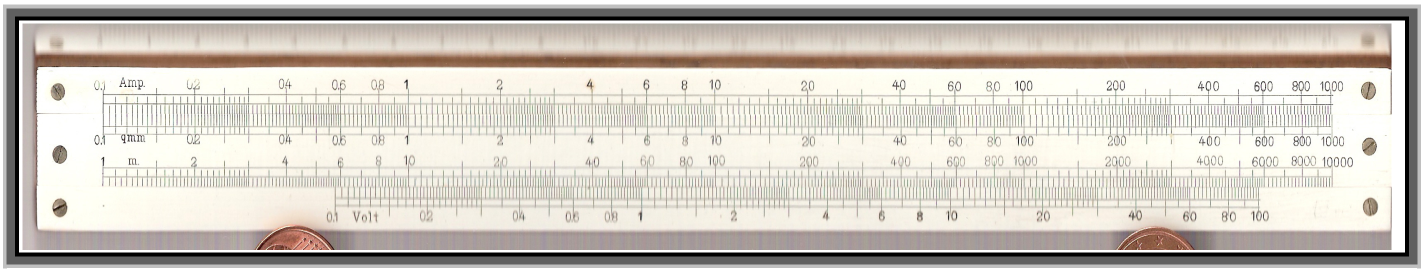
European rules and are derived from the German word *Pferdestärke*. The difference in the number of watts for the PS mark is due to the derivation of the unit using 9.8 or 9.81 m/s^2 for the gravitational constant.
Different units of area were also used. In the metric system, the sectional area of the cable was normally given in square millimetres. In the Imperial system it could be either square inches or *circular mils*. This latter unit was slightly unusual as it was based on the diameter of the conductor, in 1/1000ths of an inch squared.
Calculations using the base measurement units (i.e. inch, yard, metre) would result in values that were not usually practical for real world observation and more usual units of $10mm^2$ and 10 metres or 10yards and 0.01sq. inches were used.
The resistivity/conductivity can be expressed as a value either at 0°C (32° F) or more usually at 20°C (68° F). Typical values for copper are $1.67 * 10^{-8}$ ohm-metres resistivity at 20°C or a conductivity of $5.98 * 10^{7}$ at the same temperature. As electrical conductors could be made of differing purity and alloys of copper it should be stressed that the specific values for resistivity and conductivity are not unique. Many manufacturers placed gauge marks for conductor on their rules but usually the calculator needed to be aware of the specific properties of the cable they where using.
Some rules have gauge points for the use of metals other than copper. For example aluminium, is particularly important in the modern world where it has nearly taken over from copper as the electricity distribution industry conductor of choice.

The First Elektro Slide Rule?

Here I have relied upon the books by Peter Hopp ref [6] and Dieter von Jezierski ref [5] for information on catalogues, registered designs and also patents. The earliest mention of a patent for a slide rule for electrical calculations is the 1890 patent number 1302 awarded to a Mr A.P. Trotter for a slide rule for electrical calculations with two slides – "Wiring Slide Rule", it is unknown whether an actual rule based on this patent was actually produced.
The earliest reference to an actual "Electro" (sic) was in Dieter's book "Slide Rules. A Journey through Three Centuries". In the list of Registered Designs, a design number of 334146 is registered to Nestler in 1908 for the Slide Rule Electro 32.
In his book ref [6] Peter Hopp refers to a "Slide rule for electrical calculations" which was produced by A.E Colgate of New York in 1901, however the scale layout is unknown. Peter Hopp also mentions two other American rules which were made by the Lewis Institute of Chicago and called the "Woodworth's sliderule for electrical wireman" and the "Woodworth's sliderule for calculations with volts, amperes, ohms and watts". Both rules according to Hopp date from 1909, however again the scale layout of these rules is unknown. The earliest example in the United States of an actual rule for electrical engineering is the Roylance slide rule by Keuffel and Esser in their 1913 catalogue (more correctly the addendum to the 1913 catalogue).
A fellow collector Mr David Rance has in his collection an early A.W. Faber Elektro (398-like) with design numbers DGRM 271169 & 247514, this rule confirmed by Mr Guus Craenen in his forthcoming book is actually a A.W. Faber 368 rule (note, this is not referenced in either ref [5] or [6]) . Both Registered Designs are credited to A.W. Faber for the years 1906 and 1905 respectively in ref [5]. The 271169 DRGM refers to a cursor extension and not to any specific electrical scale, the 247514 however refers to an index edge at the end of the slide. This index edge is the first such mention of what was to become the defining feature of an Elektro rule, note that this DRGM dates from 1905.
There is also evidence of a Dennert & Pape rule, the number 15, which I believe was produced in 1905 (again confirmed by Mr Guus Craenen) which incorporated elektro scales in the well. This rule also incorporated log-log scales on the front of the rule according to the principles of the DRGM 148526 of 1901 awarded to Mr W. Schweth. This rule which had electrical scales in the well and log-log scales on the body of the rule would become the spirit of the Elektro rule for the next 70 years, alas I do not have a scan of the rule but by the courtesy of Mr Rance and Mr Craenen, I can show the Faber 368 and Nestler 32.



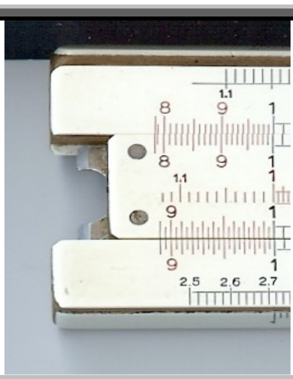
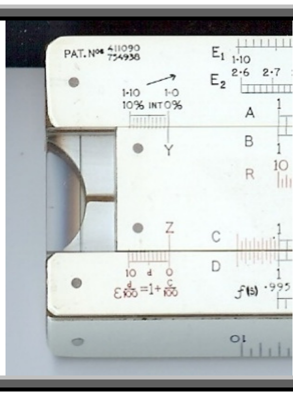
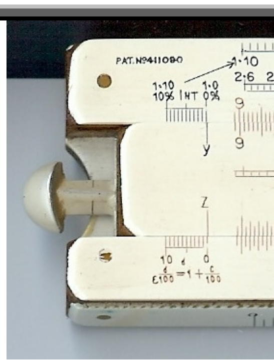
The AW Faber 368

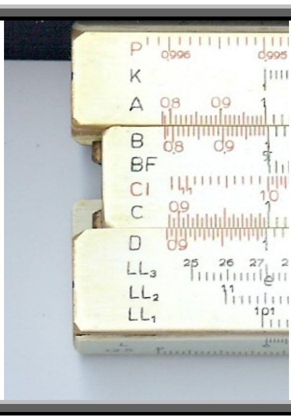
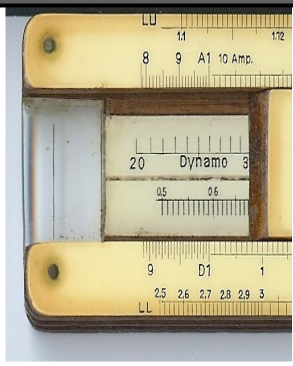


The Nestler 32

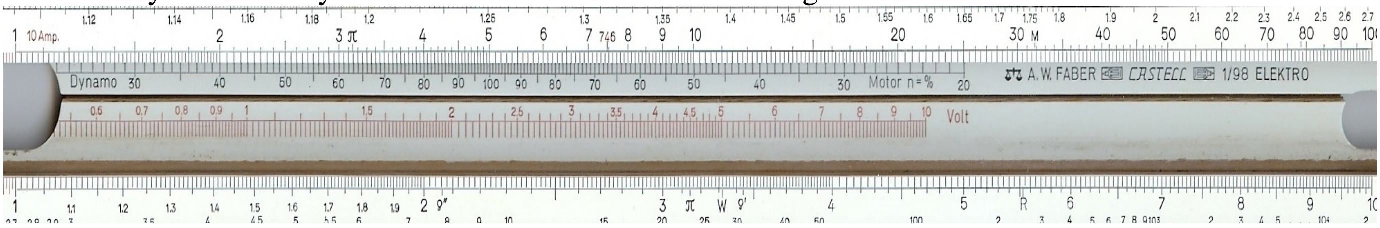
Types of Rules

It is Faber-Castell with their models 368, 378 and 398 (1/98 in later years) that seem to have established the defining feature of a number of Elektro rules in placing the motor/dynamo efficiency and voltage drop scales in the well of the slide rule and having some form of extension to the slide to read them. This layout was used by so many of the mainstream manufacturers that it came to define the layout of the Elektro rule. The reasons for this layout lie in the choice of the standard Rietz rule for the basis of the Elektro rule. With the addition of usually two LL scales most of the rule “real estate” was utilized and the only available space was the well underneath the slide Ref [8]. (Note that the Darmstadt rule used a different approach and placed extra scales on the rule edges). To read the well scales, manufacturers produced a variety of methods. Some examples are shown in the following diagrams:

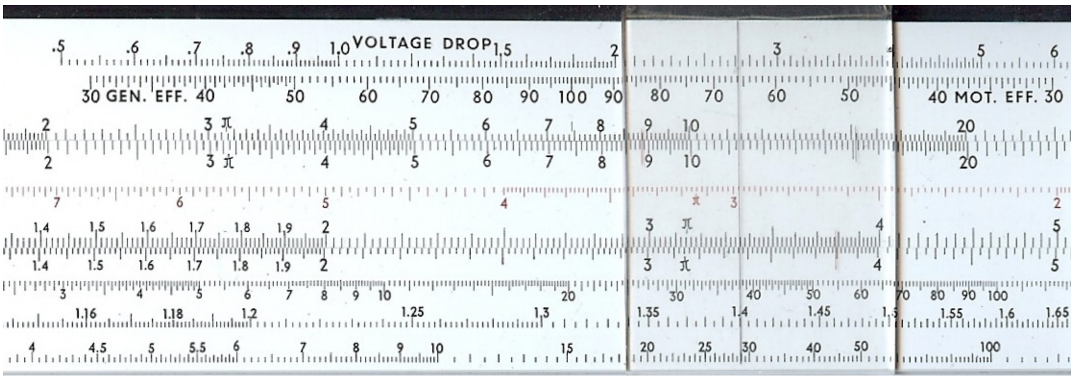
Faber Castell 1/98	PIC PC18	PIC 131
		

Politehnica	Simplon	Aristo
		

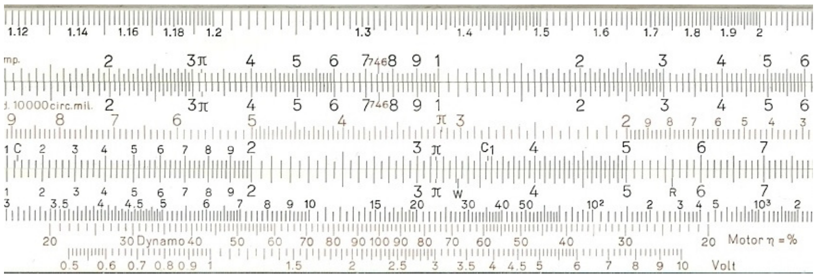
The well layout is usually of the form as shown in the next diagram.



Most other rules had the efficiency and voltage scales set either above or below the principal scales.
A number of examples are shown:

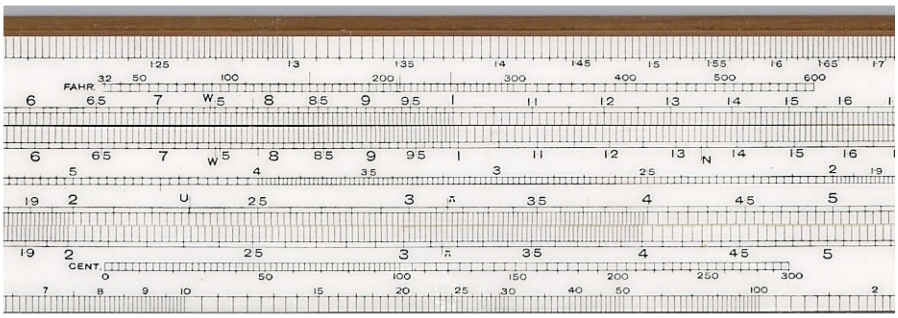


Blundell Harling 305



Faber Castell

However, some manufacturers didn't include specific scales for efficiency and voltage drop on their rules. Instead they used gauge marks for these calculations, examples are Nestler 37 and the Unique Electrical. The following diagram shows the Unique and you can see the gauge marks W and N for the motor and generator efficiency calculations.



Unique Electrical

Another unique feature (no pun intended) are the extended temperature scales up to 300 degrees centigrade and 600 degrees Fahrenheit. These are most useful for the electrical engineers engaged in transmission line design where conductor temperatures are designed to at least 120°C.

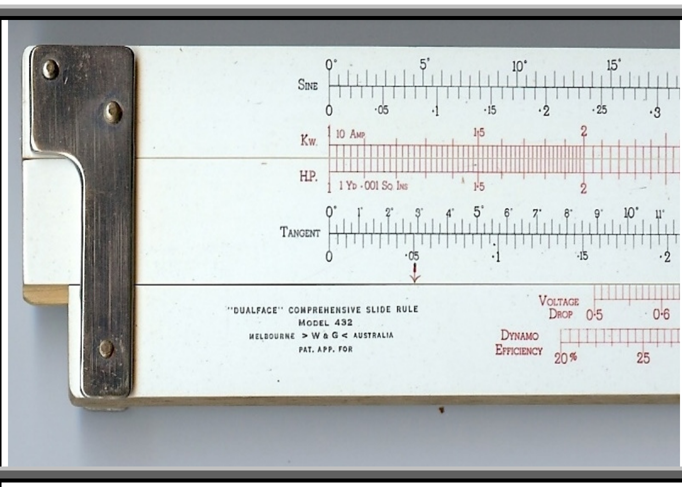
Usual Scale Layouts of Elektro Rules

Apart from the treatment of the scales required for the calculation of motor/dynamo efficiency and voltage drop the scale layouts of Elektro rules generally followed a standard system.

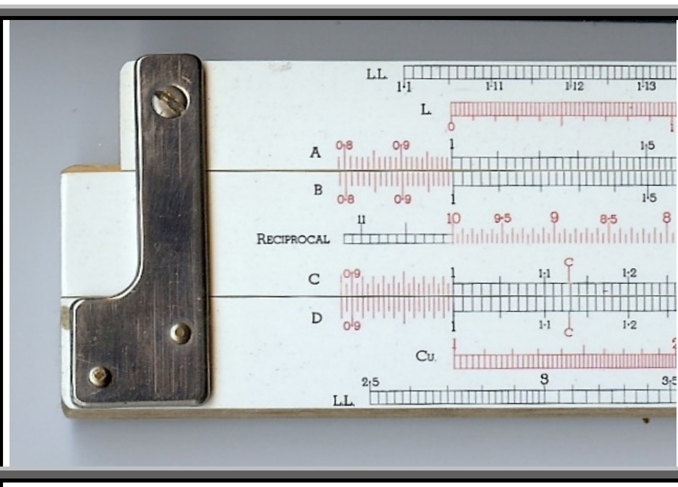
The scales usually included:

- Standard A (x^2), B (x^2), C (x), and D (x) scales
- CI (1/x) on the slide
- K (x^3) scale which could be placed on the stator or on the lower edge of the rule and read with a cursor extension
- L ($\log_{10}$) scale which could be placed on the stator, the reverse of the slide or on the lower edge of the rule and read with a cursor extension
- S (sin) and T (tan) on the reverse of the slide.
- And two exponential scales, usually indexed to the C scale and extending over a range of 1.1 to 10^5

Some examples of these layouts are presented in the following diagrams with comments on the usefulness of the layouts.

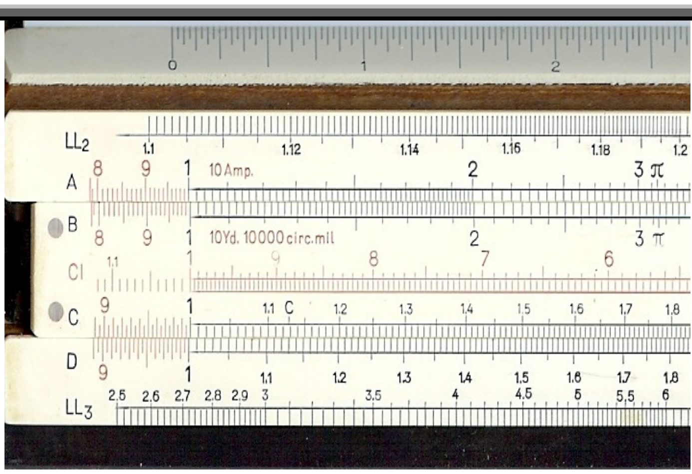


White & Gillespie 432 back



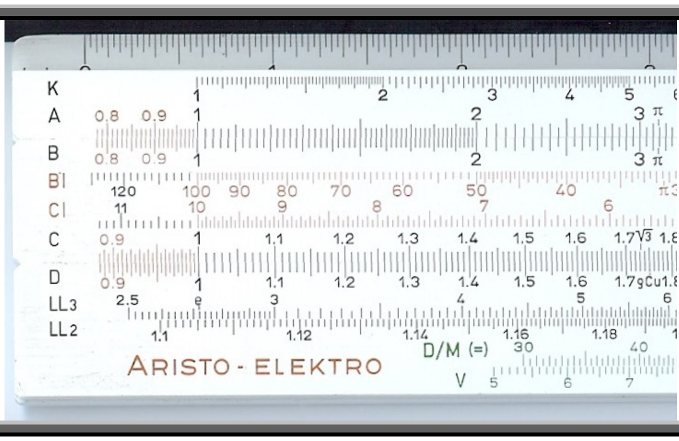
White & Gillespie 432 Front

The only Australian rule that could be termed an Elektro rule, a standard set of scales although labelled somewhat differently than the accepted notation eg Cu (Cube) for the K scale and Reciprocal for the CI scale. It is fairly unique in that it is a duplex rule and most of the normal Elektro layouts used the simplex design.



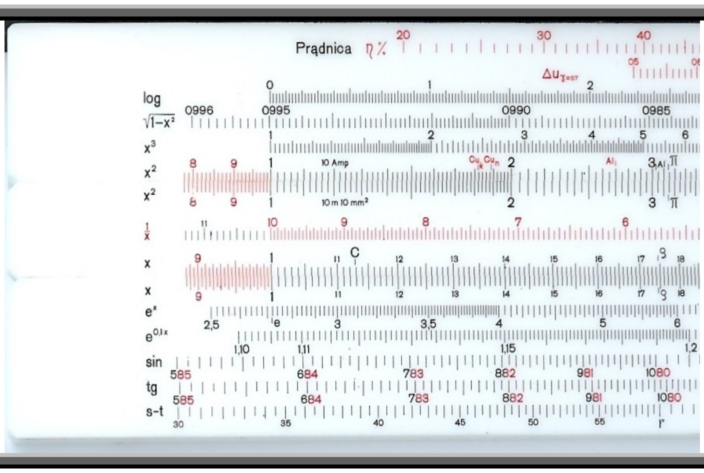
The classic Faber Castell 1/98

This is a standard layout with the special scales in the well and extensions on the slider to read the results. The two exponential scales are indicated on the top and bottom edges of the stator. The K scale is placed on the bottom edge of the rule and is read by a cursor extension and the S, L, T scales are on the reverse of the slide. Interestingly the S scale is indexed to the A scale and the T scale is indexed to the C scale, a system also used on the Hemmi 80K. This allowed the S scale to range from 34 minutes to 90 degrees and dispense with the ST scale.



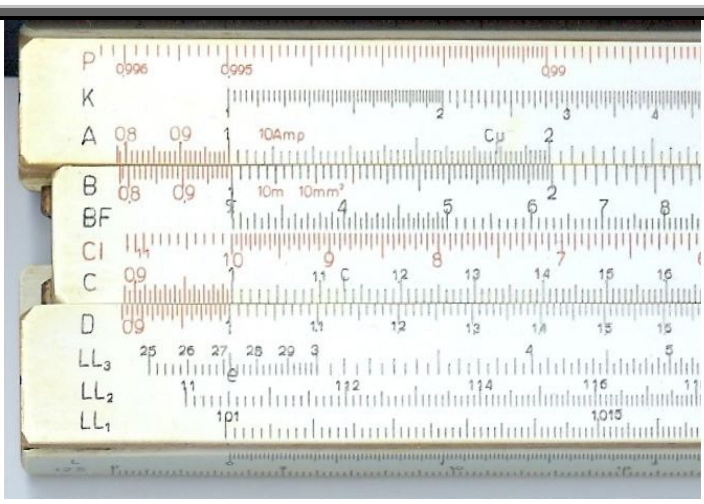
The Aristo 915E

This is a later Elektro design by Aristo where they had discarded the slide extension and scales in the well in favour of including them on the body of the rule.



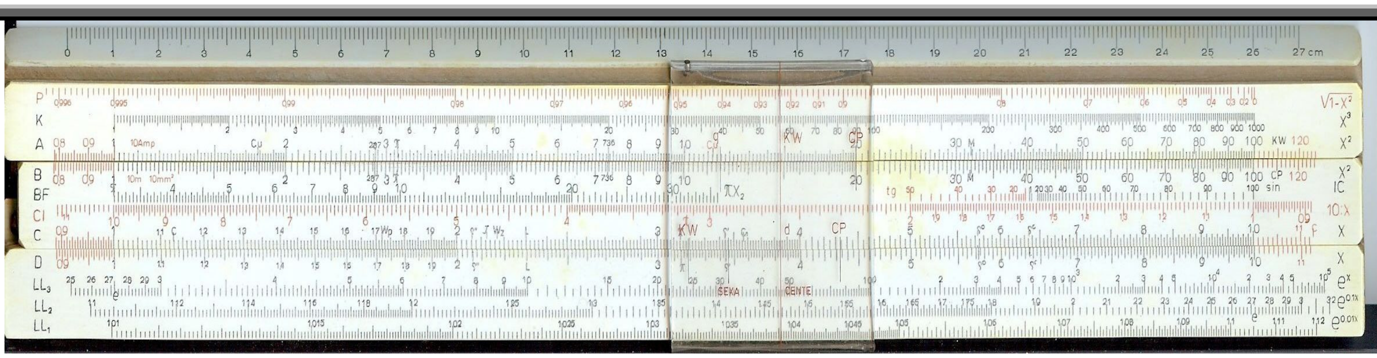
The Skala (Polish) Elektro

All scales are included on the front face of the rule, which made for a wide body rule of some 62cms. Notice on the A scale the gauge marks for what I assume to be two different alloys of copper conductor. And the P (Pythagoras) scale! A noticeable omission on many Elektro rules.

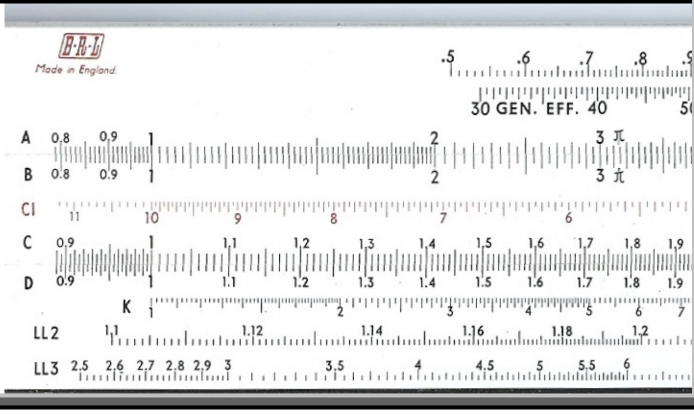


The Romanian Politehnica

Looking at this layout a number of differences to the norm immediately come to notice. Firstly, three exponential scales that extended the range downwards to e0.01x also a folded B scale and it can be seen in the following full scan of this rule. The scale is only a half scale and the other half of the scales' position is taken up by another interesting half scale. A closer inspection shows this to be a PIC-like differential trig scale but scaled in Grads not degrees as on the PIC/Thornton Rules, the only other rule where I have seen these scales used. But more importantly there is a P (Pythagoras) scale included.

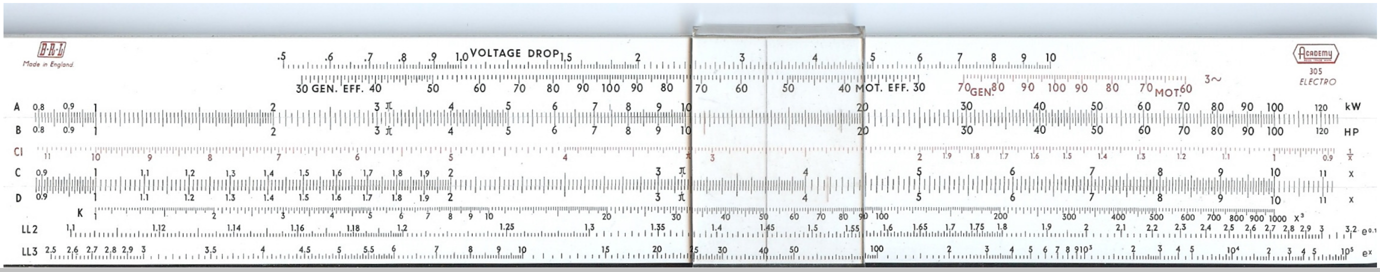


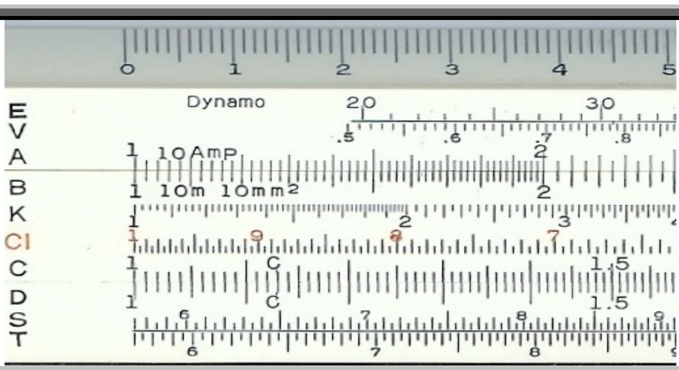
A full scan of the Politehnica, which shows the two half scales that to my knowledge are unique. A half folded B scale and an IC scale that is similar to the PIC differential trig scales but scaled in Grads.



The Blundell Harling 305

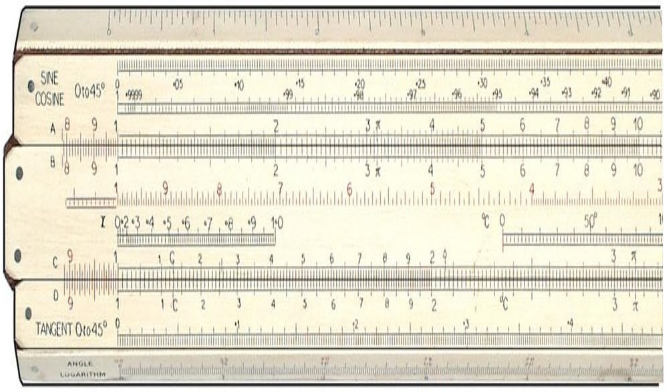
An uncluttered arrangement of scales with the S, L, T scales on the reverse of the slide. One interesting aspect of this rule is illustrated in the following diagram, an extension of the efficiency scale for three-phase motors and dynamos or more accurately for alternating current systems an “alternator” scale.





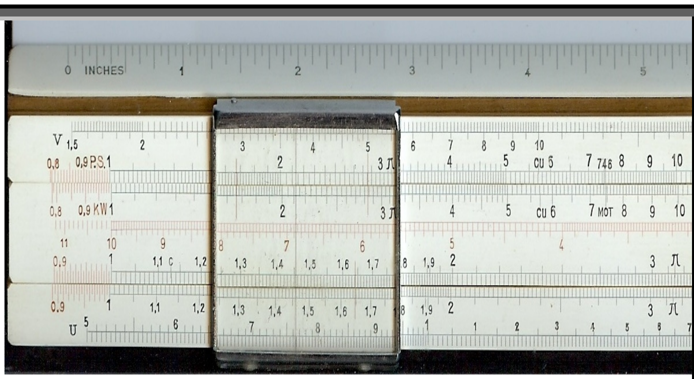
The Ricoh 107

This rule has departed from the usual scale placement. Ricoh moved the trig scales to the bottom of the stator and placed the exponential and log scale on the reverse slide of the slide. A similar arrangement to the well-known Darmstadt system.



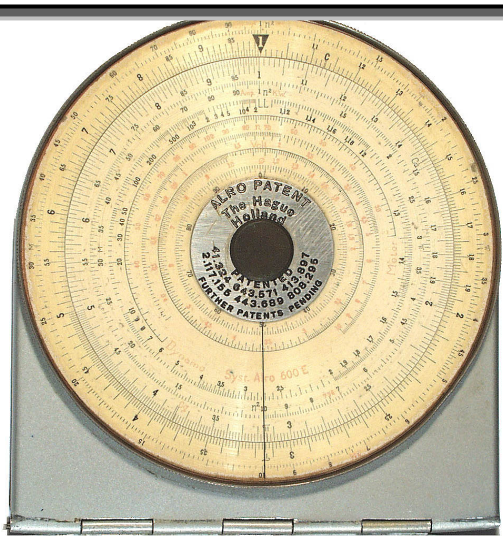
The PIC 144

This rule has an unusual scale placement. The scale layout uses a system promoted by a Dr AE Clayton and arranged the trig scales so that sin, cos and tan could be read directly for any angle, to 3 minutes. It also added a Z scale to facilitate the calculation of the sqrt of the sum of squares. The slide included on the reverse side two log log scales from 1.1 to 100000 on the D scale and a Dec log log scale from .98 to .15 on the A scale. The reverse also included a C scale to ease the use of the slide when reversed.



A Staedtler 54106

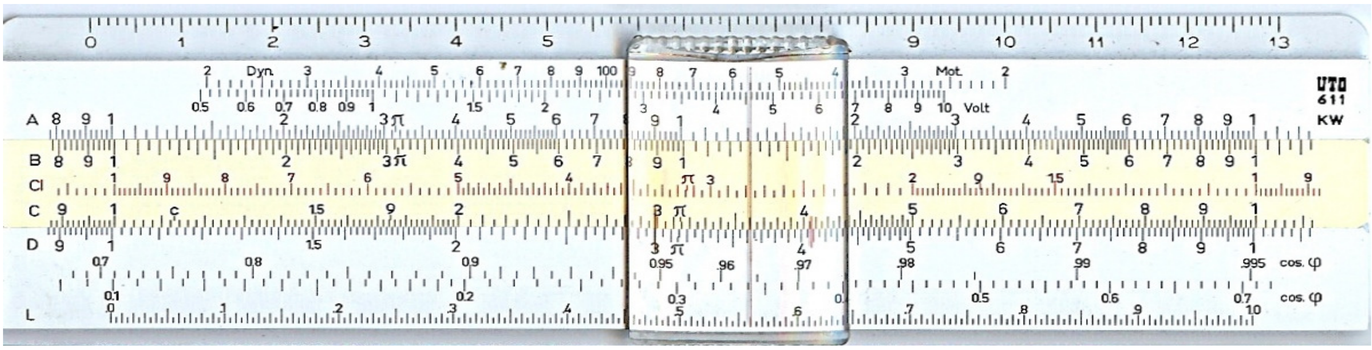
This rule appears to be an exact copy of the Nestler 37 or 370. Same scale layout and markings and the same cursor extensions to read the single LL scale and L scale on the bottom edge. Note the single LL scale. This scale worked with the A/B scales and extended over the normal range of 1.0 something to 10^5 which is a similar range to the normal two LL scale rules, albeit with less resolution. The V scale used for calculating the voltage drop along a copper wire, was matched to the C and D scales, and the U scale, folded at pi/6, was also provided, this scale was used angular speeds of machines.



The ALRO 600 E

One of the few examples of an “Elektro” circular slide rule that I know of, except for such special rules as the Kesel Circular Rule described in Issue 6 of the UKSRC Gazette [Ref 9]

Scan from Hermans Archive [Ref 3].



The UTO 611 (a 12.5cm Elektro rule)

Most manufacturers made 5 inch (12.5cm) versions of their Elektro rules and they where exceedingly popular with engineers as they could easily carry these instruments around in shirt pockets (most probably close to the pen protector!!). The rule shown is of interest as it dispensed with the useful LL scales and moved the Volt Drop and Efficiency from the well to the front of the rule. But it did include double Cos phi scales, other rules that use this scale are the Nestler 0137 and the Pickett N16.

Gauge Marks

There are many gauge marks on Elektro rules. Most can be explained but some require lengthy research in the absence of the original manuals. The most common are listed below. To compile this list I have relied upon manufacturers' manuals and the most timely production of the "Pocketbook of the Gauge Marks" by Panagiotis Venetsianos, an excellent reference book Ref [7] that was published just before I started writing this paper.

Gauge Mark	"Panagiotis" Symbol	Explanation
1124	Cu	Reciprocal of 8.9 specific weight of Cu
1257	4π	1.2566 = 4π/10 used for Electro magnetic induction calculations
134	N	Reciprocal of 746 watts used as dynamo efficiency gauge mark of the Unique Electrical Rule
136	DYN	1359 = reciprocal of 736 (watts in a metric HP) used as the dynamo efficiency gauge mark of the Nestler 37 type rules
1414	√2	1.414 = Sqrt (2)
1481	Cu	Resistance of copper whose resistivity is 0.01722 $\Omega.mm^2/m$ at 20 degrees C
1493	Cu	Resistance of Cu whose resistivity is 0.175 $\Omega.mm^2/m$ at 20 degrees C
1495	c	Resistance of Cu whose resistivity is 0.1755 $\Omega.mm^2/m$ at 20 degrees C
1732	√3	1.732 = Sqrt (3)
175	ρ_{Cu}	Resistivity of Cu 0.0175 $\Omega.mm^2/m$
175	kW	Coupled mark for kW/HP conversions
1785	Cu	Resistivity of Cu 0.01785 $\Omega.mm^2/m$
1854	A	Resistivity of Al 0.027 $\Omega.mm^2/m$ at 15 degrees C
1922	Al	Resistivity of Al 0.029 $\Omega.mm^2/m$ at 20 degrees C
218	AL	Specific weight of Al
22	220	220 volt systems
238	PS	Coupled mark for metric HP conversions
2408	-	? on a BRL E.13 rule
27	γ_{Al}	Specific weight of Aluminium
2859	-	Specific resistivity of Aluminium
287	-	For finding the voltage drop in copper wires based on resistivity of Cu 0.01742 $\Omega.mm^2/m$
29	ρ_{Al}	Resistivity of Al 0.029 $\Omega.mm^2/m$
3049	V	Resistivity of Cu of 23950 $\Omega.mil^2/yd$
3183	M	Reciprocal of π (usually on the A scale)
332	W	Specific weight of Cu

Gauge Mark	"Panagiotis" Symbol	Explanation
35	AL	Conductivity of Al 35 m/Ω.mm^2
3784	Cu	Specific weight of Cu
38	C b	Specific weight of Cu
38	380	380 volt systems
4429	√	Sqrt (2g)
572	Cu	Conductivity of Cu 57.2 m/Ω.mm^2
58	CU	Conductivity of Cu 58 m/Ω.mm^2
6283	2π	= 2π
632	PS	Coupled mark for metric HP conversions
6867	A	Specific weight of Al
688	A	Specific weight of Al
7071	Si	Reciprocal of Sqrt (2)
735	MTR	Watts in a metric HP
736	MOT or PS	Watts in a metric HP also used as the motor efficiency gauge mark on Nestler 37 type rules
746	HP	Watts in a British HP
746	W	Used as the motor efficiency gauge mark on the Unique Electrical Rule.
75	ks	75 kgm/s – 1 cheval-vapeur (i.e. a metric HP)
89	γ_{Cu}	Specific weight of CU
9866	HP	0.98659 cheval-vapeur = 1 HP

These are the more common gauge marks but depending on the grade and alloy of copper or aluminium there can be any number of gauge marks. For example the Roylance slide rule from K&E had numerous standard wire gauge marks and the Skala rule has marks designated Cu_k and Cu_n at 1818 and 1894 respectively. Which I can only assume are related to the resistivity of copper.

Some problems and how they where solved on an Elektro Rule

This section should be prefaced by the fact that the scales on Elektro side rules where in general arranged for direct current (DC). This may have been the case in the early 1900's but alternating current (AC) became the norm very quickly. And although the Elektro scales can, in general, be used for AC resistive circuits, alternating current brings to the engineer a new set of complications such as impedance instead of resistance, skin effects, frequency, capacitance, inductance and resonance.

Dynamo or Motor Efficiency Calculations Ref [1]

These were relatively simple problems which occurred with single phase motors that really did not require a separate scale for the solution. In fact many Elektro rules dispensed with this scale completely and relied on gauge marks for the calculation. In essence the scale did the conversion of horsepower (HP or PS) to kW (kilowatts) in the division of input and output of either a motor or generator. The scale was actually a composite scale consisting of part of one decade of an A scale followed by part of one decade of an AI scale. The end index of both represented 100%, and was located over 7.46 (or 7.36 for a PS system) on the

A scale, as that represented a constant for converting kilowatts to horsepower. Since the efficiency of both a dynamo or a motor must be less than unity, and that of a dynamo is expressed in terms of kilowatts per horsepower, while that of a motor is expressed in terms of horsepower per kilowatt, this arrangement served to convert both to efficiency in percentage terms.

When this scale was located on the body of the rule, the 100 percent mark was directly over either the 7.46 or 7.36 mark, when the scales where located in the well the 100 percent mark was placed such that when the slide extension was over the 100 percent mark the index on the B scale was directly opposite the relevant conversion quantity.

An interesting variation of these scales were the three-phase scales found on the Aristo 814, 914 and Blundell Harling 305 rules. As the equivalent input or output calculations for a 3 phase system contains a factor of 1.73 ($\sqrt{3}$) these scales are displaced by the conversion factor divided by 1.73. Therefore in the case of the Blundell rule (English system) the 100% efficiency mark for three-phase systems is placed above 43.1 on the A scale and in the case of the Aristo 914 (PS system) it is placed above 42.5 on the A scale.

The use of the usual Dynamo-Motor scale can be illustrated by the following examples, one using the specific scales and the other using gauge marks.

The basic equation to be solved;

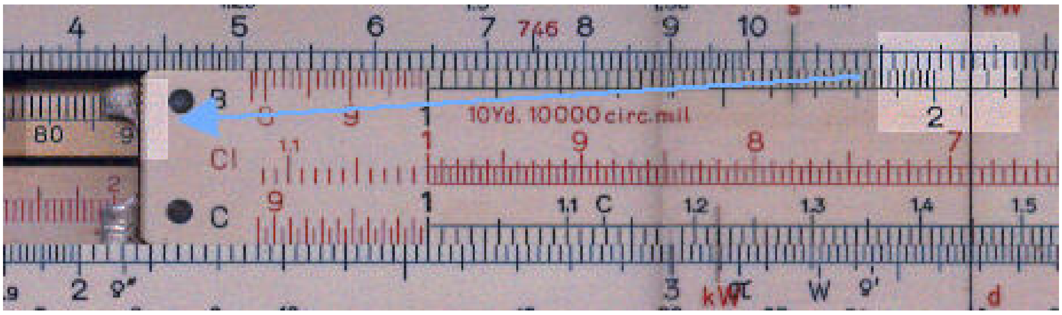
Efficiency = Electrical energy output / Mechanical energy input.

Example:

Calculate the efficiency of a dynamo which gives an output of 13.5 kW for 21.0 HP.

Faber Castell 1/98 Elektro

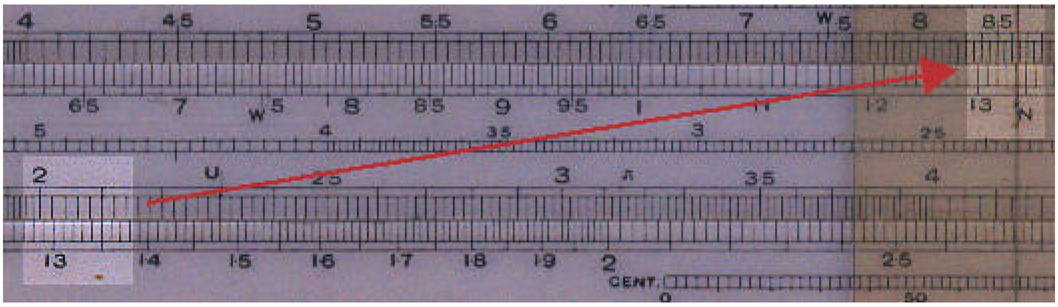
Set 2.10 on the B scale against 13.5 on the A scale.
Read the efficiency, 86.2% on the Dynamo efficiency scale in the well of the rule.



As a check, 21.0 multiplied by 0.746 is 15.67 and 13.6 / 15.67 is 86.2. As you can see it is not a complicated calculation, and personally I found it much easier to perform than to remember the actual scale settings. And as one usually needs to convert HP into watts for other calculations it was to some advantage to perform the calculation this way.

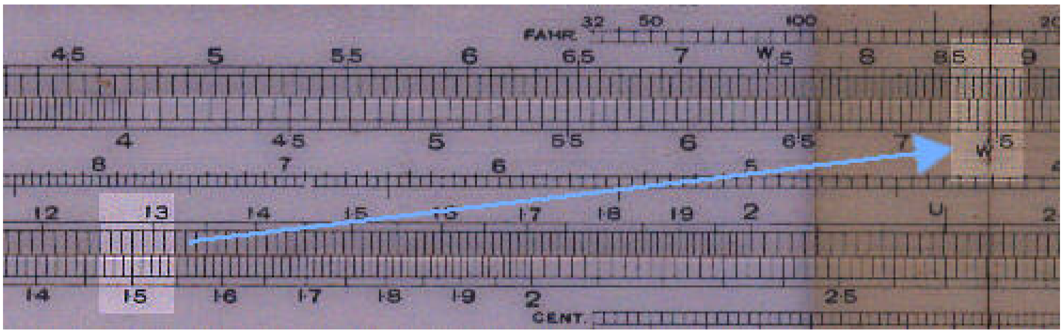
To perform the same calculation on the ***Unique Electrical*** it is necessary to use gauge points.

Set the output 13.5 kW on the D scale against the input 21HP on the C scale.
Read the efficiency, 86.6% on the DF scale, opposite the gauge mark N on the CF scale.



For most rules (i.e. ones with the special scales) the calculations of motor efficiency are simple mirror of the calculations for dynamo efficiency. However, for the Unique and others with gauge marks, the procedure is different.

Example:
Calculate the efficiency of a motor which develops 150 HP for 128 kW.
Set the output 150 horsepower on the D scale against the input 128 kW on the C scale. Read the answer, 87.5%, on the DF scale opposite the W gauge mark.



So although different, a consistent process is used. Place the output on the D scale opposite the input on the C scale. For motor efficiencies read the DF scale opposite the W gauge mark. For dynamo efficiencies, read the DF scale opposite the N gauge mark. But I wish manufacturers would have labelled the gauge marks MOT and DYN! But why where the gauge marks put in these particular locations? Firstly, notice the N mark, it is placed at 134, the reciprocal of 746 or the number of watts in a horsepower. The calculation divides the input 21 horsepower by the output 13.5 kW on the normal C and D scales. Thereby if the result is multiplied by the reciprocal of 746, the answer is obtained. As efficiencies are normally in the range of 80 to 100%, the folded scale arrangement ensures that the answer can be read on the rule. Compare this calculation with a rule that has A, [B, C], D scale arrangement.

Also worthy of note is the use by Unique of the C and D scales for these calculations. Almost invariably other manufacturers used the A and B scales (and even Nestler used the A and B scales with gauge marks). The reasons why they used the A and B scales escapes me. I have always found that one-order C and D scales prevented confusion with the number setting. And the use of one-order scales i.e. the CF and DF scale for reading the efficiencies allowed the result to be read with greater precision.

Voltage Drop Calculations Ref [1]

Voltage drop is given by the formula:

$$V = (I * L)/ (C * A)$$

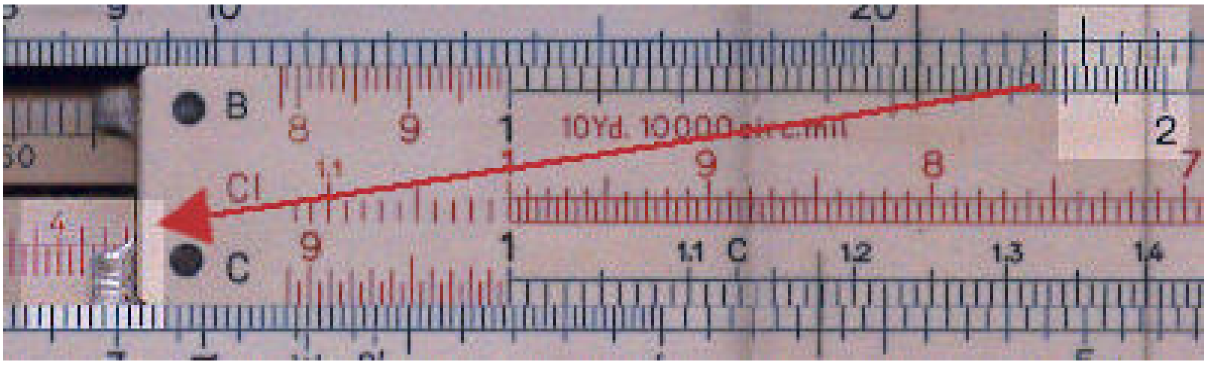
Where:

- V is voltage drop (volts)
- I is the current (amps)
- L is the length (yards)
- C is the conductivity of copper
- A is the section of the conductor.

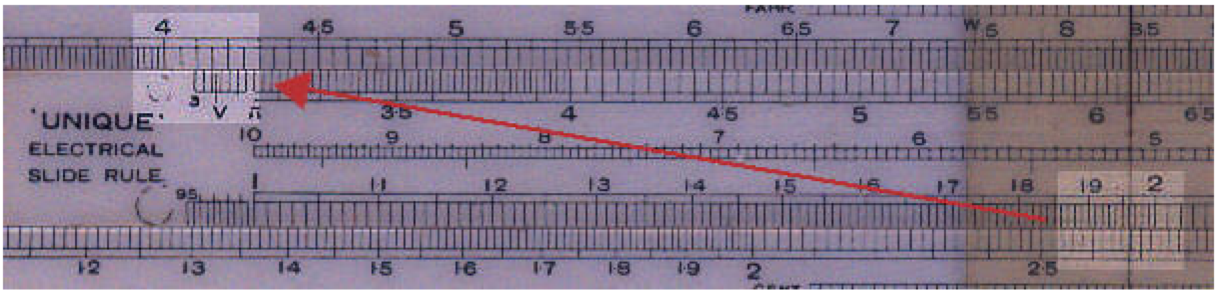
Typical units for A are square inches, square millimetres and circular mils. Circular mils are calculated from the diameter of the wire in thousandths of an inch squared.

The following calculations all assume copper wire and direct current.
Example:
Calculate the volt drop in a copper conductor 131 (119.7 m) yards long, 0.14 in (3.56 mm) diameter, carrying a current of 20.4 amps.
The area of a wire 0.14 diameter is 0.0154 in^2, equivalent to 9.94 mm^2 and 19600 circular mills (=140 * 140).

Faber Castell 1/98 Elektro
The Faber Castell 1/98 is set up for units of 10 amps, 10 yards and 10000 circular mils.
Align 1 on the B (length and area) and scale against 2.04 (2.04*10amps = 20.4 amps) on the A (current) scale.
Cursor to 13.1 (13.1 * 10 yards = 131 yards) on the B (length and area) scale.
Align 1.96 (1.96 * 10 000 circ. mils = 19600 circ. mils) on B (length and area) scale.
Read the answer 4.14 volts in the well of the stock.



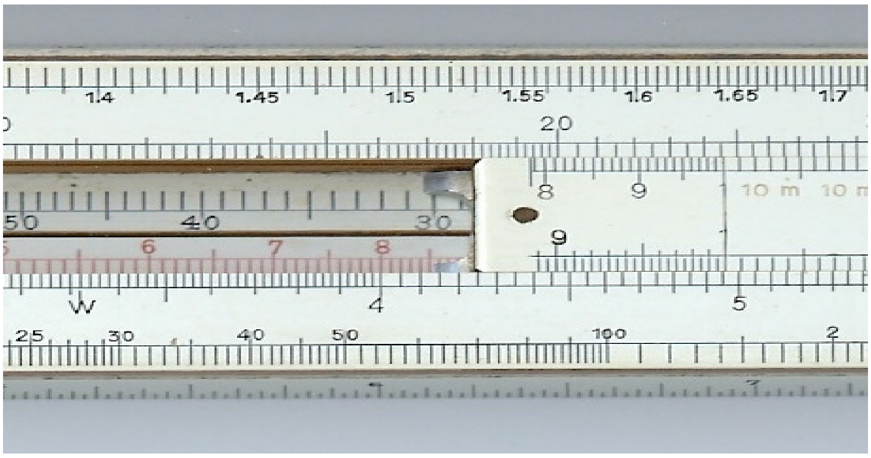
Unique Electrical
Area is 1402 = 19600 circular mils.
Set 1 on C against 2.04 on D.
Move cursor to 1.31 on C.
Move 1.96 to the cursor.
Read volt drop, 4.16, above V on the CF scale.



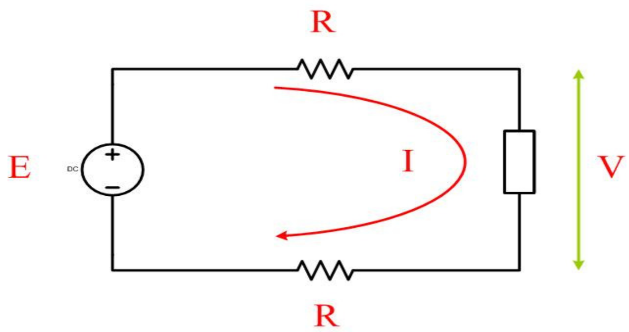
Note the similar result, although not identical. This could only be the case if all manufacturers agreed on using the same copper cable alloy or agreed to use pure copper as the material for specific resistivity or conductivity. A perusal of various manufacturers rule, manuals and also the recent publication "Pocketbook of the Gauge Marks" by Panagiotis Venetsianos Ref [7] provide any number of resistivities in use. A number of these are indicated in a later clause on Gauge Marks.
It is also interesting to note that usually Metric rules give an answer that is double the voltage drop calculated above, e.g.

Faber Castell 378
The Faber Castell 378 is set up for units of 10 amps, 10 metres and 10 mm2.

Align 1 on the B (length and area) and scale against 2.04 (2.04*10amps = 20.4 amps) on the A (current) scale.
Cursor to 11.97 (1.197 * 10 metres = 119.7 metres) on the B (length and area) scale.
Align 0.994 (0.994 * 10 mm^2 = 9.94 mm^2) on B (length and area) scale. Here, as the 378 has scale extensions the answer 8.5 volts is read in the well of the stock. This doesn't equal 4.1 something. WHY?



As can be seen the answer is twice the value given by the other rules and should be multiplied by 0.5. A similar result is obtained using a Graphoplex Elektro rule. Why is this the case? I believe it results from the way the problem is stated and formulated. In the "English" rules i.e. ones with units of yards, mils or sq ins, the problem is thought of in isolation to any other system. The calculation is based upon current through a single resistance. Whereas in the metric system, the designers assumed that the calculation was to solve the problem of voltage drop from source to load and to therefore determine the voltage available at the load. This can be illustrated by the following diagram:



V = E – (2 x R x I)

As we can see in the practical world transporting power to a load requires a return path through which the current has to travel. Therefore using the resistance of the length of wire to a load would not produce the correct total resistance and a factor of two would be required. Therefore the designers of the metric rules built this factor into their rules. It also explains why on some rules a gauge mark at 28.7 exists. This is the reciprocal of twice the resistivity of copper (0.01742 Ω.mm^2/m). Using this figure the correct value of conductivity for the metric or two-wire solution can be used in the formulae for Voltage Drop.

A discussion with another collector (Richard Hughes) has introduced the quandary. Should the "two-wire" solution be multiplied by 0.5 to agree with the "one-wire" solution or should "one-wire" solutions be multiplied by 2 for the real world as discussed? My preference is still for the one-wire calculation, as this is ubiquitous. The two-wire solution presupposes the calculation to be for a motor or load situation whereas the one-wire solution is a basic calculation of current through a resistance. If the calculator is aware of the problem (as they should be!!) then it is quite normal to add twice the length if this is the nature of the problem. Richard has a number of Elektro's in his collection

Nestler 0370 (March 65) L in metres and q in mm squared;
Aristo 915 (Jan 69) meters and mm squared;
Faber-Castell

- 1/98/398 (Feb 38) yard and Cmil;
- 1/98/398 yard and Cmil;
- 1/98 (March 66) yard and Cmil;
- 1/98 (Jan 71) metre and mm squared;
- 67/98 b (Jan 74) metre and mm squared.

All of these are the "one-wire" types. Another Elektro in his collection is the Sun-Hemmi 80K (Dec 65?) which is a "two-wire". Thus Richard has several "metric" versions that are of the "one-wire" type. Therefore my previous hypothesis is not entirely correct. So is this another dilemma for the collector i.e. how many Elektro rules are "English" rule "one-wire" types and how many are "Metric" rules "two-wire" types?

Modern Day Practical Problems and the scales that would have helped.

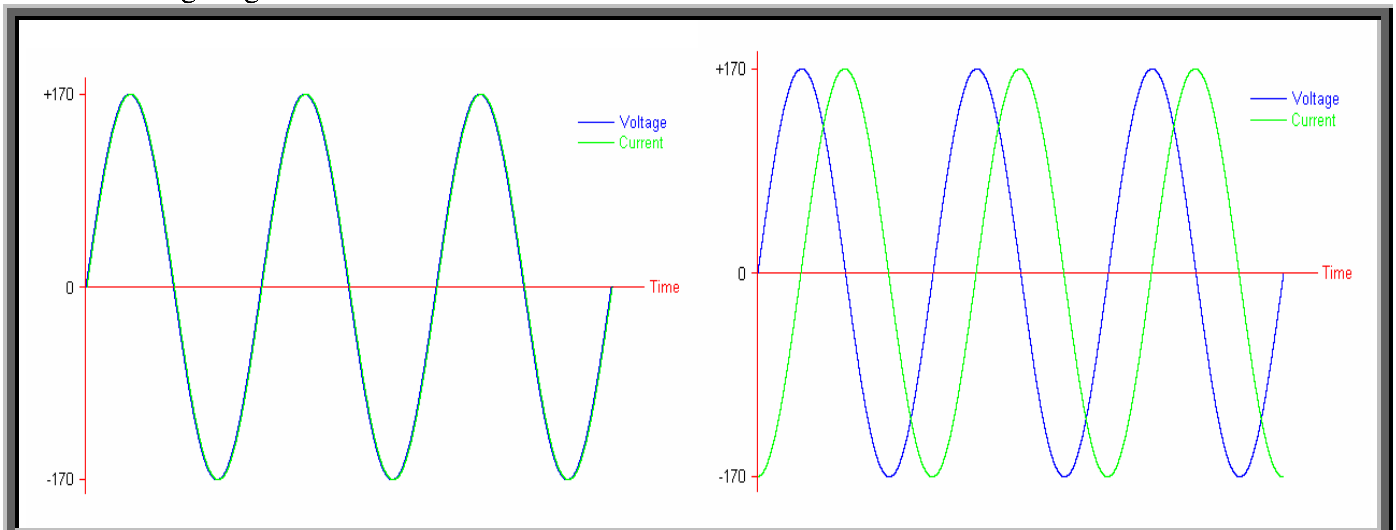
As seen in the earlier sections of this article, the problems that the Elektro rules tried to address are mainly concerned with Motor and Dynamo efficiencies and voltage drop along copper conductors. However, as most areas of life have evolved in the face of a changing technological age, so has electrical engineering. No longer do we rely on direct current as power distribution medium (if ever) or copper conductors to transmit electricity. The electrical engineer is probably more interested in problems of the following nature:

Alternating Current (AC) Power Calculations

Calculation of power in direct current systems involved the direct application of Ohm's Law where

Power = Voltage * Current

However, in alternating current systems the voltage and current can be out of phase. This is illustrated in the following diagram:



Resistive Circuit	Reactive Circuit

Power is then described as:

Power = Voltage * Current * Cosine θ

Where ***θ*** is the phase angle between the two waveforms. This calculation would be easily facilitated by a ***cos scale on the slide***.

Three-Phase Power

The above equation applies to single phase systems, however the majority of electricity transmission and distribution systems uses the three-phase system. The power delivered by such three phase systems can be calculated by the following formulae:

P = 1.73 * Line Voltage * Line Current * Cos θ

The value 1.73 is the square root of 3. Again calculation of this formula would have been made easier with the addition of a ***gauge mark at 1.73 on the C or D scale***. This is a surprising omission on most Elektro rules.

Impedance Calculations

The impedance of an ac system is the equivalent of resistance in a dc system. However where resistance is scalar, impedance is a vector quantity and is usually quoted as a complex number in terms of:

> R+ jX ohms (the Cartesian form) where R is the real (resistive) component and X is the imaginary (reactive) component
> *Or*
> Z ∠ϕ ohms (the Polar form) where Z is the magnitude (impedance) and ϕ is the angle (phase)

The key to determining impedance is the calculation of reactance and depending on whether the reactance is capacitive or inductive the reactance is given by the following equations:

> $\frac{1}{\omega * C}$ Ohms if Capacitive or $\omega * L$ Ohms if Inductive

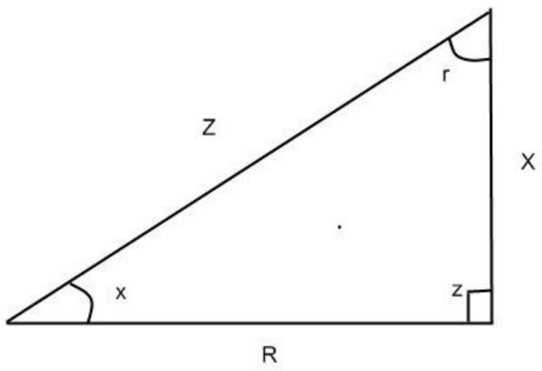
Where ω is equal to 2π times the frequency of the alternating current. This calculation is carried out numerous times a day by a practicing electrical engineer. It would be extremely convenient if gauge marks where added to the Elektro rules. It is surprisingly that this was the exception instead of the rule. However, 50 cycles/sec (hertz) countries had an advantage in this area as 2πf was equal to 100π. So the π mark doubled as the ***gauge mark.*** However, in 60 Hz countries, 2πf was ***equal to 377.*** This is nowhere to be seen on any rule I have in my collection and it even doesn't rate as a known gauge mark in Mr Venetsianos' book. The reciprocal of 2πf is also equally useful for calculation of the capacitive reactance and thus gauge marks at 3183 and 2653 would be advantageous, but again 3183 is not common and 2653 is never seen. Another technique or scale addition that would have assisted in these calculations would have been to include a ***CF and DF scale folded at π or even more useful folded at 2π.***

Polar to Rectangular conversions

The concept of impedance was identified in the previous section and could be written in the cartesian form or the polar form. Each form offered an advantage, multiplication and division is easier if vectors are in the polar form, addition and subtraction is easier if the vectors are in the rectangular or Cartesian form.

Thus polar to rectangular conversions and vice a versa were common everyday practice for engineers in this discipline.
The mechanics of the conversion from polar to Cartesian and vice a versa can be demonstrated via simple trigonometry relationships

For instance:



In the impedance triangle above, the relationship known as the sine rule specifies;

$$\frac{X}{Sin(x)} = \frac{R}{Sin(r)} = \frac{Z}{Sin(z)} \quad = \text{Z (as sin 90 =1)}$$

And as the polar form of an impedance vector is usually quoted as Z∠x   for example use 5∠30° ohms

$$\frac{X}{\sin(30)} = \frac{R}{\sin(90-30)} = 5$$

X and R are easily solved, and the calculation is fairly efficient on a rule with the trig scales on the back of the slide. For X in the above formulae, place 30° on S scale to the index mark on back and read the answer, 2.5 on C scale, against 5 on D scale. For R, place 60 on the S scale to the index mark on the back and read the answer 4.33 on the C scale against 5 on the D scale.
If the trig scales are on the front of the slide the method is as efficient. However, an additional advantage of trig scales on the front of the slide is in chain calculations involving trig values and I would have preferred to see a rule with a larger slide so that at least a sine scale could have been included

Power Factor

Power Factor (PF) is the ratio of active power to apparent power and is equal to the cosine of x in the impedance triangle shown previously. If the PF of a power system load is given as 0.8 then the engineer knows that the resistive component is 0.8 times the impedance and conversely using the Pythagorean relationship the reactive component is 0.6. This calculation is a straightforward conversion if the slide rule contains a P scale.
Consider the following example. An electrical load of 100 kVA has an effective power of 85kW. Therefore cos x is 85/100 or 0.85. Setting 0.85 on the D scale provides the answer for reactive power of 52.9 kVA on the P scale.
The addition of a ***P (Pythagoras) scale*** would have been more than convenient, but rarely provided on Elektro rules. The P scale would have also assisted in polar to rectangular conversions.

Exponential Decay

In any switching of electric circuits containing inductance and/or capacitance, the rise or decay of current and voltage depends on a time constant that is established by the values of reactive and active components of the system i.e. the resistance and inductance/capacitance. For a circuit containing resistance and inductance the relationship for current is:

$$\text{Current} = \frac{\text{Voltage}}{\text{Impedance}} * \left(1 - e^{\frac{-Rt}{L}}\right)$$

Similar equations can be written for voltage and also for capacitive circuits. Notice the exponential function is in terms of a negative number. The consequence is that the equation tends towards steady state solutions equal to the value of voltage divided by impedance. On rules that have only positive LL scales like Elektro rules this is an inconvenient equation. Of course we could always find the solution to e^x and then take the reciprocal, but it would be simpler to have ***inverted LL scales***.

Currents in Long Transmission Lines

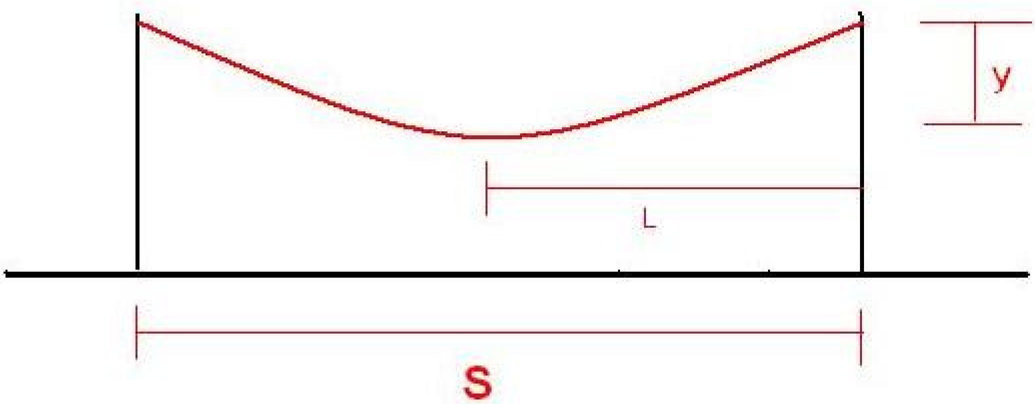
The relationship between voltages and also currents in long transmission lines can be realized by the following equation:

$$Es = Er \cosh \sqrt{ZY} + Ir\sqrt{\frac{Z}{Y}} * \sinh \sqrt{ZY}$$

Where the subscripts s and r stand for the **s**ending end and **r**eceiving end and Z is the series impedance of the line and Y is the shunt admittance (the reciprocal of the impedance to ground) of the line. For most electrical engineers in the electricity supply industry this is a well known and not uncommon equation. ***Hyperbolic functions*** would be a nice addition to the slide rules.

Catenary Calculations

The suspension of cables from electricity pylons also is expressed in terms of hyperbolic functions ref [4]. For example:



$$y = C\left(\cosh \frac{S}{2C} - 1\right) \text{ And } L = 2C \sinh \frac{S}{2C}$$

S is the span, s equals the sag, L is the length to the point of sag and C is a constant. Again, ***hyperbolic functions*** would have been an advantage.

Missing P Scales, WHY?

There is a continuing question with “Elektro” rules. That, in a discipline that has, as an important and frequent calculation, many polar to rectangular conversions and power factor calculations, why there isn’t a “P” scale included on many Elektro rules.

In all of the “classical” rules the P scale does not feature, why?

Is this a legacy from the days of direct current where complex mathematics did not feature or was it a preference of distribution engineers where impedance was not an important concern? The origins of Elektro rules begin in the early 1900’s when Direct Current (DC) was much more common as a distribution medium than Alternating Current (AC). But AC was soon the dominate system as it made transportation of power far easier for large distances and allowed easy conversion between voltage levels. So I doubt that the manufacturers of the rules would not be aware of such changes in technology.

Was it because of the adoption of the standard Rietz pattern, and the available space was restricted?

Perhaps in the practical application of electric problems of voltage drop and motor efficiency, the designers of the rules where being pragmatic and contended that there is little difference at the low voltage, low frequency level between the two systems. But in the daily working of an electrical engineer, even at distribution voltage levels (110 volts to 11,000 volts) calculations of impedance required polar to rectangular conversions and power factor calculations. The particular advantage offered by a rule with a P scale was and is obvious to many people, but apparently not to the manufacturers of Elektro Rules.

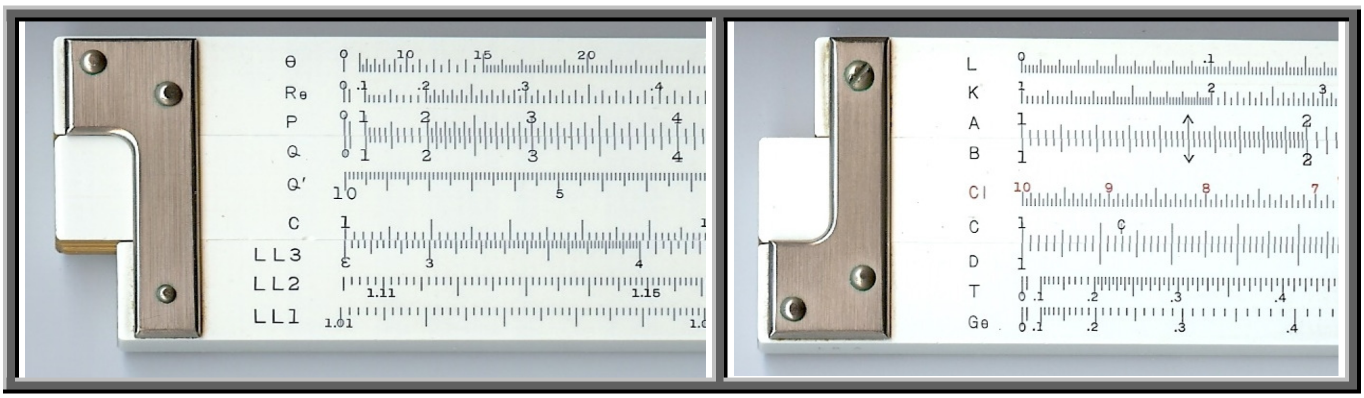
Improved versions of “Elektro” Rules

Although mentioned in the Hemmi 1931 catalogue the model 153 could be called the first improved version of the Elektro side rule. This rule used a “theta” scale and also an indexed radian scale (Re) in cooperation with the “un-logarithmic” scales called the square P and Q scales. But the strangest scale of all on the 153 was the Gudermanian scale “Ge”.

The Gudermanian function, named after Christoph Gudermann (1798 - 1852), relates to the circular and hyperbolic trigonometric functions without resorting to complex numbers. The identities can be defined as follows;

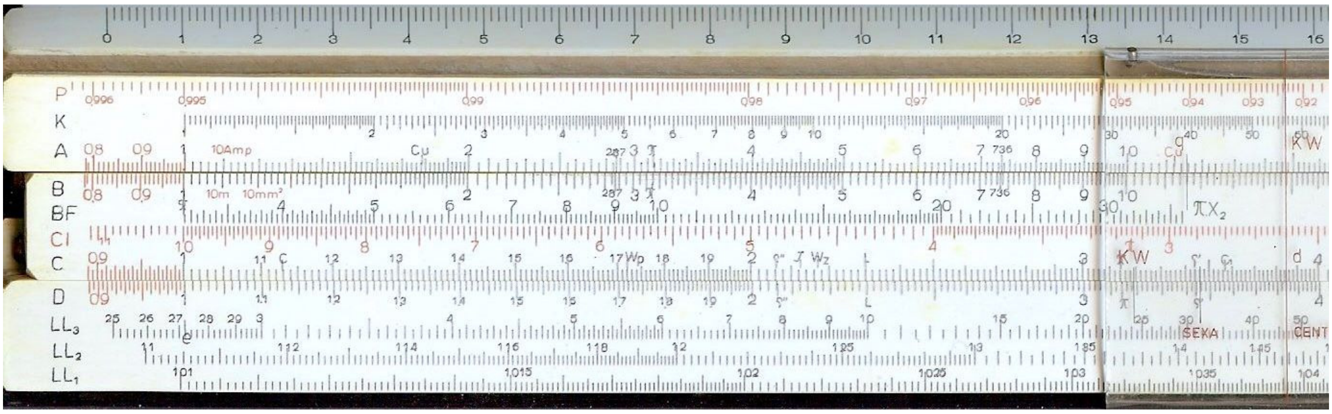
$$\begin{aligned} \sinh(x) &= \tan(\mathrm{gd}(x)) \\ \cosh(x) &= \sec(\mathrm{gd}(x)) \\ \tanh(x) &= \sin(\mathrm{gd}(x)) \end{aligned}$$

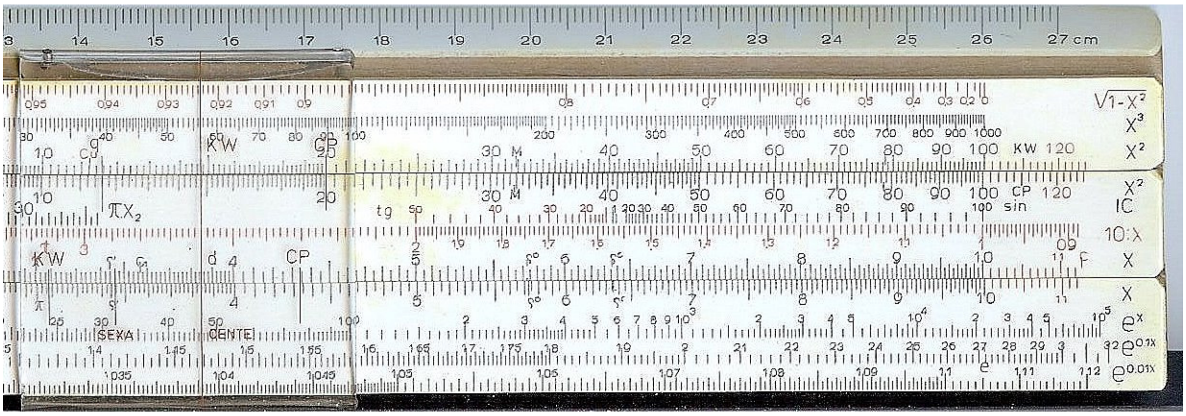
The actual usage and development of this scale on Hemmi rules was invented by Hisashi Okura and a US patent was issued in 1937.



To obtain hyperbolic values of an argument x the Ge, T, P, Q and Q’ scales where employed. Although the uses of the special scales on the 153 are not particularly intuitive they were, by and large useful in vector calculations. After some practice, the Ge scale provided very easy way to calculation of at least Sinh and Tanh values without the need for hyperbolic scales.

The Romanian rule depicted earlier seemed to combine most of the so called improvements required by a ‘normal” Elektro rule.





Some of the improvements or additions to the normal Elektro rules are:

the addition of a P scale,

the addition of an extra LL scale down to e $^{0.01x,}$

the metric system (10m and 10mm^2 for conductors),

an ST scale for small angles,

scale extensions to 0.7854 (i.e. to at least π/4 the constant factor for the area of a circle).

This rule was probably produced in the late 60’sand the 1970’s and so benefited from hindsight.

An “Ideal” ELEKTRO Rule

It would be hard to define such thing but given the previous dialogue I could offer a number of scales and gauge marks an ideal rule might have:

- Standard A (x^2), B (x^2), C (x), and D (x) scales.
- CI (1/x) on the slide.
- K (x^3) scale which could be placed on the stator or on the lower edge of the rule and read with a cursor extension. Although this is a usual scale included on Reitz and Darmstadt rules I found this

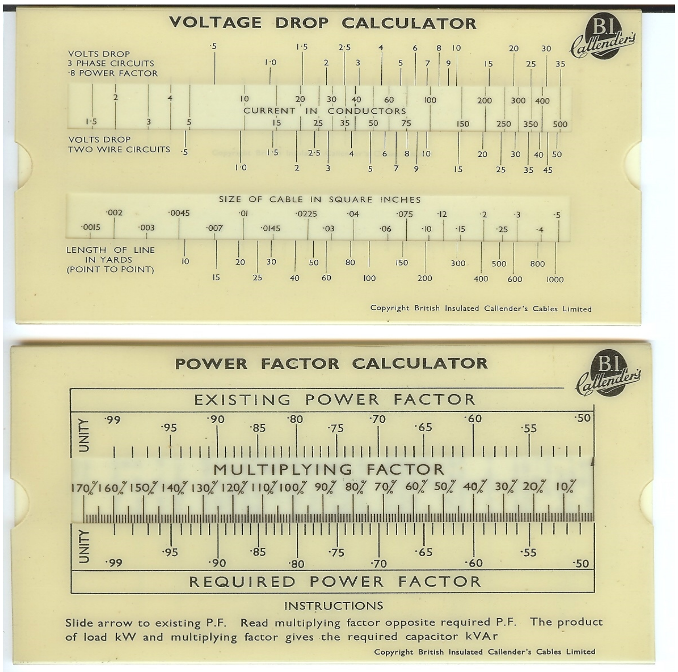
scale little used in electrical engineering calculations and would have easily dispensed with this scale for the inclusion of some of the scales listed below.

- L ($\log_{10}$) scale which could be placed on the stator, the reverse of the slide or on the lower edge of the rule and read with a cursor extension.

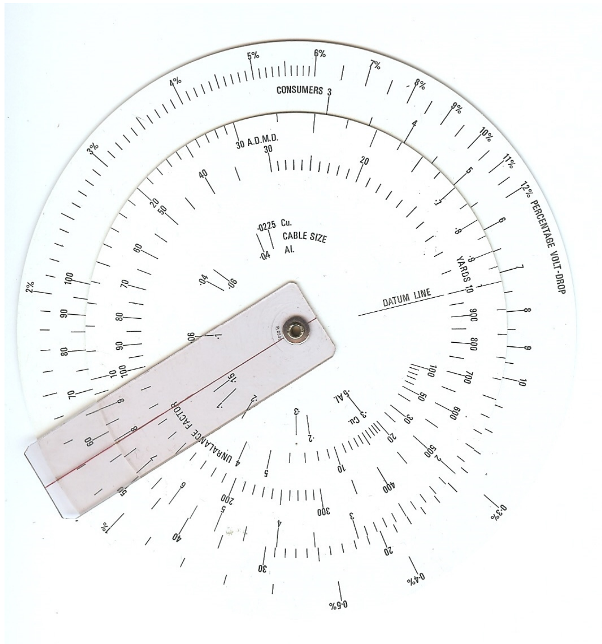
- S (sin) and T (tan) on the reverse of the slide.

Note the preceding are standard scales appearing on nearly every Elektro rule and follow the normal Rietz pattern.

- I would dispense with the actual “defining” scales for an Elektro rule (i.e. the Volt drop and Motor/Dynamo efficiency scales) in favour of gauge marks similar to the Nestler and Unique rules. The classic scales take up valuable rule real estate and as Snodgrass in his book “The Slide Rule” [Ref 2] points out, efficiencies are nearly always in the order or 80 to 90% thus the answer is always in a crowed part of the rule if using small 5 inch special scales. Voltage drop calculations are always dependent on the value of resistivity assigned to the conductor metal. They would be better dealt with via gauge marks for the particular conductor resistivity or by a special purpose rule such as the Voltage Drop Slide Rule by C.C. Moler which was described in JOS Vol 11, No.1. Other examples speciality rules are:



BICC PF and Voltage Drop Rules



BICC circular Voltage Drop Rule

Note: BICC is an acronym for British Insulated Callender’s Cables

The additional scales proposed are:

- Positive LL scales in the range from .01 to 10 at least and if real estate allows inverted LL scales.

- Extra Sin and Cos scales on the slide to assist with chain and power calculations.

- CF and DF scales folded at 2π or at least π.

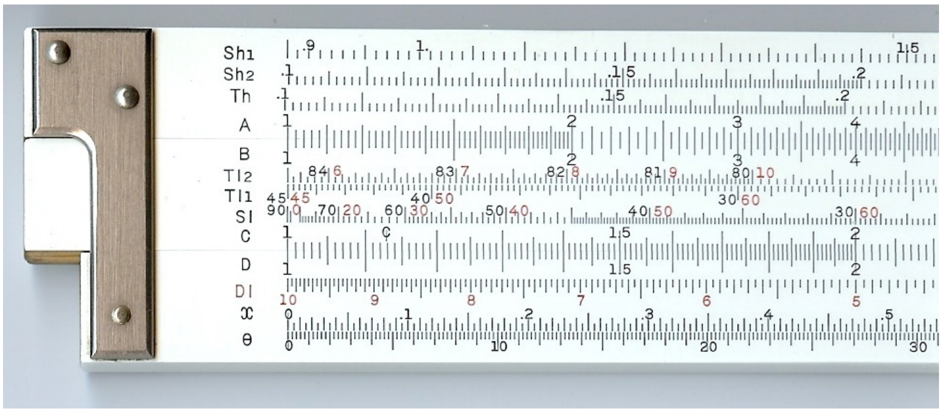
- Hyperbolic Functions.

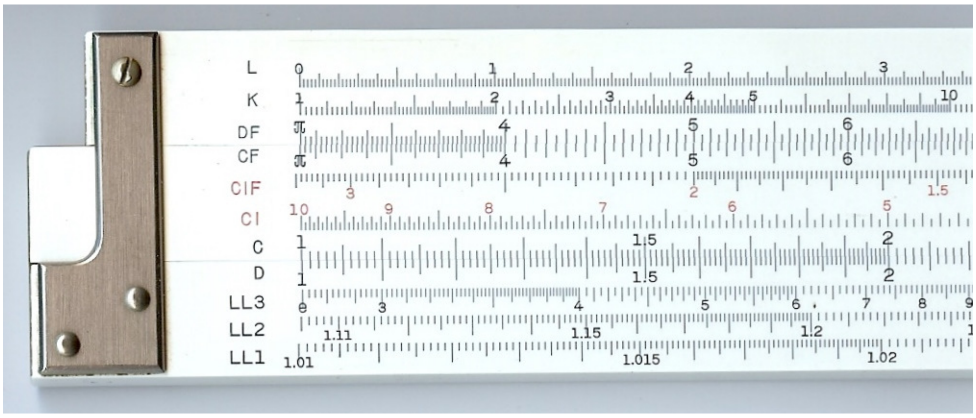
- Pythagoras scale (ideally two similar to the Aristo MultiTrig as power factors are nearly always between 0.85 and unity).

- Other possible scales but not essential would be a CIF scale and a Ln scale.

- The inclusion of Gauge Marks, other than those already suggested for voltage drop and efficiency calculations, at:
    - sqrt of 2 and 3,
    - $2\pi f$ for both 50 and 60 Hertz systems,
    - 746 and 736,
    - resistivity of Cu and Al.

All of these requirements would have meant a duplex rule and in the latter period of slide rule manufacture duplex "Elektro" rules started to appear. One such rule was the Hemmi 255D:

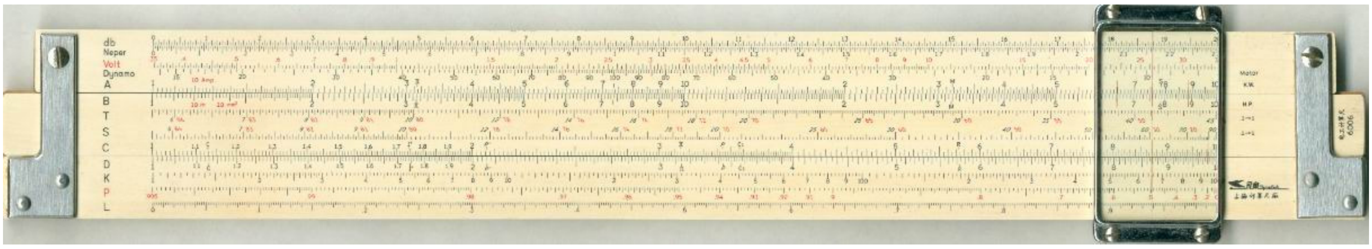


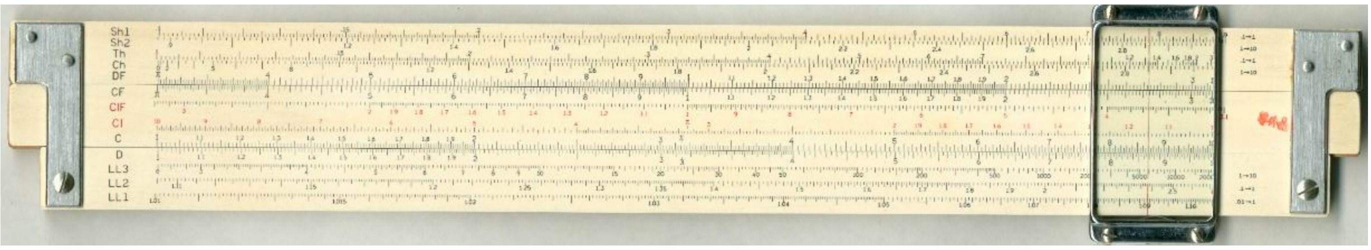


As can be seen from the scans, it has:
- the "standard" scales,
- hyperbolic functions,
- CF and DF scales folded at π,
- a SI scale, an interesting idea in as such it is a Cos scale to the 84 degree,
- a radian scale that can be used for degree to radian conversion,
- the scale layout with the trig scales that allows for easy polar to rectangular conversions.

There is however no gauge marks on this rule. The original purpose of Elektro rules has been given scant regard and the defining scales have been completely omitted from this rule.

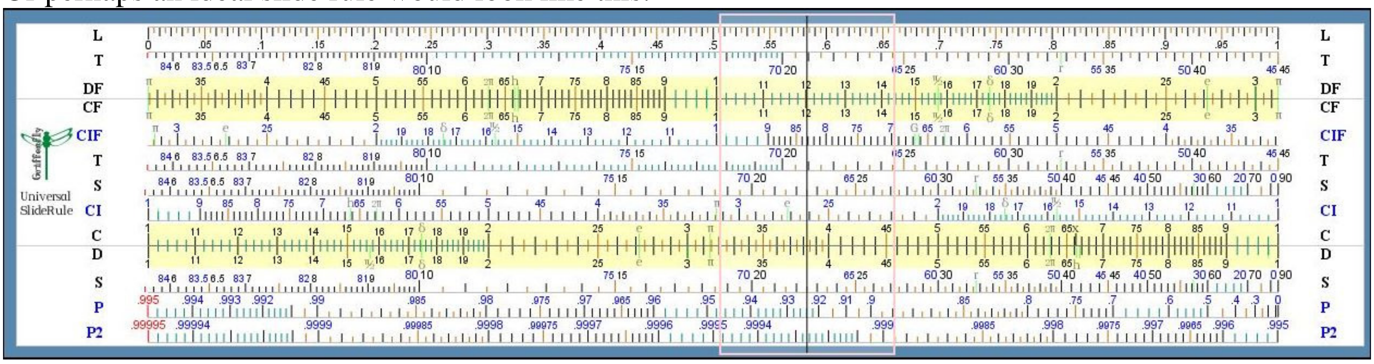
Another late era slide rule that incorporated everything that the Hemmi 255D did plus had space available for the trad ional scales of Voltage Drop and Efficiency was the Flying Fish 6006. It even included dB and Neper scales!

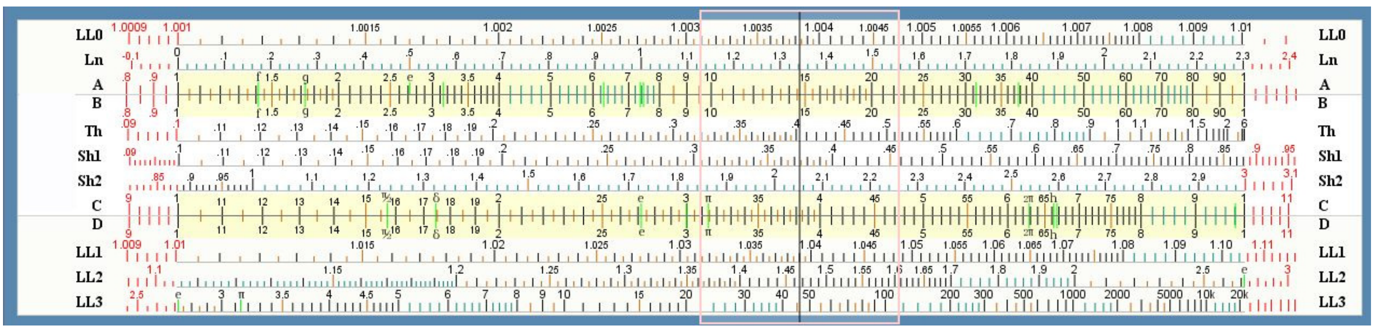




The scans of the Flying Fish 6006 are used with the kind permission of GuiSheng Xu and more details of this rule can be found at his “Slide Rule Zone” website http://www.sliderule.com.cn

Or perhaps an ideal slide rule would look like this:





The above rule faces were built using the GriffenFly Universal slide rule package available from www.griffenfly.com.

As can be seen this rule dispenses with the normal Elektro rule scales for efficiency and voltage drop and moves towards a scale arrangement to allow easy manipulation of vectors and added:

- folded C and D scales around π,
- matched sets of S and T scales,
- extended range P scales,

- four Log-Log scales,
- hyperbolic functions,
- a Ln scale.

Conclusion

I hope the paper has provided some insight into the requirements of a slide rule by the electrical engineering industry and engineers within the industry. Although the speciality scales of Elektro rules provided answers to some common problems within the industry, these problems were in themselves trivial and could be handled by simple calculation with the standard Reitz or Darmstadt rules. Then why where these rules ubiquitous and produced right to the end of the slide rule era? I have no answer to this question, except to add that maybe the simple Reitz layout with the addition of a couple of LL scales produced an inexpensive and efficient rule that many people were comfortable with using this arrangement.

Acknowledgements

I must acknowledge the valuable assistance of Ron Manley and his permission to use, without restriction, the motor efficiency and voltage drop calculation descriptions from his web site. His permission and assistance saved many hours of work and also provided accurate and succinct descriptions of these calculations, far better than I could have achieved.
And I would also like to thank both David Rance and Richard Hughes for providing valuable suggestions for the improvement of this paper and in particular David for his assistance in editing and his continued support.

References

1. Ron Manley's Web Page http://www.sliderules.info/
2. *"The Slide Rule"* by Burns Snodgrass
3. "Herman's Archive" by Herman van Herwijnen http://sliderules.lovett.com/herman/begin.html
4. *"The Slide Rule – Principles and Applications"* by Joseph Norman Arnold
5. *"Slide Rules A Journey through Three Centuries"* by Dieter von Jezierski
6. *"Slide Rules – Their History, Models, and Makers"* by Peter M Hopp.
7. *"Pocketbook of the Gauge Marks"* by Panagiotis Venetsianos
8. *'The Slide Rule, Technical Cultural Heritage"* by Ir. IJzebrand Schuitema
9. *Slide Rule Gazette – A Publication of the UKSRC Issue 6 Autumn 2005*

Appendix 1

Known Electrical or Electronic Rules
Data taken from ref [3], ref [6] and my collection

Rule (Manf, Model)	Elektro	Electronic	50 cm or 20 inch	25 cm or 10 inch	12.5 cm or 5 inch	Circular	Special Scales		Gauge Marks	Scales	Scales
							Well	Stock or Slide		Front	Back
Ahrend 15 Electro (Dennert & Pape 15)	•			•			•			LL2 A = B C = D LL3 # Dyn-Mot V #	
Ahrend 654 Electro	•			•			•			LL2 A = B C = D LL3 # Dyn-Mot V #	= S T =
Alro 200R	•					•			•	S T S&T N2 N = N N2 R N3	
Alro 600E	•					•		•		n2 C = D n2 LL Dyn-Mot V ? L	
Antica Fabbrica Vittorio Martini Elettro Cosfi 401	•				•			•	•	V A = B CI C = D U	= S ST T =
Antica Fabbrica Vittorio Martini Elettro Cosfi 416	•			•				•	•	V A = B CI C = D P K LL || L	= S ST T =
Archimedes 18 C Electro	•								•	A = B CI BI C = D L LL1 LL2 LL3 P	= S T =
Aristo 814 Elektro	•				•		•	•		LL2 A = B CI C = D LL3 #V D/M(=) (opt G/M3~))#	= S L T =
Aristo 815 Elektro	•				•			•		K A = B BI CI C = D D/M(=) V	= S ST L T =
Aristo 914 Elektro	•			•				•		LL2 A = B CI C = D LL3 #V D/M(=) (opt G/M3~))#	= S L T =
Aristo 915 Elektro	•			•				•		K A = B BI CI C = D LL3 LL2 D/M(=) V	= S ST L T =
Aristo 949	?	?		•						?	?
Aristo 1014 Elektro	•		•					•		LL2 A = B CI C = D LL3 #V D/M(=) (opt G/M3~))#	= S L T =
Aristo 1015 Elektro	•		•					•		K A = B BI CI C = D LL3 LL2 D/M(=) V	= S ST L T =
Aristo 10175		•		•				•		LC 2phi A = B CI C = D S T L	Special Scales
Blundell 305 C Electro Academy	•			•				•		V Dyn-Mot G/M3~ A = B CI C = D K LL2 LL3	= S L T =
Blundell 404 Electro Omega	•			•	•		•			LL2 A = B CI C = D LL3 # Dyn-Mot V #	= S L T =
Blundell 604 Electro Omega	•			•	•		•			LL2 A = B CI C = D LL3 # Dyn-Mot V G/M3~ #	= S L T =
Blundell 805 Electrical Academy	•			•				•		V Dyn/Mot A = B CI C = D K LL2 LL3	
Blundell E 3 Electrical	•			•				•		Volt A = B Cos C øF = D Dyn-Mot	

Rule (Manf, Model)	Elektro	Electronic	50 cm or 20 inch	25 cm or 10 inch	12.5 cm or 5 inch	Circular	Special Scales		Gauge Marks	Scales	Scales
							Well	Stock or Slide		Front	Back
Blundell E 13 Electricians	•			•			•			K LL1 LL2 DF = CF 1) CRF CR C = D P LL3 A # Dyn-Mot V #	
Blundell E 18 Electricians	•			•			•			V D A = B C = D øF øC cos # Dyn-Mot V #	
Blundell E 25 Electricians	•			•			•			LL3 A = B R C = D LL3 K # Dyn-Mot V #	
Blundell P 16 Electricians	•				•			•		Volt Dyn-Mot A = B cos C = D LL1 LL2 Res Cos	
Colgate	?									? Mentioned in Ref 6	
Concise 200 EE Data Center	•					•		•		D = C CI L A S T K M	Data Tables for Resistance and Reactance
Concise 380 Radio Computer		•				•		•		Special Scales	Special Scales
Concise EE - 112	•					•		•		D = C CI L A S T1 T2 ST	
Davis Electrical	•			•						?	
Dennert & Pape 15	•			•			•			LL2 A = B C = D LL3 # Dyn-Mot V #	
Dennert & Pape 141	•				•					? Mentioned in ref 5	
Dennert & Pape 143	•			•						? Mentioned in ref 5	
Dennert & Pape 145	•		•							? Mentioned in ref 5	
Dennert & Pape 49/20	•			•						? Mentioned in ref 5	
Dimier Electric	•				•		•			kW A = B(cv) C = D(cv) # Dyn-Mot V #	= mm2 mm =
Diwa 111 Electro	•			•			•			LL2 A = B CI C = D LL3] K # Dyn-Mot V #	
Diwa 311 Electro	•			•				•		K A = B CI C = D Volt tg. cin.	= LL1 LL2 LL3 =
Diwa 511 Electro	•			•				•		Dyn-Mot K A = B CI C = D V tg. sin.	= LL1 LL2 LL3 =
Diwa 611 Electro	•				•			•		cosj A = B CI C = D cosj # Dyn-Mot V #	= LL1 LL2 LL3 =
Duval Regle Electro	•			•			•			L K A = B CI C = D LL1 LL2 LL3 #30-20# #0.5+10Volts#	=cossin Tg C =
Faber Castell 319	•				•		•			LL2 A = B CI C = D LL3] K # Dyn-Mot V #	= sin lg tg =
Faber Castell 368	•			•			•			LL3 LL2 / A = B C = D / 27cm # Dyn-Mot V #	= sin lg tg =
Faber Castell 378	•			•			•			LL2 A = B C = D LL3 # Dyn-Mot V #	= sin lg tg =
Faber Castell 379 Elektro	•				•		•			LL2 A = B C = D LL3 # Dyn-Mot V #	= sin lg tg =
Faber Castell 388	•		•							LL2 A = B C = D LL3 # Dyn-Mot V #	
Faber Castell 388 N	•		•							LL2 A = B C = D LL3 # Dyn-Mot V #	
Faber Castell 398	•			•			•			LL2 A = B CI C = D LL3] K # Dyn-Mot V #	= sin lg tg =

Rule (Manf, Model)	Elektro	Electronic	50 cm or 20 inch	25 cm or 10 inch	12.5 cm or 5 inch	Circular	Special Scales		Gauge Marks	Scales	Scales
							Well	Stock or Slide		Front	Back
Faber Castell 1/78 Elektro	•			•			•			LL2 A = B C = D LL3 # Dyn-Mot V #	= sin lg tg =
Faber Castell 1/78/378 Elektro	•			•			•			LL2 A = B C = D LL3 # Dyn-Mot V #	= sin lg tg =
Faber Castell 1/98 Elektro	•			•			•			LL2 A = B CI C = D LL3] K # Dyn-Mot V #	= sin lg tg =
Faber Castell 1/98/398 Elektro	•			•			•			LL2 A = B CI C = D LL3] K # Dyn-Mot V #	= sin lg tg =
Faber Castell 111/98 Elektro	•			•				•		LL2 A = B CI C = D LL3 Dyn-Mot V] K	= sin lg tg =
Faber Castell 167/98 Elektro	•				•					LL2 A = B CI C = D LL3 Dyn-Mot V] K	= sin lg tg =
Faber Castell 379 Elektro	•				•		•			LL2 A = B C = D LL3 # Dyn-Mot V #	= sin lg tg =
Faber Castell 4/98 Elektro	•		•				•			LL2 A = B CI C = D LL3] K # Dyn-Mot V #	= sin lg tg =
Faber Castell 61/78	•				•		•			LL2 A = B C = D LL3 # Dyn-Mot V #	= sin lg tg =
Faber Castell 61/78/379	•				•		•			LL2 A = B C = D LL3 # Dyn-Mot V #	= sin lg tg =
Faber Castell 61/98/319 Elektro	•				•		•			LL2 A = B CI C = D LL3] K # Dyn-Mot V #	
Faber Castell 67/98 Elektro	•				•			•		LL2 A = B CI C = D LL3 Dyn-Mot V	= sin lg tg =
Faber Castell 67/98 Rb Elektro Addiator	•				•			•		LL2 A = B CI C = D LL3 Dyn-Mot V	= sin lg tg =
Flying Fish 1018	•			•				•		LL01 LL0 LL1 K A = Q QI L I = D DI LL02 LL2	f Rf P' P =B T S C = J J' T Gf
Flying Fish 6006	•			•				•		dB Neper V Dyn-Mot A = B T S C = D K P L	Sh1 Sh2 Th Ch DF = CF CIF CI C = D LL3 LL2 LL1
Fuji 208 Electro	•			•				•		K E A = B CI C = D LL3 LL2 L	= S ST T =
Graphoplex 643 Electro Log Log	•			•				•		L cos B3 B2 = b2 a b = B LL3 LL2 LL1	= S&T S T b =
Graphoplex 650 Electro	•			•				•		L B3 cos? B2 = b2 a b = B cos? Dyn-Mot V	= S&T S T b =
Graphoplex 697 Electro	•			•				•		L 1) Dyn-Mot V A = B Cap./Ind. CI C = D f I DI	ST T S DF = CF CIF K CI C = D LL3 LL2 LL1
Graphoplex 698 Electronicien		•		•				•		f XC f XL A = B L Cap CI C = D f' f Log x-decibels	ST T S DF = CF CIF K CI C = D LL3 LL2 LL1
IWA 0272 Electronic		•		•				•		Lamda, Cw f = C L Rc = LC Rl	K S T A = B CI C = D Ln cm
IWA PIA Electronic		•			•			•		A = B Cap, Ind C = D f	l2/l1 db p/p = S L T =
Jakar 66	•			•				•		K Dyn-Mot V A = B CI C = D LL3 LL2 L	= S S&T T =

Rule (Manf, Model)	Elektro	Electronic	50 cm or 20 inch	25 cm or 10 inch	12.5 cm or 5 inch	Circular	Special Scales		Gauge Marks	Scales	Scales
							Well	Stock or Slide		Front	Back
Kesel	•					•		•	•	K C R Special, Cu price, Cu wght, V, Eff, PS, Belt, Rev, PS, Cu dia	
Keuffel & Esser 4133 Roylance Electrical	•			•				•		A = B (F C) CI C = D] B & S Wire Gauge # Wire Amp #	= S L T =
Keuffel & Esser 4139 Cooke Radio		•		•						LC A = B T ST S = D DI	L DF = CF CIF CI C = D 2phi
Keuffel & Esser National Radio Union		•		•				•		Xr,Xc = F Ind = Cap	
Lawrence 8-L Voltage Drop	•			8"				•		Cable Distance = Current VD = Wire Size	
Loga 30sE	•					•				C = D	Cos
Loga 30sT	•					•			•	Sqrt1 Sqrt2 D = C CI K L	Cos
Loga 300 Tt.-El	•			•						?	?
Lyra - Orlow 41E	•			•					•	?	?
Marcantoni 12.5 RE	•				•		•			cos? A = B CI C = D cos? # Dyn-Mot V #	= S L T =
Marcantoni 25	•			•					•	?	
Nelson - Jones Circuit Designers Slide Rule		•		•				•		db A = B CI C = D LL3 LL2	XL = L&C F = XC
Nestler 11ZE	•				•		•			cos A = B CI C = D cos # Dyn-Mot V #	= S L T =
Nestler 32 Elektro (Presser)	•			•						C = D A = V	
Nestler 36 Elektro	•		•	•	•			•		LL2 A = B CI C = D LL3	= Dyn-Mot V =
Nestler 37 Elektro	•		•	•	•				•	V A = B C = D U // LL3 K #30-56cm#	= S S&T T =
Nestler 39 Elektro (Besser system)	•				•			•		Special Scales	
Nestler 0137 Elektro	•				•			•		Dyn-Mot Volt A =B CI C= D,P1 P2	= S L T =
Nestler 0297 Electronic I		•		•				•		Special Scales	Special Scales
Nestler 0370 Elektro	•			•					•	V A = B C = D U] LL3 K #30-56cm#	= S S&T T =
Nestler 0374 System Moisson		•		•				•		2πf Ind = Cap D/l D-n = Lambda f	?
Nestler 375 Elektro	•		•						•	V A = B C = D U] LL3 K #30-56cm#	= S S&T T =
Ohico Electro 15	•				•		•			LL2 A = B C = D LL3 # Dyn-Mot V #	= S L T =
PIC Electro	•			•				•		S A = B Dyn-Mot Volt C = D T	= LL L K =

Rule (Manf, Model)	Elektro	Electronic	50 cm or 20 inch	25 cm or 10 inch	12.5 cm or 5 inch	Circular	Special Scales		Gauge Marks	Scales	Scales
							Well	Stock or Slide		Front	Back
PIC 130	•				•		•			LL2 LL3 A = B CI (Isd ITd Td Sd) C = D K # Dyn-Mot V #	
PIC 131 / 132 / 134	•		•	•	•		•			LL2 LL3 A = B CI ISb Tb C = D P # Dyn-Mot V #	
PIC 144 AC Electrical (model F)	•			•				•		S C A = B CI (Z c f)C = D T // S T	= LL1 LL2 LL3 C =
PIC 141 AC Electrical (Model E)	•			•				•		S C A = B CI (Z c f)C = D T // S T	
PIC Electrical	•		•	•	•		•			LL1 A = B CI C = D LL2 D&ILL # V Dyn-Mot #	= S T L =
Pickett N16ES		•		•				•		SH1 SH2 TH DF = CF L S ST T CI C = D LL3 LL2 LL1 Ln	21 special scales
Pickett N515T Electronic		•		•				•		(Lr)H (fx)2phi A = (Cr)B S T (Lx or Cx)CI xL or fr-C = D L Ln	Special Scales
Pickett N531 CREI Electronic		•		•				•		L Ln A = B CI C = D 2Phi K	LL2 LL1 = S ST T C = D LL3
Pickett N535 Electronic		•		•				•		L Ln A = B CI C = D 2Phi K	Special Scales
Pickett N931 Electronic		•		•				•		L Ln A = B CI C = D 2Phi K	LL2 LL1 = S ST T C = D LL3
Pickett N1020 NRI		•		•				•		K A = B ST T S C = D DI	2Phi DF = CF L CI C = D DI
Reed Service Electronic Engineers		•		•			•		•	K A = B CI C = D L #D/L#	= S S&T T =
Reiss Elektro	•			•				•		K A = B CI C = D L	LL2 Dyn-Mot = sin sin/tg tg = V LL3
Relay 157	•			•				•		Sh2, Sh1, A = B, K, Th, C = D, Tr1, Tr2, dB	Sr, S theta, P', P = Q, CF, CI, C = D, DF, LL2, LL1
Relay 158		•		•				•		Sh2 Sh1 Th A = BI S T CI C = D LL3 LL2 LL1	X1 X2 P2 P1 = Q Y L Lx I =
Relay 605	•				•			•		Dyn-Mot L1 A = B CI C = D L2 Volts	= S L T = Eq. Tbl
Ricoh 107	•			•				•		Dyn-Mot V A = B K CI C = D S T	= LL3 LL2 LL1 L =
Ricoh 156	•			•				•		db DF =CF CIF CI C= D A	Xc XL K =KI S T= F2 F1 DI
Rista 2 Electro	•			•			•			Motor K A = B CI C = D Volt T S	= LL1 LL2 LL3 =
Rista 22 Electro	•				•			•		Dyn-Mot V A = B CI C = D COS COS L	= S S&T T =
S.R.E ELEKTRON 25	•			•					•	S T F A = B CI C = D P R	I/I0 dB P/P0
Seehase Elektro Praktikus	•				•			•		Special Scales	
Sydney Service Rule	•			•					•	LL2 A = B C = D LL3	= S L T =
Tianjin Gong Nong Bing 6504		•		•				•		T1 T2 K A = B F CI C = D L S	LL01 LL02 LL03 SG1 = SG2 SG2' C R1 =

Rule (Manf, Model)	Elektro	Electronic	50 cm or 20 inch	25 cm or 10 inch	12.5 cm or 5 inch	Circular	Special Scales		Gauge Marks	Scales	Scales
							Well	Stock or Slide		Front	Back
											R2 LL3 LL2 LL1
Simplon Electro Log-Log	•			•			•			LU A = B CI C = D LL # Dyn-Mot V #	= A S T D = L D
Skala	•			•				•		Pradnica Silk Volt L P K A = B CI C = D LL3 LL2 S T s-t	
Staedtler 54106 Electro	•			•				•		V A = B CI C = D U] LL3 K	= S S&T T =
Stanley "Electrical or Mechanical engineers Rule"	•			•			•			LU A = B C = D LL # Dyn-Mot V #	= S L T =
J. Hemmi 4	•			•			•			LL2 A = B C = D LL3 # Dyn-Mot V #	= S L T =
Sun Hemmi 80	•						•			LL2 A = B C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 80/1	•						•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 80/3	•						•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 81/1	•						•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 81/3	•						•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 82	•				•		•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 83	•				•		•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 84	•				•		•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 85	•				•		•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 86/3	•				15cm		•			Dyn-Mot V A = B CI C = D LL3 LL2] K	= S L T =
Sun Hemmi 86	•				15cm		•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 87/3	•				15cm		•			LL2 A = B CI C = D LL2 # Dyn-Mot V #	= S L T =
Sun Hemmi 80K	•			•				•		Dyn-Mot V A = B CI C = D LL3 LL2] K	= S L T =
Sun Hemmi 86K	•				•			•		Dyn-Mot V A = B CI C = D LL3 LL2] K	= S L T =
Sun Hemmi 152	•			•				•		K A = B CI C = D T	Θ R_{θ} = P Q Q' C = LL3 LL2 LL1
Sun Hemmi 153	•			•				•		L K A = B CI C = D T Ge	L Re P = Q Q' C = LL3 LL2 LL1
Sun Hemmi 154	•		•					•		DF P' = P Q CF CI S' = A D K	S T = T' Th Sh C = D L X
Sun Hemmi 255 Electrical Engineering	•			•				•		Sh1 Sh2 Th A = B TI2 TI1 SI C = D Θ	L K DF = CF CIF CI C = D LL3 LL2 LL1
Sun Hemmi 255D Electrical Engineering	•			•				•		Sh1 Sh2 Th A = B TI2 TI1 SI C = D DI Θ	L K DF = CF CIF CI C = D LL3 LL2 LL2

Rule (Manf, Model)	Elektro	Electronic	50 cm or 20 inch	25 cm or 10 inch	12.5 cm or 5 inch	Circular	Special Scales		Gauge Marks	Scales	Scales
							Well	Stock or Slide		Front	Back
Sun Hemmi 256 Electronics		•		•				•		L db Neper DF = CF CIF CI C = D LL3 LL2 LL1	A L = C SI TI = D lambda F
Sun Hemmi 266 Electronics		•		•				•		LL3 LL1 LL2 LL2 A = B BI CI C = D dB L S T	XL XC F r1 P = r2 Q L Cf Cz = L Z f0 l
Sun Hemmi 275D	•		•					•		L K DF = CF CIF CI C = D LL3 LL2 LL1	Sh1 Sh2 Th A = B TI2 TI1 SI C = D DI x Theta
Tavernier Gravert 2184 Electro	•			•				•		LL2 A = B CI C = D LL3	= Dyn-Mot V =
Tecnostyl 41/E Electro	•				•			•		cos A = B CI C = D cos	= S lg T =
Thornton Electrical	•			•			•			LL2 A = B C = D LL3 # Dyn-Mot V #	= S L T =
Thornton 3650										LL2 LL3 A = B CI C = D K # Dyn-Mot V #	= S L T =
Timisoara Politehnica	•			•			•			P K A = B BF,IC CI C = D LL3 LL2 LL1 \ L R # Dyn-Mot V#	= S ST T =
Unique Electrical	•			•					•	LL2 FAHR. CF = DF V CI C = D CENT. LL3	
Unis Electricien No.5	•				•			•		kW A = B C = D Dyn-Mot	
UTO 551 - U Darmstadt Electro 1A	•			•				•		Motor K A = B CI C = D Volt T S	= LL1 LL2 LL3 =
UTO 611 Richter Electro 22	•				•			•		Dyn-Mot V A = B CI C = D cos cos L	= S S&T T =
VEB Mantissa Electric	•			•				•		LL1 LL2 LL3 A = B L CI C = D P S T	Special Scales
White & Gillespie 432	•			•				•		LL L A = B Reciprocal C = D Cu LL	Sine Kw = H.P. F Tangent = V Dyn-Mot
Westec Electronics Slide Rule		•		•				•		Lr K 2phi A = B S T CI C = D L Ln ST	Special Scales
Woodworth (Electrical Wireman)	?									? (Lewis Institute, USA) mentioned in Ref 6	
Woodworth (Volt, amps, ohms and watts)	?									? (Lewis Institute, USA) mentioned in Ref 6	
Unknown Maker (Czech origin) No 11	•				10cm				•	L A = B CI C = D K	= S ST T =