# NESTLER

# Directions for Use

of the

# Slide Rule "Oilrule"

System

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The slide rule "Oilrule" was especially developed for the requirements of the oil industry. It is as useful for the engineer as for the chemist and the merchant. Its handy construction saves the consulting of voluminous tables which is particularly troublesome in conferences. This slide rule is provided with the standard scales for multiplication, division, calculations of proportions, powers and percentage, and for solving of simple equations. Special scales serve for converting English measurements into metric ones and vice-versa for length, area, and space measurements, weights, gravities, pressures, temperatures, heat units and viscosities as they occur in oil calculations. The computing accuracy is satisfactory for the most practical requirements and corresponds nearly to that of a logarithm table of 4 decimal places.

The "Oilrule" bears the following scales from top to bottom:

**Front Side**

Stock. top: . . λ°F scale to correct the gravity per degree Fahrenheit.
°F scale } both in correlation to each other and to the
°C scale } x-scale
$x^2$ Scale

Slide: . . . . . . $x^2$-scale
Inverted or reciprocal scale (1 : x)
x-scale

Stock. below: x-scale
d 15°C scale for the specific gravity at 15°C
log x/°API scale giving the common logarithm for the correlated figures of the x-scale and multiplied by 10 serving at the same time as °API scale correlated to the specific gravity scale.

λ°C scale to correct the specific gravity per centigrade.

**Rear Side**

Stock. top: . . Explanations of the indices used in the equations below.

Slide: . . . . . . Scale for the Walther-figure W (log log $\nu + 0{\cdot}8$)
Centistoke scale
Engler degree scale
Scale in Universal Saybolt seconds
} All four inter-related.

Stock. below: Equations for computing unknown viscosities from known ones, for the slope m of the viscosity straight line, the V. I., for computing oil blends and the required percentages of components.

The "Oilrule" is made of white dimensionally stable material which is light- and heat-proof (excessive heat must naturally be avoided). When the slide rule is not used it should be covered with the cardboard box furnished with each slide rule in order to avoid damages. Pencil notes can easily be removed by a good eraser. Use of an indelible pencil has to be avoided. Cleaning is suitably carried out by using finest steel-wool, clean oil free of acids; pure vaseline or pure naphtha (no motor spirit) may also be used.

## Application of the Slide Rule

It is presumed that the computing work with the scales x, $x^2$, $\frac{1}{x}$ and log x is known. These scales are, therefore, not explained here.

### 1) Conversion of English Measurements into Metric and back

The conversion is carried out with the marks in the inverted scale:

| | | | |
|---|---|---|---|
| l. t. | equal | 1 Long Ton | = 1·0160 metric tons |
| bbl | ,, | 1 Barrel (US) | = 0·15898 cubic meters |
| BTU | ,, | 1 British Thermic Unit | = 0·252 kcal (kilogram calories) |
| in | ,, | 1 Inch | = 2·540 centimeters |
| ft | ,, | 1 Foot | = 0·3048 meters |
| gal | ,, | 1 Gallon (US) | = 3·785 liters |
| lb | ,, | 1 Pound | = 0·4536 kilograms |
| or | equal | 1 Imperial Gallon | = 4·543 liters |
| lb/in² | ,, | 1 Pound per Square Inch | = 0·07031 kilograms per square centimeter |
| s. t. | ,, | 1 Short Ton | = 0·9079 metric tons |

Multiplication is done by placing one number on the lower x-scale against the other on the 1:x inverted scale using the runner and reading the result at the end of the inverted scale on the x-scale. Another multiplication can follow instantly without new setting of the slide as the following example shows:

> Conversion of 435 barrels oil of the gravity 0·810 into metric tons: By means of the index line the "bbl" mark is opposed to the figure 435 of the fixed x-scale. Below the "1" of the slide the number of cubic meters is found, in this case 69·2. The result is found below the "0·810" of the x-scale of the slide, in this case 56·0 metric tons. (Sometimes the slide has to be shifted by unity when the result cannot be read directly).

Division is correspondingly carried out by multiplying with the reciprocal figure, viz. by bringing the (left or right) "1" of the slide in line with the figure to be converted and by reading the result below the pertinent conversion mark with the index. Also here a double division can be carried out without moving the slide a second time as the following example shows:

Conversion of 37 metric tons oil of the gravity 0·920 into barrels: The "0·920" of the slide x-scale is opposed to the mark "37" of the fixed scale yielding 40·2 cubic meters. Then opposite to the "bbl" mark the result of 253 barrels is found on the fixed scale, when following the index line on the runner.

In addition the mark "KOH" on the inverted scale corresponding to the equivalent weight of potassium hydroxide is to be seen serving for the well known computation of neutralization and saponification numbers.

### 2) Temperature Conversions

a) Degrees Fahrenheit are converted into centigrades or viceversa by direct transition from one scale to the other along the index line, e. g. 500°F = 260°C or minus 40°C = minus 40°F (The changing scale graduation has to be observed since the two scales diminish logarithmically).

b) Conversion to absolute temperatures (°K): Fahrenheit degrees or centigrades are converted into degrees Kelvin by transition from the °F or °C scale along the index line to the fixed x-scale where the corresponding absolute temperature is found (0°K = 273°C), e. g. 227°C = 500°K or 140°F = 333°K.

c) Finding of the logarithm of the absolute temperature: The logarithm of the absolute temperature is found by transition along the index line from the °F or °C scale to the log x-scale, e. g. for 100°F the log T is equal to (2.)4925*) and for 100°C equal to (2.)5717*). These values are needed in computing viscosities by the Walther-Ubbelohde equations.

### 3) Specific Gravity Conversions

The conversion of a specific gravity into degrees API is carried out by transition along the index line from the d 15°C-scale to the °API scale or viceversa, e. g. 41·0 °API = 0·820 or 0·946 = 18·0 °API. The position of the scales is corrected by the difference in measuring at 60°F referred to water of 60°F and measuring at 15°C referred to water of 4°C. This difference amounts to 0·0005 units maximum.

### 4) Correction of the Specific Gravity not Determined at 15°C (60°F)

For each gravity a correction factor is found by transition along the index line to the black $\lambda$°C-scale or in case of English measurements to the red $\lambda$°F-scale. This factor has to be multiplied by $10^{-5}$. By multiplying these factors with the number of degrees by which the measuring temperature differs

*) The characteristic can be omitted being 2. for all cases.

from 15°C or 60°F a correction figure is obtained. This has to be added to or deducted from the measured gravity according to whether the measuring temperature is higher or lower than the standard temperature.

**Examples:**

Determined a specific gravity of 0·728 at 6·5°C. The correction factor amounts to 0·00082 and has to be multiplied with the difference of 8·5°C yielding 0·0070 which figure has to be deducted. Result: Specific gravity at 15°C 0·721.

Determined a specific gravity of 0·892 at 85°F. Multiplying the correction factor 0·00036 with the temperature difference of 25°F yields 0·0090. This figure added to the above gravity yields 0·901 at 60°F.

### 5) Determination of Tank Capacities

Quick computations of tank capacities are possible by means of the above gravity correction and known tank dimensions.

**Example:**

Gasoline of the specific gravity 0·721 at standard temperature has to be stored in a tank of 8·75 m diameter and 7·0 meters height at 0°C temperature. By multiplying the correlated correction factor 0·00083 with the temperature difference of 15°C a gravity correction of 0·0125 results which has to be added. Thus a gravity of 0·7335 at 0°C is found. Since the tank possesses a capacity of 420 cubic meters ($\pi d^2/4 \times h$) 308 tons gasoline can be stored in the tank at 0°C.

### 6) Conversions of Viscosity Figures of the Various Systems and Reading of W-Figures

On the back of the slide rule are established the interrelated scales of three viscosity measuring systems and the scale of the W-figures. The conversion is carried out by transition along the index line, e. g.:

17·8 cs = 2·62°E or 21·5 cs = 104 SSU or 9·4°E = 330 SSU (Pay attention to the double logarithmic graduation of the scales much diminishing in the direction of high values!).

The W-figure is the Walther function log log ($\nu + 0{\cdot}8$), $\nu$ being the kinematic viscosity in centistokes. By putting the W-values into the attached equations viscosities at arbitrary temperatures can be computed from two given viscosities at other temperatures.

**Examples:** W-figure for 20·0 cs = 0·1200
for 40·0°E = 0·3950
for 110 SSU = 0·1380

### 7) Computing Oil Viscosities at Arbitrary Temperatures from Two Known Viscosities

Unknown oil viscosities are computed from two given viscosities by means of the Walther-Ubbelohde equations:

$$A)\ m = \frac{W_1 - W_2}{\log T_2 - \log T_1}$$

$$B)\ W = m\ (\log T_1 - \log T) + W_1$$

In these equations W is the W-figure of the unknown viscosity at the absolute temperature T, while $W_1$ and $W_2$ are the W-figures of the known viscosities at the correlated absolute temperatures $T_1$ and $T_2$. (Conversion of °F or °C vide paragraph 2c).

After computing the slope m of the viscosity straight line using equation "A", equation "B" can be easily solved. To keep the error small it is advantageous to use in equation "B" that $W_1$-figure the correlated temperature of which is nearest to that of the viscosity to be computed. In this way not only viscosities at temperatures between two other known temperature-viscosity couples can be calculated, but also such beyond that range, in which case, however, the accuracy of calculation is lower than in the former case according to known principles.

**Examples:**

**a)** The 100°F viscosity of an oil is to be computed from its viscosity at 50°C = 116 cs and that at 100°C = 17·87 cs. When the correlated W-figures ($W_1 = 0{\cdot}3158$ and $W_2 = 0{\cdot}1040$) are put into equation "A" as well as the logarithms of the absolute temperatures correlated to 50 and 100°C ($\log T_1 = 0{\cdot}5100$ and $\log T_2 = 0{\cdot}5724$) it follows:

$$m = \frac{0{\cdot}3158 - 0{\cdot}1040}{0{\cdot}5724 - 0{\cdot}5100} = \frac{0{\cdot}2118}{0{\cdot}0624} = 3{\cdot}39 \text{ and}$$

$$W = 3{\cdot}39\,(0{\cdot}5100 - 0{\cdot}4932) + 0{\cdot}3158 = 3{\cdot}39 \times 0{\cdot}0168 + 0{\cdot}3158 = 0{\cdot}0569 + 0{\cdot}3158 = 0{\cdot}3727.$$

This figure corresponds to a viscosity of 328 cs. Similarly a viscosity at 210°F of 18·50 cs is found. (Note: In case of negative W-figures the minus sign has to be taken into account, e. g. figures have to be added where a minus occurs in the equations).

**b)** The temperature at which the same oil as used in example 7a) exceeds the viscosity of 50°E has to be computed. After computing first the slope m as above equation "B" is solved for T:

$$T = \text{antilog}\left(\log T_1 - \frac{W - W_1}{m}\right)$$

Using the figure correlated to 50°E for W the computation yields:

$$T = \text{antilog}^{*}) \left(0{\cdot}5100 - \frac{0{\cdot}4116 - 0{\cdot}3158}{3{\cdot}39}\right) =$$

$$= \text{antilog} \left(0{\cdot}5100 - \frac{0{\cdot}0958}{3{\cdot}39}\right) =$$

$$= \text{antilog}\,(0{\cdot}5100 - 0{\cdot}0283) = \text{antilog}\,0{\cdot}4817 =$$

$$= 303\,^{\circ}\text{K or } 30\,^{\circ}\text{C or } 86\,^{\circ}\text{F}.$$

### 8) Computing the Viscosity Index

Following equation borrowed from an American author and adjusted slightly permits computation of the viscosity index with satisfactory accuracy:

$$\text{V. I.} = 3{\cdot}63 \left(60 - \text{antilog} \frac{\log \nu\, 100\,^{\circ}\text{F} - 0{\cdot}4336}{\log \nu\, 210\,^{\circ}\text{F}}\right) - 2$$

Attention has to be paid to the fact that in case of spindle oils small errors in determining viscosities result in rather great fluctuations of the V. I. due to the V. I. measuring method. Therefore, V. I. calculations for oils of viscosities lower than 25 cs at 50°C are useless. Unless the viscosities at 100 and 210°F have been directly determined they have to be computed from other known viscosities as demonstrated above under 7a). These figures (for the oil of 7a) is $\log \nu\, 100\,^{\circ}\text{F} = 2{\cdot}3580$ and $\log \nu\, 210\,^{\circ}\text{F} = 1{\cdot}2675$ are put into the above equation:

$$\text{V. I.} = 3{\cdot}63 \left(60 - \text{antilog} \frac{2{\cdot}3580 - 0{\cdot}4436}{1{\cdot}2675}\right) - 2$$

$$= 3{\cdot}63 \left(60 - \text{antilog} \frac{1{\cdot}9144}{1{\cdot}2675}\right) - 2$$

$$= 3{\cdot}63\,(60 - \text{antilog}\,1{\cdot}510) - 2 = 3{\cdot}63\,(60 - 32{\cdot}4) - 2$$

$$= 3{\cdot}63 \times 27{\cdot}6 - 2 = 100 - 2 = 98$$

### 9) Computing Viscosities of Oil Blends

Oil blends display lower viscosities than given by the arithmetic mean. Following two equations serve for an exact calculation:

$$W = q_2 (W_2 - W_1) + W_1 \text{ and } W = W_2 - q_1 (W_2 - W_1)$$

**Example:**

Two oils having viscosities of 3·5 and 18°E resp. determined at the same temperature are to be blended in the proportion 1 to 3. In the above equation W is the W-figure of the viscosity to be computed, $W_1$ the W-figure of the

*) "Antilog" means transition the logarithm of a number to the number itself.

viscosity of the thin oil (= 0·1514), and $W_2$ the W-figure of the thick oil (= 0·3300), while $q_1$ is the percentage of the thin oil in the blend (25% = 0·25) and $q_2$ the percentage of the thick oil in the blend (75% = 0·75). The calculation yields whether the first or the second equation is applied:

$$W = 0{\cdot}75\ (0{\cdot}3300 - 0{\cdot}1514) + 0{\cdot}1514 = 0{\cdot}75 \times 0{\cdot}1786 + 0{\cdot}1514$$
$$= 0{\cdot}1338 + 0{\cdot}1514 = 0{\cdot}2852 \text{ or}$$

$$W = 0{\cdot}3300 - 0{\cdot}25\ (0{\cdot}3300 - 0{\cdot}1514) = 0{\cdot}3300 - 0{\cdot}25 \times 0{\cdot}1786$$
$$= 0{\cdot}3300 - 0{\cdot}0447 = 0{\cdot}2853$$

From both figures results a viscosity of 11·1°.

### 10) Computing Component Qualities Required for a Blend

A blend of 15°E is to be made from the two oils of example 9). For that purpose the two above equations are solved for $q_1$ and $q_2$:

$$q_1 = \frac{W_1 - W}{W_2 - W_1} \quad \text{and} \quad q_2 = \frac{W - W_1}{W_2 - W_1}$$

The meaning of the letters are the same as in the former equations. W is the W-figure for 15°E = 0·3135. Thus, the calculation yields:

$$q_1 = \frac{0{\cdot}3300 - 0{\cdot}3135}{0{\cdot}3300 - 0{\cdot}1514} = \frac{0{\cdot}0165}{0{\cdot}1786} = 0{\cdot}093 = 9{\cdot}3\% \text{ and}$$

$$q_2 = \frac{0{\cdot}3135 - 0{\cdot}1514}{0{\cdot}3300 - 0{\cdot}1514} = \frac{0{\cdot}1621}{0{\cdot}1786} = 0{\cdot}908 = 90{\cdot}8\%$$

Both figures add up to roughly 100%, which is a check in itself.

Note: The computations as per the equations of paragraph 9) and 10) are equivalent to the well known graphic method using a double logarithmic grid.