Sikes's Hydrometer and Related Slide Rules

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Introduction

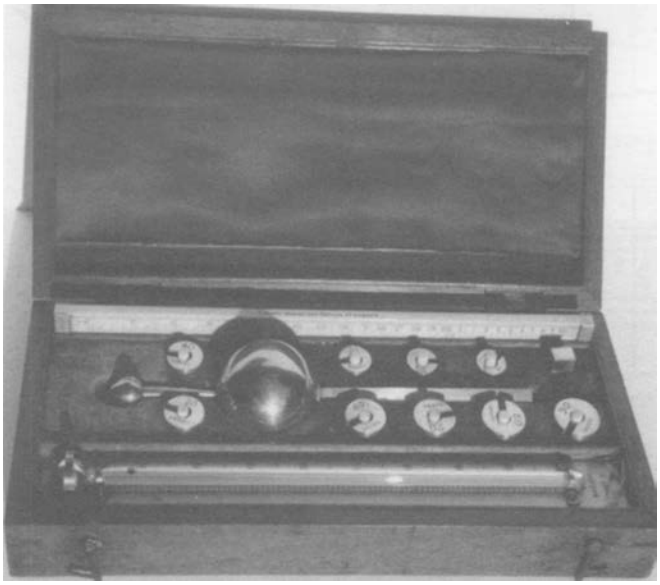

Figure 1. The Sikes's Hydrometer kit.

My attention was drawn recently to an ivory slide rule displayed in the window of an antique shop in the center of Brussels.

I decided to enter the shop to examine that object and of course to check the price. The dealer drew my attention to the fact that the slide rule was part of a kit including a float, some weights, a thermometer, and the slide rule. The rule was not new to me (I have a couple of such rules in my collection, of different materials and sizes) but the assemblage of very nice objects in a beautiful case, marked "Sikes's Hydrometer", finally convinced me to spend some money on it.

Hydrometers have been used for many hundreds of years to measure the strength of alcohol, largely for tax purposes. For slide rule collectors who are interested in these devices, Sikes's Hydrometer is probably the most common alcohol hydrometer, though it should be noted that only "deluxe" sets come with either one or two slide rules.

The purpose of this article is to present Sikes's Hydrometer, its accessories, and the use of both the hydrometer and associated slide rules.

This article was written by a slide rule collector with no previous idea about the strength of spirits, alcohol chemistry and the use of the associated side rules.

Some Definitions

In order to make clear what follows, some definitions and preliminary explanations are useful.

Hydrometer An instrument for measuring the density or relative density of liquids. The common type consists of a weighted bulb with a graduated slender stem; the apparatus floats vertically in the liquid being tested. In liquid of high density a greater length of stem is exposed than in liquid of low density.

Spirit The liquid containing ethyl alcohol and water that is distilled from an alcoholic liquid or mash.

Proof spirit Ethanol containing 49.28% alcohol by weight, or 57.10% by volume, and having a relative density of 0.91976 at 51°F (10.6°C). [USA equivalent: 44% alcohol by weight and 50% of alcohol by volume and having a density of 0.7939 at 60°F (15.6°C).]

Proof spirit, degrees The number of degrees under proof is the volume percentage of water in a solution regarded as containing proof spirit and water. Spirits are usually sold on the basis "30° under proof" or "70° proof" both of which mean the same. Such spirit contains $57.1 \times 70/100 = 39.97\%$ alcohol by volume. [NB: in the US, alcoholic strength is indicated by a number that is twice the percent by volume of alcohol present; whisky of 90 proof is 45% alcohol.]

The Customs and Excise act of 1952 (UK) defined the spirits of proof strength as follows: "Spirits shall be deemed to be at proof if the volume of ethyl alcohol contained therein, made up to the volume of the spirits with distilled water, has a weight equal to that of twelve-thirteenths of a volume of distilled water equal to the volume of the spirits, the volume of each liquid being computed as at fifty-one degrees Fahrenheit."[1]

History

Spirit of proof strength was the technical standard by which strength was measured until January 1, 1980. Hundreds of years ago proof spirit was defined as the weakest solution of alcohol that would fire gunpowder when brought into contact with it and ignited. Spirit of this strength was held to have been "proved".

The important dates relating to the hydrometer's history are:

1675 First recorded use of hydrometers

1791 USA Act that specified the use of the Dicas Hydrometer

1740 Clark's Hydrometer

1816 Hydrometer Act had a competition to find the most useful/accurate hydrometer; The competition was won by Bartholomew Sikes, an itinerant customs officer

In the 1740s the Custom and Excise and the London distillers began to use Clark's hydrometer. A more ac-

[1] In other words, proof spirit meant that the spirit, at a temperature of 51°F, weighed exactly 12/13 of a volume of distilled water equal to the volume of the spirit.

curate version by Bartholomew Sikes was enshrined in legislation in 1816 with the "Sikes Hydrometer Act" and remained the legal standard until 1907 (although Sikes's Hydrometer remained in common use until 1980).

Components of the Sikes's Hydrometer Kit

Hydrometer kits can be found in which all components were from one manufacturer, or in which they were supplied by a variety of specialist manufacturers to retailers who added their name to the case. Generally all the components of the hydrometer (i.e., the float and weights) would have come from one manufacturer, the thermometer from a second, and the slide rule from a possible third manufacturer.

The following description relates to the kit shown in Figure 1 (the Sikes's Hydrometer from my collection).

Dating The estimated hydrometer fabrication date is circa 1850.

The hydrometer The hydrometer consists of a spherical ball (a bulb) and an upper stem with markings and a lower stem that takes adjusting weights.

The all-brass float Similar to the glass hydrometers used today, the float is provided with a bulb that can be weighted down to calibrate for various strengths of alcohol solutions. The slender stem is graduated with 10 main increments ranging (downward) from 0 to 10, with intermediate marks at intervals of 0.2.

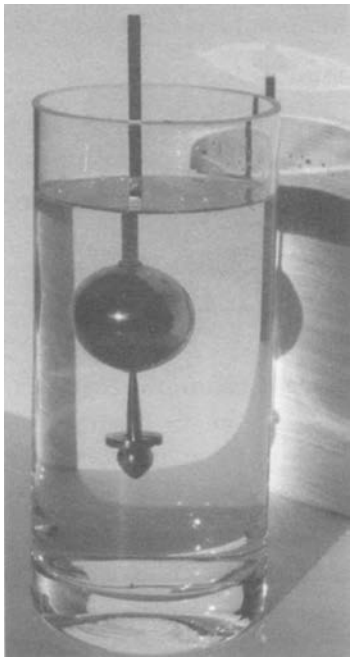

Figure 2. The hydrometer.

The weights The float is weighted down with various brass weights to take a gravity reading of various spirits. The ten principal divisions of the upper stem are completed by the separate application of nine weights in succession. The standard weight set supplied in the kit is the top calibration (cubic) cap and nine weights labelled 10, 20, ...80, 90. The calibration of 10 corresponds to the 10 graduations of the stem (the hydrometer in figure 2 is provided at the bottom with a #60 weight). The calibration cap is exactly 1/12th the total weight of the hydrometer float and is used to calibrate the hydrometer in distilled water at 51°F.[2]

It is important to note that along with the float stamp, each weight is also stamped with the serial number of the hydrometer (stamped 25929 in this example). This ensures that the hydrometer was used with the weights it was calibrated for.

The thermometer The mercury thermometer with an ivory back is calibrated in degrees Fahrenheit from 25° (−3.9°C) to 108° (42.2°C), and is marked "J. LONG LONDON".

The slide rule The kit includes a "comparative rule" calculating comparative values, taking stocks and reducing spirits from one strength to another. The ivory slide rule has a dimension of 227 mm by 33 mm by 5 mm and is marked "LOFTUS MAKER, 146 OXFORD ST LONDON".

The case The kit is supplied in a polished mahogany case with ivory inlay on top bearing the maker's name "SANDERS & SONS; 228 HIGH HOLBORN, LONDON".

Figure 3. The ivory inlay on the case.

The Slide Rule Relating to Spirits

The slide rule supplied with the above described Sikes's Hydrometer is a so-called "comparative rule".

This slide rule has a double function. The "comparative value side" facilitates the calculation of the value of a spirit as a function of the strength. The "reducing side" facilitates the calculations for the reducing of the spirit strength.

Another kind of slide rule (not supplied in this kit) but supplied in other similar kits is the "proof rule". This slide rule calculates the strength of spirits as a function of the indication read on the hydrometer.

More detailed explanations are given in the following sections.

The Comparative Slide Rule

This double-sided slide rule has two functions:

On the "comparative value side", by placing the slide so that a known strength is facing a (money) value, the rule gives, opposite to every other strength, the value in proportion thereto.

[2]Since the proof spirit weighed exactly 12/13 of a volume of distilled water equal to the volume of the spirit, after addition of a weight of 1/12th of the float, the float should stick out of the distilled water at the same level as in a proof spirit without that cap.

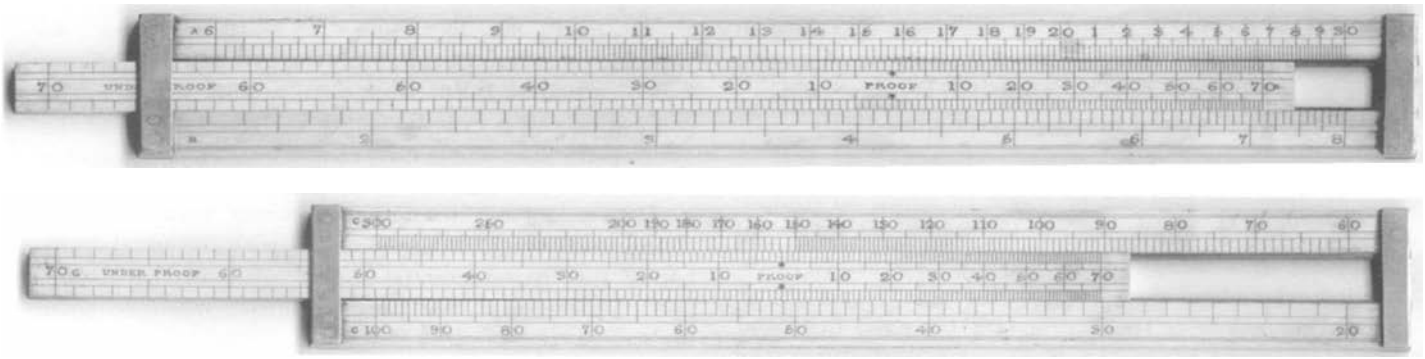

Figure 4. The comparative slide rule.

On the "reducing side", starting from a given number of gallons and strength of spirits, the rule is giving the number of gallons to be made up at any given strength.

The comparative slide rule shown above is the ivory slide rule supplied with the kit.

The formulæ and scales

Without a users' manual it was difficult at first to understand the scales and operation of the slide rule. I was also disturbed by the fact that the scales had no 1, 10 or 100. However, after some trial and error, I was surprised to discover the simple formulæ that serve as the basis for the comparative rule.

The formulæ are:

For the comparative value side:

(Strength of B) × (Value of A) = (strength of A) × (value of B)[3]

For the reducing side:

(Strength of A) × (volume of A) = (Strength of B) × (Volume of B)

The scales For both sides the slide scale ranges from "70° under proof" to "70° over proof".

For the comparative value side the top scale (A) denotes shillings from 6 to 30; the bottom scale (B) from 1 shilling and sixpence to 8 shillings (there is thus an overlap between the two scales).

For the reducing side the top scale (C) denotes gallons from 300 to 60; the bottom scale (C also) from 100 to 20 (there is thus an overlap between both scales).

The (logarithmic) construction of the scales.

For the comparative value side:

The actual distance "X" between the "6" and the "30" is 200 mm; what is the "module length L0"[4] of that slide rule?

L0 × (log 30 - log 6) = 200
L0 = 200/(1.4771 - 0.7782)
L0 = 286 mm

Any other distance "X" from "6", for a given value "x", may now be constructed from the formula

X = L0 × log x - L0 × log 6

For "x" = 15 ⇒ X = 286 × (log 15 - log 6)
[or 286 × log(15/6)]
X = 286 × (1.1761 - 0.7782)
X = 114 mm (which is verified)

The slide scale is constructed following the same system and with the same module length L0, but the strength under proof should be converted to 100 - strength (30 under proof has to be considered as 70) and the strength over proof should be considered as 100 + strength (30 over proof has to be considered as 130).

For the reducing side

The top and bottom scales (on the stock) are inverted scales. The slide is identical on both sides.
The actual distance between the "300" and the "60" is 200 mm.

L0 × (log 300 - log 60) = 200
L0 = 200 / (2.4771 - 1.7782)
L0 = 286 mm[5]

Practical Example Number 1.

The schematic shown in Figure 5 shows how the "comparative" side of the rule is used to solve the problem described below.

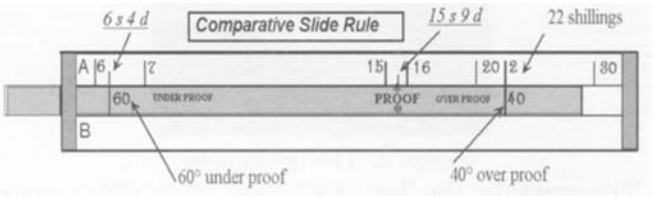

Figure 5

Known data: Spirit strength: 40° over proof (on slide scale) value : 22 shillings (on A scale, facing the 40, on the right of the "PROOF" mark * on slide)

[3]For the use of the formula, it has to be noted that (strength = 100 - strength under proof) and (strength = strength over proof + 100).

[4]By definition, in case of common logarithms, the "module length" is the physical length of one cycle (from 1 to 10, 10 to 100, ...).

[5]This result, which is the same on the *comparative value side,* is not surprising since the two starting values 300 and 60 are both a multiple of ten of the figures 30 and 6 on the *comparative value side.*

Unknown data: Value of a proof solution?

Solution: Facing the * (proof) on the slide scale, the answer is a value of 15 shillings 9 pence.

Checking: (100+40) × 15.75 ≈ 100 × 22 ≈ 2200.

Similarly, as for any slide rule, opposite to every other strength, the value is found, on the A scale, in proportion thereto (e.g. "6 s 4 d" is facing 60° under proof).

Practical Example Number 2

The schematic shown in Figure 6 shows how the "reducing" side of the rule is used to solve the problem described below.

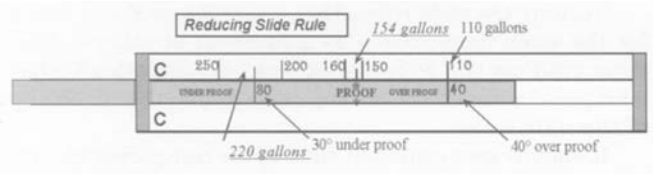

Figure 6

Known data: Volume of spirit : 110 gallons (on top C scale)

Strength: 40° over proof (on the right side of "proof" on slide scale)

Unknown data: Number of gallons (volume) to be made up in order to reduce the solution to a proof solution?

Solution: Facing the * (proof) on the slide, the answer is a volume of 154 gallons on the C top scale

Checking: (100+40)×110 = 100×154 = 15400

Similarly, as for any slide rule, opposite to every other strength, the volume is found on one of the C scales in proportion thereto (e.g., 220 gallons is facing 30° under proof).

The Proof Slide Rule

This slide rule calculates the strength of spirit for a given solution when the temperature is provided (as measured by the thermometer supplied with the kit) and the reading on the upper stem of the hydrometer (after the appropriate weight is added). This slide rule replaces the strength tables and is not necessarily part of the Sikes's Hydrometer kit.

The "duplex" double–sided slide rule shown in Figure 7 is one from my collection and was most probably supplied with Sikes's Hydrometer kits. This boxwood slide rule, 227 mm by 34 mm by 5 mm (about the same dimensions as for the ivory comparative slide rule), is marked "FARROW & JACKSON MAKERS LONDON".

The formulæ I have explored the relationship between strength vs. indication as a function of temperature. The following graph, Figure 8, shows the data from a "Sikes's Hydrometer table" and the calculation of the "best fit" polynomial third degree line and formula. Frankly, I do not understand this relationship and I would welcome an explanation.

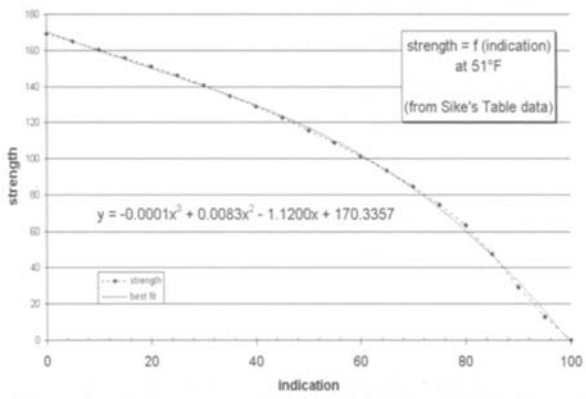

Figure 8. Plot taken from a table of Sikes.

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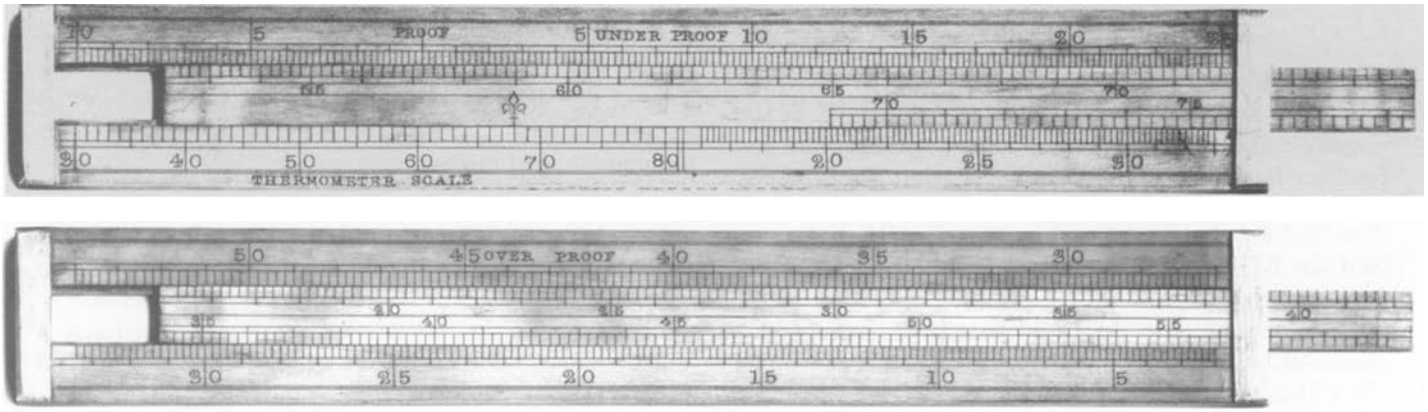

Figure 7. The proof slide rule.

The scales Looking at the first side of the slide rule, the bottom scale on the left part of the stock is "the thermometer scale" ranging from 30°F (−1.2°C) up to 81°F (27.2°C). On this particular slide rule, the range of the thermometer scale is less than the range of the thermometer in this kit; it is not known why. The bottom right is an extension of the top part.

The upper scale on the stock is the scale with the spirits' "strength" with, as usual, the under proof and over proof divisions, ranging from "10° under proof" to "25° over proof".

The slide scale is the "indication" scale. The indication is the data read (after correction by the added weight) on the upper stem of the hydrometer. The index is stamped on the slide by a "fleur-de-lis"; it is not known why.

On the other side of the slide rule, the "strength" scales and the "indication" are respectively extended on both sides of the stock and on the slide.

The construction of the scales

Again I tried in vain to find out the scale design logic. The "indication" and "strength" scales are obviously not logarithmic scales. They would appear to be quadratic scales [$X = L0 \times f(x)$ where $f(x) = ax^2 + bx + c$]. An explanation relating to the correct formula and its demonstration would be welcome.

Practical Example Number 3

Please refer to the schematic below (Figure 9) of the proof slide rule which has been set to correspond to Figure 7.

Known data: Temperature of the spirit : 68°F (20°C) (on the thermometer bottom left scale).

Indication on the hydrometer: 65 on slide scale [from a weight of 60 + 5 read on the stem at the surface of the spirit].

Unknown data: Spirit strength?

Solution: Setting the "fleur-de-lis" index facing the 68 on the thermometer scale, the answer strength of 12.6° under proof is facing, on the upper scale, the indication of 65 on the slide.

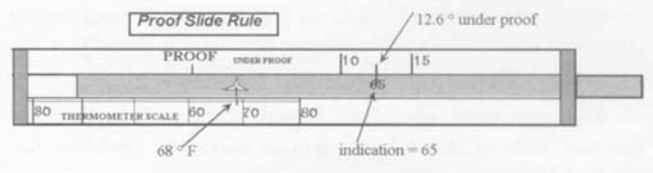

Figure 9. A practical example.

Turning the slide rule, other strengths could be found for the same temperature as a function of other indications read on the hydrometer; e.g., a strength of 29.8° over proof is found on the top scale facing the 35 on top of the slide scale.

It should be mentioned that when comparing the results with some copies of old tables, I have found slight differences in the results (an error of ±3%) which is within expected accuracy for such equipment.

Conclusion

I hope that the descriptions and practical examples presented will help collectors to better understand the use of spirits-related slide rules in their collection. Since the slide rules described are closely related to Sikes's Hydrometer, I hope also that the description of this particular hydrometer kit is helpful in setting the comparative and proof slide rules in their proper context.