

## Some Typical Slide Rules Under the Low Power Microscope

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*(The UKSRC is the United Kingdom Slide Rule Circle, website [www.uksrc.org.uk](http://www.uksrc.org.uk) where membership benefits and other resources are described.)*

### Introduction

A latent fascination with slide rules was revitalised two years ago when I dusted down my trusty Hemmi P280 which was used at high school in the mid 70s just before I could afford my first calculator. I also enjoy exploring the macro / microscopic world both natural and manmade, an interest which dates back to my early teens. Although amateur microscopy isn't as well known as amateur astronomy, it has a long history and continues to thrive with a range of clubs, publications and online resources.

My own collection of slide rules to date is very modest, currently sixteen models, and have only acquired some typical representatives of the major types and makers (mainly from after 1950). There are early signs of a collecting addiction though! Combining the two interests, I was curious as to whether the low power microscope at mags ca. 20X and possibly higher revealed any additional insights into the rules owned beyond that which a typical low power loupe up to ca. 10X could offer. In particular, construction details and do features at the microscopic level such as fineness of scales, quality of inking etc reflect on the subjective visual 'look' of each rule?

From literature searches to date, I'm unclear whether a stereo microscope or higher power loupes and pocket microscopes have an established role for slide rule study and would welcome comments. Otto van Poelje in his fascinating article 'Which Dividers to use on Gunter rules' (1), quantified the geometry of the needle points on different styles of dividers and remarked on how a stereo microscope can show the potential damage that different point styles may have on rules and their scales. A review of 29 'student' slide rules by 'Which?' in 1961 (8) included scale length and alignment measurements to 0.01 mm before and after rigorous tests which suggests they were using a microscope. A summary of my own tentative explorations with a stereo are presented below with some comments on what features of a low power microscope, lighting and image capture methods were found useful. Observations made are for my own examples of each model (a mix of new and used) and may not be representative.

### Flatbed scanner or low power microscope for recording fine detail?

The CCD design of flatbed scanners have sufficient depth of field (d.o.f.) to be widely used for excellent imaging of the whole or major parts of slide rules. My own Canon 5600F (CCD) has a d.o.f. of at least 10 mm compared with a Canon LiDE 60 (a typical example of the alternative CIS design) with a d.o.f. of barely 1 mm (ref. 2). The highest optical scan setting of a consumer flatbed paper scanner is typically 1200 dpi, this corresponds to a theoretical resolution of 0.021 mm (21  $\mu\text{m}$ ). This may be insufficient for recording fine detail on slide rules and potentially compounded by soft images if scans viewed at 1:1 because of the limitations of the scanner optics; the rule design and/or scanner size also often does not permit close contact with the scanner platen. In comparison, the optical resolution of a typical quality stereo microscope as used for the imagery below was ca. 7  $\mu\text{m}$  (at 20X) and increasing to ca. 3  $\mu\text{m}$  at the highest optical mag of 80X.



The slider detail of a Hemmi P280 shown above was scanned on a Canon 5600F at its maximum optical

1200 dpi, image crop at 1:1. This is a best case example for this scanner model because the slider was removed and it touches the platen, this will not always be possible. The image is soft and flat showing no fine detail of the images below taken using a stereo at typical mag of 20X.

### Low power microscope setup

My own stereo microscope is shown right which is used for more demanding biological subjects. A much simpler and cheaper set-up is likely to be equally suited for examining rules. Although a stereo provides comfortable binocular views and is particularly suited for 3D subjects, they can be more awkward than monocular optics for photographing flat subjects. Most stereo models with a third photo port use one of the eyepiece optical trains for photography which is typically at  $6^\circ$  to optical axis and therefore not ideal to give an in-focus photograph across the field of view of a flat subject. Presenting a flat subject at ca.  $6^\circ$  to photo port axis can correct for this (as shown right). A low power monocular could serve well without the need for such a correction for photo work. The commonest has a fixed mag of 20X, the mag I found most useful on my variable zoom stereo for rule studies. See Appendix for an example of a good value quality monocular microscope (typically £50 in UK).



### Equipment

Leica S8 1-8X continuous zoom stereo microscope (mag changer labelled 'M', focus 'F'), with 10X eyepieces, to give a total optical mag range of 10X to 80X.

This example has the flat base option, some bases are more raised, especially if a light source in base. I preferred to lay rules on the desk as shown, by rotating the optics around on the stand and counter balancing at rear.

Lighting, two types were used (light beams in red):

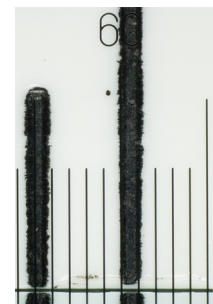
1) 144 LED ringlight (labelled 'R') clamped to base of stereo optics with intensity control and each quadrant switchable for modelling. (Control box labelled 'C').

2) 30W fixed intensity halogen focussed through a flexible light guide (labelled 'L'). (Dual light guide models are available.) The power supply sits at rear.

Camera: Sony NEX-5N body. White balance preset using custom control. 'Front Curtain Shutter' option set for vibration free imaging.

### Measurements

To explore whether measurements of scale features provided any insight into the different models, I measured the width of an inked scale mark at same point on each rule (the '1' of '10' on the A scale) and the height of the scale number '1' at that point. A method I preferred for rule study was to lay a microscope eyepiece reticule directly on the rule and read values with the aid of the stereo set at 20X. A useful reticule is the common 10 mm linear scale divided into 0.1 mm divisions (typically a thin 19 – 25 mm glass disc) which allowed repeatable and reliable measurements to ca. 0.02 mm (shown right on a Hemmi P280). The scale touches the rule and thus no parallax error. This method is independent of the mag setting of a continuous zoom model. This allowed a visual assessment of the typical width of a scale mark across its full length which was of value for slightly tapered marks or those with ill-defined edges; more accurate point to point measurements



typically used in microscopy didn't seem justified for this study.

The widths of inked cursor lines were also measured. Their fineness (some <0.1 mm) and the well defined edges of most, justified a more accurate method than for the scales. A reticule (100 divisions) in the eyepiece was calibrated with a 0.01 mm microscope calibration slide at the stereo's highest 8x magnification. The cursor lines subtended 5 – 13 divisions in the eyepiece field of view.

Given that a mix of new old stock and used slides from near mint to some wear were being measured, any wear in the markings could be a factor affecting measurements. After careful examination, the only rule where felt that wear (or cleaning) was masking original sizing was the oldest, the Faber 367 (see below).

### Lighting methods

A benefit of a microscope over a scanner or handheld loupe is that the large working distances allow modelling of the light for revealing any fine surface texture. The typical modern stereo ringlight used with individual lighting quadrants can give some useful modelling but the lights are still close to the stereo's optical axis. A flexible light guide can give more pronounced off-axis lighting by experimenting with the angle and height of the guide with respect to the rules. Much simpler and cheaper lighting approaches can also be used for directional lighting, e.g. a small torch on a stand (see Appendix).

As an example, of the rules owned, the Aristo 0903 Scholar (new) is noted for its 'raised' scales both in look and to the touch (3). Experimenting with different lighting methods with a stereo can reveal the nature of such surface features as illustrated below.



Aristo 0903 Scholar (new). '10' on A/B scale, 20X optical mag.

Left: LED ring lighting using top and bottom quadrants only. This was the flatter lighting used to measure scale widths but isn't ideal for modelling any surface detail.

Middle: LED ring lighting using one quadrant only from the right. This shows the raised ridges around scale marks better.

Right: Light guide placed to right and just above the rule. This stronger off-axis lighting shows the ridges best but at the penalty of more uneven lighting.

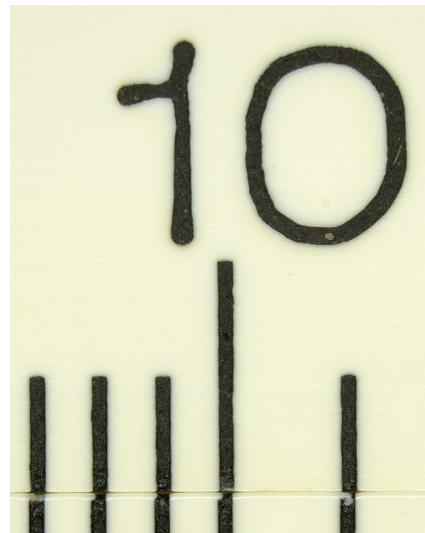
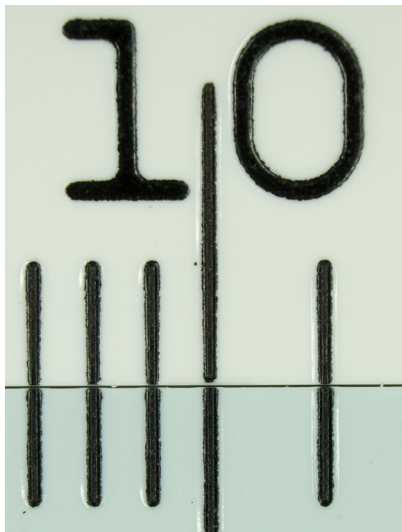
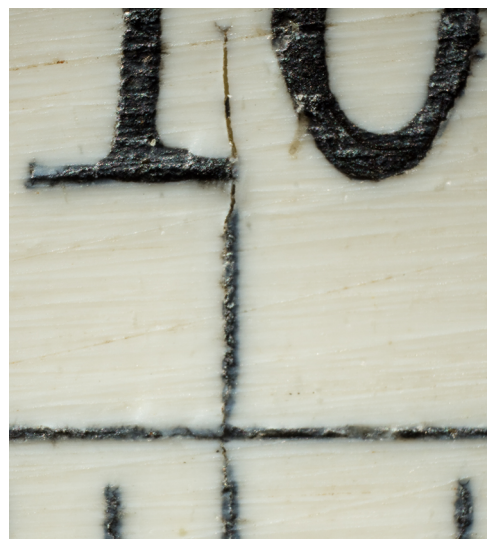
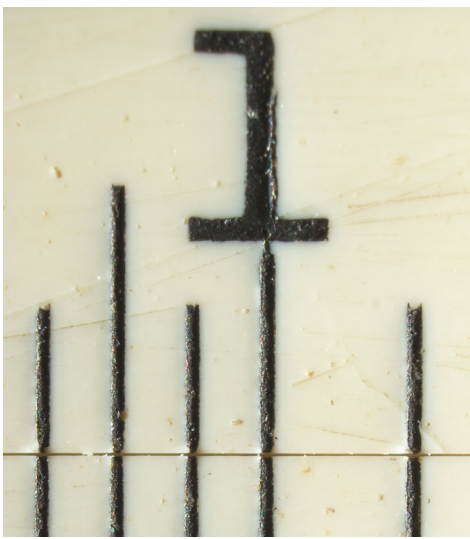
### A Selection of Images



An optical mag 20X was used for all the images below unless stated, but are not necessarily shown to the same scale depending on the features being shown. An LED ringlight was used unless stated. For clarity, scale bars aren't included as the features serve as their own scaling for these familiar rules.

Left below: Hemmi 257 'Chemical' rule. Plastic on bamboo. Scale width 0.10 mm. Low angled lighting with light guide shows no ridging of scale marks. Although the surface shows abrasion, this rule seems to have normal wear without damage to the scales. Compare with Faber 367 right.

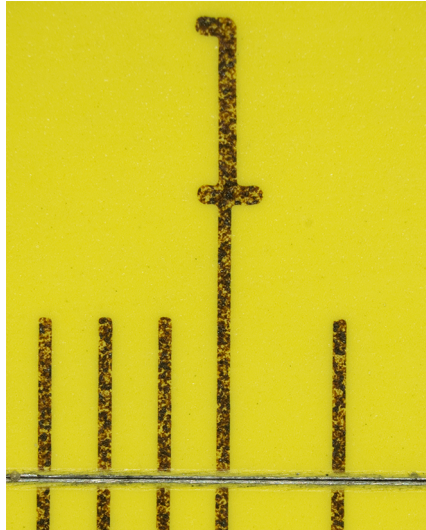
Right below: Faber 367 showing how the scale marks at the numbered scale positions extend beyond the inked area (as they also do for the Hemmi 257 left). To the eye the inked scales on this rule have a 'thinned' look (scale width in current condition ca. 0.07 mm, studies of the few unworn areas suggest originally 0.10 mm). The microscope shows deformation of the plastic stock face into the scale marks. Is this normal wear, or does this together with the visually heavily abraded surface, suggest too heavy abrasive cleaning?



Left above: Hemmi P280, plastic. Scale width 0.13 mm. The scale marks were densely inked and have rather irregular edges but they are not obvious visually and has contrasty scales to the eye.

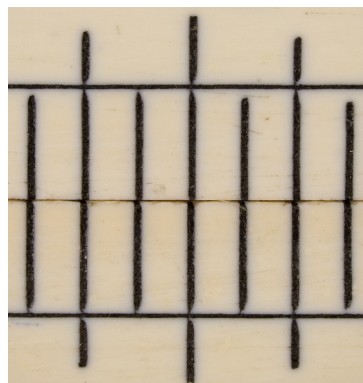


Right above: British Thornton AD150 Advanced, plastic. Scale width 0.13 mm. Well defined and densely inked scales, coupled with the largest fonts of the linear rules owned, contribute to a crisp easy to read 'look' to the scales. The '1' numbering is rather stylised of other rules owned. A microscope (or loupe) also draws attention to the range of font styles used by makers.



Left above: Pickett N902-ES ('new in box'). Scale width 0.13 mm. I only own this one example of a Pickett, so uncertain whether either the brown ink and/or the 'mottled' inking are characteristic, either new or after ageing.

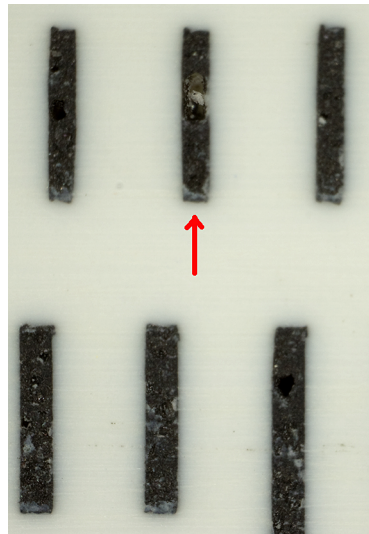
Right above: Blundell Harling 802 Log-Log. Scale width 0.15 mm (not shown). The annotated scales to the eye looked somewhat over inked, seen here on two of the scale indexes. It was most evident with the black inking. Of the linear rules owned, this model had the widest measured scale markings.



Left above: Faber-Castell 1/92 scale detail. Scale width 0.10 mm. Of the limited slide rules owned with so-called 'railroad track' type scales, this was the only example that featured crisply defined tapering of the scale bars as they meet the horizontal lines but not detected by eye.

Right above: British Thornton AD150 Advanced, underside of slider, image field width 5.3 mm. Optical mag 20X. To the eye there is a hint of surface structure. Under the microscope with low angled side lighting from the light guide, this structure is seen more clearly. Possibly the result of a milling operation on the

base?



Left above: Faber-Castell 2/83N. Scale width 0.13 mm. In my new example from the Faber-Castell shop, there is pitting in many of the black and red inked scale marks.

There are extensive whitish deposits, some inked, in the scales, especially along edges. Seen as encroaching material (arrowed). Not sure if there's incursion of the plastic of the stock into marks or deposits from the manufacturing process but gives a less contrasty 'look' to the scales of some other rules owned.

Right above: Faber-Castell 2/83N. As well as pitting, there is what looks like metal particles embedded in places, seen here in the top of the '3' (above the two black dots).

A microscope can focus through glass / plastic faces to allow closer study of features as well as take measurements without dismantling. The paint on my example of the Matsku KL-1 pocket watch shown left below is mottled which may contribute to its attractive matte look to the eye. The flexible light guide was used to give side lighting to emphasise this mottling. Scale width 0.12 mm.

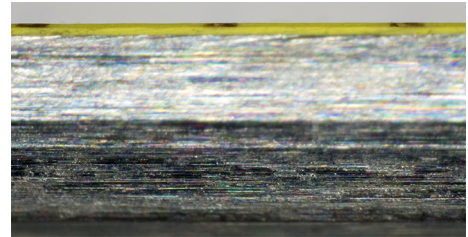
Also shown below is the base and tip of the tapered pointer (0.40 – 0.10 mm wide) of the KL-1 with stereo set at 50X.



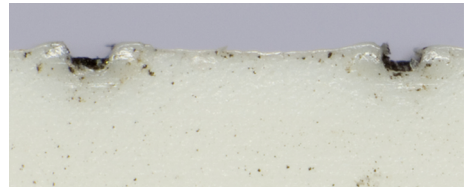
From Peter Hopp's extensive studies of pocket watch slide rules (5), my example of the Matsku KL-1 is a '3-screw' and 'thick pointer' variant. Peter shows in his article that some 'Sunshine' branded models have thinner pointers.

The four images below show edge-on views of sliders, to illustrate varieties of scale construction (all with stereo set at an optical mag of 50X).

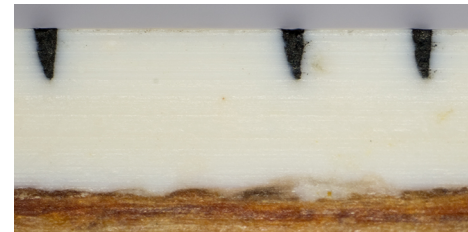
Right: Pickett N902-ES with 'Eye-Saver' yellow finish (seen as top yellow strip with surface inked scale marks). By calibrating the camera image field of view with a micrometer microscope slide and measuring the pixel depth with Adobe CS2's measuring tool, the even paint film was calculated to be 0.043 mm thick.



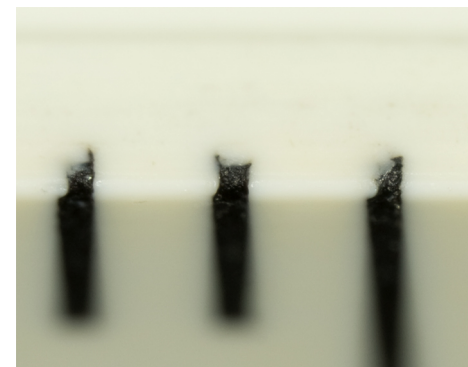
Right: Aristo Scholar 0903 showing its scale ridges. The profiles of the Aristo and Faber-Castell 1/92 below are illustrated with typical measurements in Dieter von Jezierski's invaluable book 'Slide rules. A Journey Through Three Centuries' (6).



Right: Faber-Castell 1/92 with the distinct 'V' shaped scale profile. The Faber 367 and Hemmi 357 showed similar features.

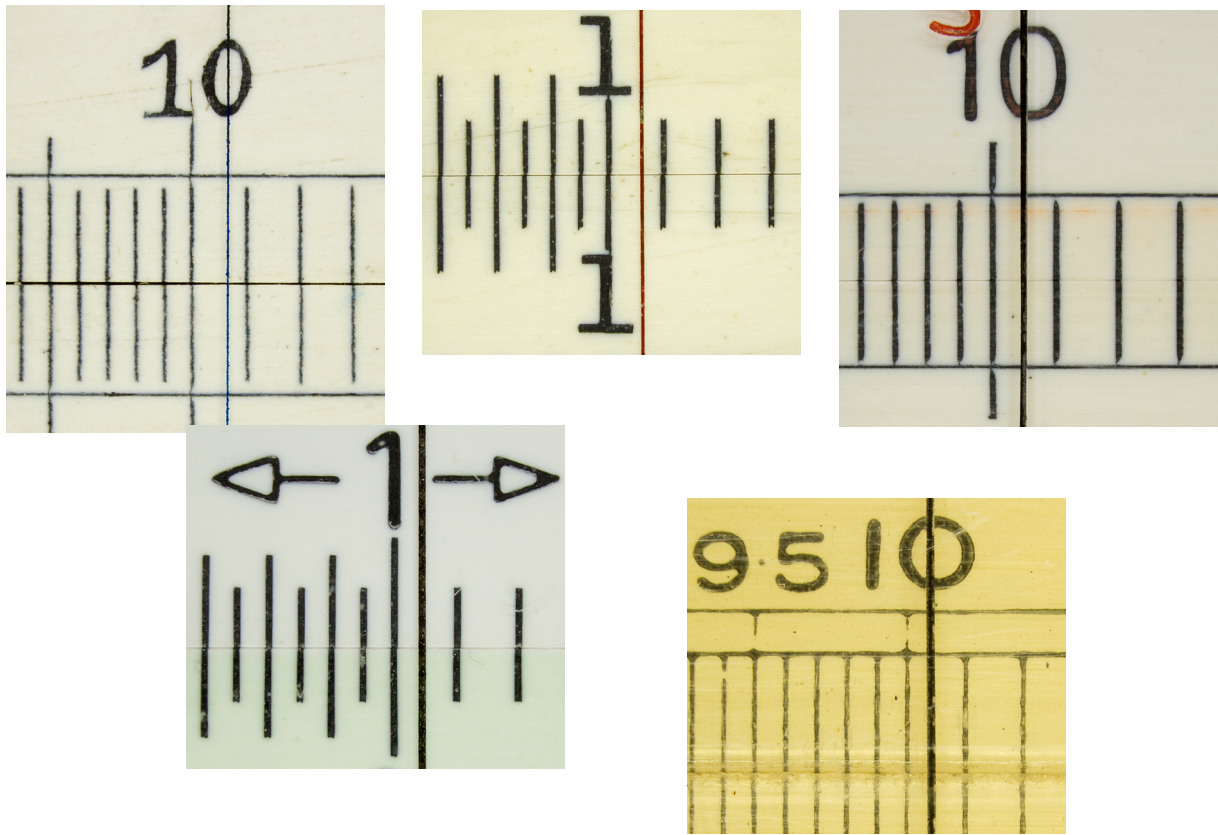


Right: British Thornton AD150 Advanced. A more angled view to show slider top and edge (at the expense of depth of field). The rectangular section scale marks are seen also with some incursion of plastic into the scales on slider edge, likely caused by normal use and wear.



The images below show how the relative widths of scale marks to cursor line vary between models possessed (quantified in later bar chart). The Faber 367 (left, with worn scales) and Hemmi 257 (middle), both have glass cursors and the cursor lines are noticeably thinner than their scale widths. For a glass cursor, the 257 cursor line has very well defined edges.





Most rules possessed with plastic cursors had lines of similar width to the scale marks e.g. the Faber-Castell 1/92 (upper right) and 2/83N (lower left). A marked exception was the Unique Log-Log (lower right), with a cursor line noticeably wider than its scales (and to a lesser extent also seen for the Aristo 0903).

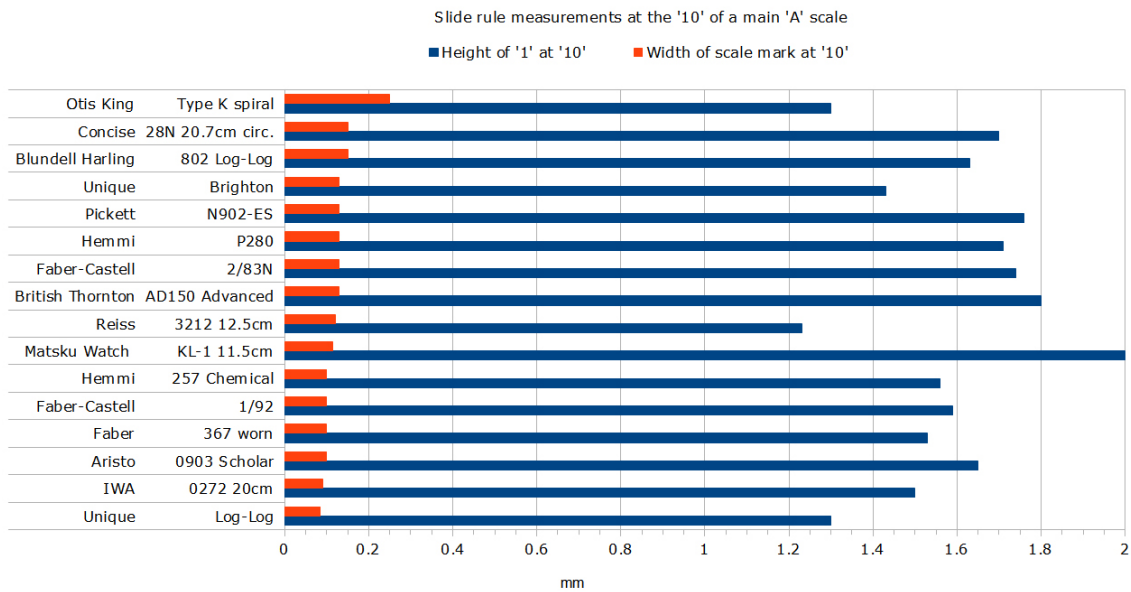
## Measurements

**1) Scale and font sizes:** A bar chart summarising the scale measurements is shown below in decreasing order of scale width. All rules are 10" / 25 cm linear models unless otherwise stated. For clarity, error bars aren't shown but features could be repeatedly measured to ca. +/- 0.01 mm (or visually averaged if uneven or tapered edges) using the reticule and using the stereo at 20X as aid. Although for all measurements presented it was trends and any extremes that were of interest rather than absolute values.

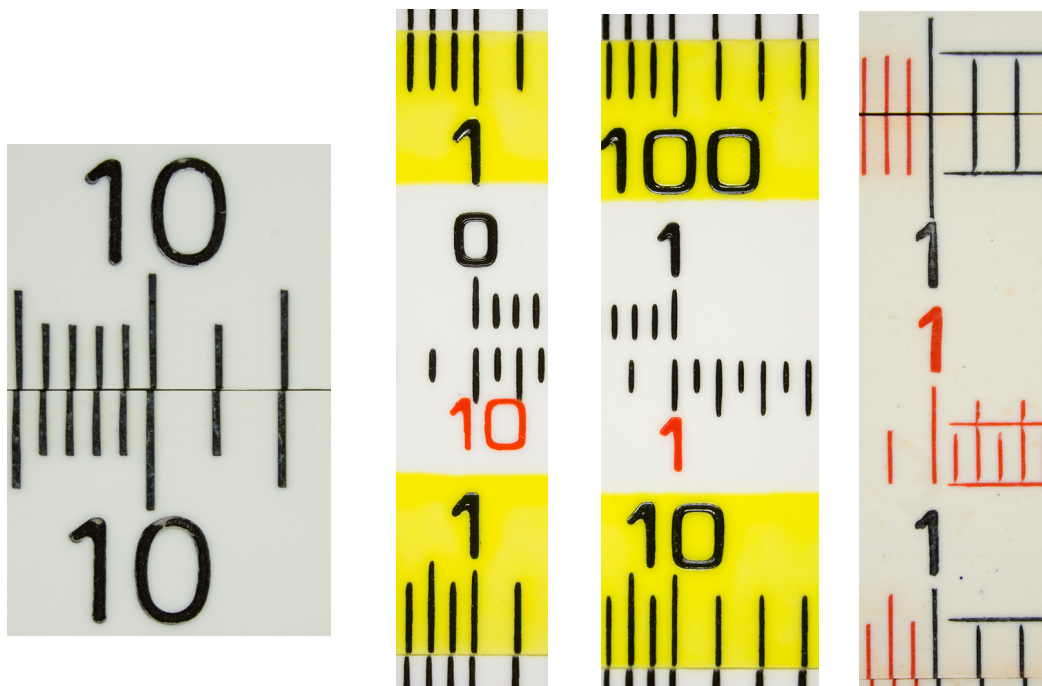
Of the '25 cm' rules owned, the width of the inked scale markings varied within a range of ca. 0.07 mm; from the narrowest at 0.08 mm (Unique Log-Log) to the widest at 0.15 mm (Blundell-Harling 802 Log-Log). Subtle variations within the main group were barely noticeable to the eye, but models compared towards both extremes were more distinct. For example, the Blundell-Harling's thickest markings did give a noticeable over inked and denser 'look' to the rule of those with thinner scales such as the Aristo 0903.

The scale width of the one 12.5 cm rule studied, the Reiss 3212 (0.12 mm) and the Matsku KL-1 watch (0.12 mm) both had values that were comparable to the larger rules. Of all the rules, the 20 cm IWA 0272 had one of the thinnest (0.09 mm) with a very crisp look to the scales. Overly thin or thick markings may affect a rule's use as well as likely limitations in what is practical to make for a given style of rule.

The number height of main scales for the 25 cm rules varied over a wider range, ca. 0.5 mm. The differences were particularly noticeable if the two extremes, the Unique Log-Log (the smallest at 1.30 mm) and British Thornton AD150 (the tallest at 1.80 mm) were viewed side by side. Of all rule types, the tall, thin (and to my eye, elegant) numbering on the Matsku KL-1 watch was distinctive. The number height of the Reiss 3212 12.5 cm rule was the lowest at 1.23 mm, presumably for clarity on a pocket rule.



**2) Scale alignment:** The rigorous review of 29 'student' slide rules in the May 1961 issue of the consumer products review magazine 'Which?' included full scale length and end of scale misalignment measurements accurate to 0.01 mm and noted that any misalignment greater than 0.02 mm was visible to the unaided eye (8, 10). This finely tuned ability of the eye to align marks is known as hyperacuity or vernier acuity as it is exploited in the use of verniers and is typically cited as over 5X better than its limit of visual acuity i.e. the ability to *resolve* finely spaced detail (7, 9). The 'Which?' review found examples of rules that had scale differences from less than 0.02 mm through to 0.1 mm; misalignment of 0.04+ mm becomes increasingly obvious to the unaided eye (see image of vernier at ref. 8 and Blundell-Harling below).



Left above: Faber-Castell 2/83N (new)  $W_2 / W_2'$  scale. With lefthand end perfectly aligned under the stereo, a misalignment of ca. 0.05 mm at righthand end was visible to the eye.

Middle above: Blundell Harling 802 (new). Scale misalignment was marked, especially the righthand end of A/B scales of ca. 0.08 mm. Perceived misalignment was exacerbated by the differential inking of scale marks between slider and stock.

Right above: Faber-Castell 1/92, lefthand end of A/B and C/D scales. Age and a slight twisting of wooden stock may be contributing to the lefthand misalignment of C/D scales of ca. 0.06 mm. My oldest rule, the Faber 367 also showed A/B scale misalignment of ca. 0.06 mm.

For the examples shown above, I inspected my own rules by eye and used a loupe to narrow down those models with some visual misalignment at either end of scale. The stereo microscope then allows this alignment to be measured (I aligned the '1' at left of A scale accurately to assess alignment elsewhere. (The full scale length measurements described by 'Which?' would require a travelling microscope.)

**3) Cursors:** For all rule types owned, the cursor widths varied over a range of ca. 0.11 mm as shown in the chart right (for duplex rules, the width for front face is given). The finest lines were on the two '25 cm' rules owned that had glass cursor plates, i.e. the Faber 367 and Hemmi 257. Unique had models with both one of the widest cursor lines and one of the finest; the Log-Log and Brighton respectively. Again, subtle variations within the main group were barely noticeable to the eye, but models compared towards both extremes were quite distinct.

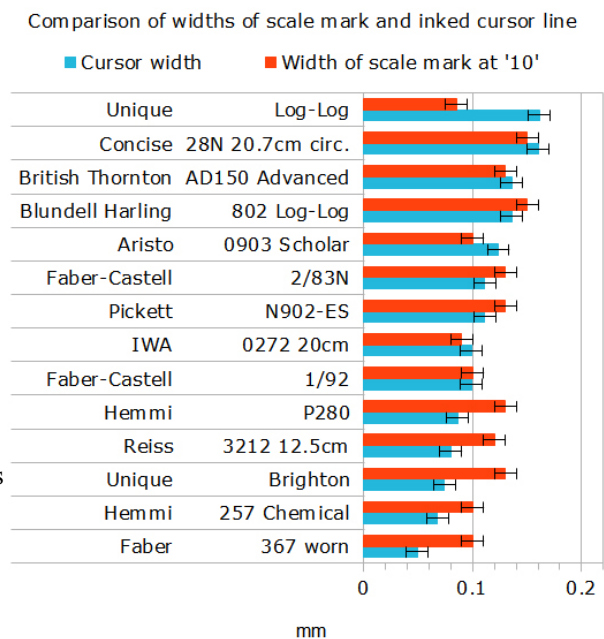
The chart right also illustrates that of the rules owned, there was no obvious correlation between the widths of the cursor line relative to each rule's scale marks. For many where the difference was slight this wasn't noticeable visually but was evident for the extremes; i.e. the Faber 367 and Unique Brighton where the cursors are thinner than the scale marks and the Unique Log-Log where cursor was thicker than the scale marks as illustrated earlier.

Of course, without studying multiple examples of a given model for the parameters measured above, variations could to a greater or lesser extent be manufacturing variations within a given model as well as differences between maker / model / vintage.

The stereo microscope at its highest mag also revealed different cutting profiles of the cursor lines, from a 'V' shaped notch, gentle curved depressions to straight sloping sides with flat bottom.

### Potential merits of the low power microscope over other optical aids?

There are a variety of quality handheld optical aids available with mags from 5X to 20X and beyond. I own and regularly use a selection as do no doubt many collectors to reveal the finer features of rules. Handheld aids are all considerably cheaper than a good quality stereo microscope and more portable. I'm fortunate to have access to a good stereo as part of my other interests but it's arguable if a stereo could be justified solely for slide rule studies. The benefits I found for the stereo over handheld optical aids were as follows.





1) Hands free and relaxed use of both eyes for extended studies with the much greater working distances than loupes allowing space for modelling the light. The four quadrant ringlight was extremely useful for this sort of work for quickly changing light orientation to bring out subtle surface features. Simpler directional lighting can readily be devised using e.g. small torches on stand etc (see Appendix).

2) Mags beyond 20x and higher are more suited for stereo studies than most handheld optical aids. These include studies of slider edges for nature of scale manufacture and details of cursor lines.

3) Measurements of finer features or scale alignment. Some handheld optical aids do have built in scales but many aren't suited for measurements of features at or below 0.1 mm. The eye has been shown to detect scale misalignment on slide rules of 0.03+ mm (8).

4) Studies of inaccessible features. A stereo can focus through e.g. glass / plastic faces of pocket watch and similar rules without dismantling to study features such as the scales and pointers, as illustrated for the Matsku KL-1 above or lines on cursor plates that don't wish to remove such as screwed duplex designs.

5) If photography of fine features is of interest a monocular or stereo microscope is valuable. A dedicated photo port on the microscope isn't vital as there are a variety of approaches to capture images, such as in-eyepiece microscope cameras or suitable consumer digital camera supported over an eyepiece. Handheld solely digital microscopes are also available that connect to the computer to view the image on the screen; a variety of models are widely available on eBay and elsewhere. Macro lens attachments for mobile phones and adaptors to attach mobile phones to microscopes also allow close-up imagery to be quickly shared.

### **Concluding remarks**

Is there any merit in studying the rules much beyond the capabilities of the unaided eye (7, 8, 9) or low power loupe? Exploratory microscopy studies of my own rules was certainly most enjoyable, informative and gave me an insight as a novice collector into the 'look' of a rule, the nature of their construction and if any flaws. Taking the detailed measurements was an interesting exercise, not as remarked for absolute measurements, but for spotting trends and extremes. The results can only be a 'snapshot' of the limited examples I own so can't comment on whether these type of studies have a wider value in learning about the rules in a collection. Although formal measurements did draw my attention to some features. For example, although the eye readily spots the overinking on my example of the Blundell Harling 802, it was only after completing the measurements that I appreciated that the IWA 0272 had one of the finest and crispest scales or noticed how fine the cursor lines were on the rules with glass plates with respect to scale marks of the broader lines on more modern examples with plastic cursors.

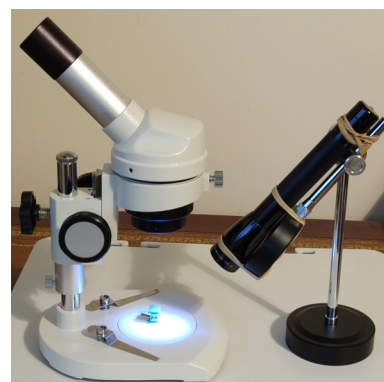
Such studies also raised queries for me on other aspects of slide rules. For example, does the fineness of the cursor line relative to the scale marks affect reading accuracy of the last significant figure; do the makers decide on a cursor line width relative to mark width and/or does the cursor plate material dictate limitations? A stereo microscope may also have a role in showing how different cleaning protocols are best for minimising rule damage. My example of the Faber 367 may have been cleaned with a too abrasive method as the deformation of the plastic into the inked scales did not look like normal wear of other rules owned.

Of the 'modern' rules I own, my two favourites overall in my modest collection for 'look', handling and use are the British Thornton Advanced AD150 and my original first slide rule, the Hemmi P280. But the Faber 367, the oldest rule I own and the Faber-Castell 1/92 with their beautiful craftsmanship are a delight to handle. For learning how to perform more complex calculations, the Faber-Castell 2/83N enjoys regular use.

### **Appendix: A simple low power microscope**

The design on the right (shown in use studying a record player stylus with simple directional torch lighting) is a widely available monocular with sturdy metal body and a fixed mag of 20X (2X glass achromatic objective with 10X eyepiece). I no longer have my example but believe should be suited for slide rule studies. As

remarked earlier, a monocular is better suited to photography of plane surfaces with a suitable camera than a stereo. Rotating the optical head around on the support and with a weight on the base would allow rules of any size to be laid on a desk for study. This model is recommended by the Royal Microscopical Society (UK) for first time young microscope users but suitable for any age as 20X is ideal for exploring the world around us without the sample preparation required of a compound microscope; so it could have a dual role in the family. Typically £50 from UK microscope dealers. The versatility of this design for both visual and photographic use is described in ref. 4 below.



The traditional compound microscope typically seen in use in labs and schools may have both the option of lower power objectives and a module for lighting and studying opaque subjects, but their much smaller working distances and small stages primarily intended for microscope slides make them less suited for regular slide rule studies.

### Acknowledgements

Thank you to Peter Hopp for encouraging me to share my microscopy explorations of slide rules and for kindly informing me of reference 10'. Any errors in the article are solely mine.

Thank you to Rod Lovett for his invaluable website <http://sliderules.lovett.com/> allowing research of the slide rule literature.

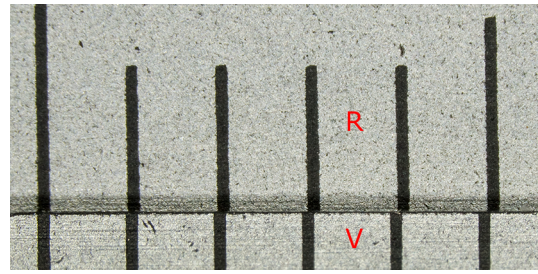
### References and Notes

1. van Poelje, Otto E., *Which Dividers to use on Gunter rules*, UKSRC Slide Rule Gazette, 2008, Autumn, Issue 9, pp. 65-71.
  2. Walker, David, *Comparing the depth of field of two types of flatbed scanner, a CIS and a CCD model*, 'Micscape Magazine', January 2013, <http://www.microscopy-uk.org.uk/mag/artjan13/dw-scanner-type.html> accessed 22/05/2013.
  3. Mosand, John, *The Aristo Scholar Series*, Journal of the Oughtred Society, 2005, vol. 11, no. 1, pp.63-64.
  4. Walker, David, *Getting started with a low power microscope*, 'Micscape Magazine', December 2005, <http://www.microscopy-uk.org.uk/mag/artdec05/dwmicro20x.html> accessed 22/05/2013.
  5. Hopp, Peter M., *It's all in the detail .... More about Russian pocket-watch slide rules*, UKSRC Slide Rule Gazette, 2012, Autumn, Issue 13, pp.103-107.
  6. von Jezierski, Dieter, *Slide Rules. A Journey Through Three Centuries*, Translated Second Edition, 2000, Astragal Press, Fig. 17A, p.31.
  7. The visual acuity of the unaided normal human eye is typically cited as just being able to *resolve* black and white lines ca. 0.1 mm apart at a viewing distance of ca. 30cm, e.g. in the article *Visual Acuity of the Human Eye* at the link below, the acuity limit is cited as 0.00349 inches at 12 inches, i.e. (0.09 mm at 30.5 cm.). <http://www.ndt-ed.org/EducationResources/CommunityCollege/PenetrantTest/Introduction/visualacuity.htm> accessed 05/06/2013.
- Visual acuity is likely less relevant to slide rules than what is termed 'hyperacuity', i.e. the eye's ability to align fine black lines or spot their misalignment. See reference 8.
8. *Slide Rules, Which?*, May 1961, pp. 116-119. Published by the Consumers' Association Ltd in the UK. (Republished as part of ref. 10.)
- A rigorous review of 29 'student' models from 11 European manufacturers. The tests included 10 000 slider and cursor cycles at 20 cycles a minute (not all rules survived!). They measured the full length of A-D scales to 0.01 mm before and after tests which would likely require a form of travelling microscope. Scale alignment between slider and stock at both ends was also measured which could use either a static or travelling microscope. They noted to what extent a difference in scale alignment was visible to the unaided eye as follows (models fitting within all these groups were found and stated):
- 0.02 mm or less – 'no visible differences'
  - 0.03 mm – 'just visible'
  - 0.05–0.06 mm – 'visible as slight errors'

0.1 mm – 'distinct errors'

The eye's 'hyperacuity', also called 'vernier acuity', is typically cited at 5-10x greater than its visual acuity to resolve detail (9).

A vernier caliper reading to 0.02 mm is a good demonstration of the alignment categories noted by 'Which?' in their review. A close-up of a Draper Expert caliper with scale mark widths comparable to slide rules is shown right. ('R' – 1.0 mm scale divisions, 'V' – vernier reading to 0.02 mm). From left to right the scale and vernier marks are offset from 0 to 0.1 mm in 0.02 mm increments. On this magnified view, the 0.02 mm offset is just visible but not to my unaided eye (in isolation to other marks).



This also illustrates the demands placed on the slide rule manufacturer even for their cheapest range. A misalignment of 0.04+ mm on a 25 cm rule is becoming noticeable to the user as it is over third of the width of a typical slide rule mark.

9) Bach, Michael, *Visual Acuity – Hyperacuity*, web page includes an interactive demonstration which allows a user to compare their own visual acuity and hyperacuity. [http://www.michaelbach.de/ot/lum\\_hyperacuity/](http://www.michaelbach.de/ot/lum_hyperacuity/) accessed 15/06/13.

10) Soole, Peter, *Troubles at Blundells*, UKSRC Slide Rule Gazette, 2003, Autumn, Issue 4, pp. 57-61.