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SAMA & ETANI

REFERENCE TABLES

AND CIRCULAR SLIDE RULE

Telephone—617-448-6500, 6501

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INTRODUCTION

The SAMA & ETANI reference tables and circular slide rule series was designed and constructed to facilitate calculations encountered daily by engineers, scientists and students. The tables provide handy reference to many frequently used conversion factors and physical data, while the slide rule is sufficiently accurate for all but the most precise calculations.

The circular slide rule has the following characteristics:

1. The outer scales have a circumference of approximately 7½ inches and as many subdivisions as a 10-inch linear slide rule.

2. Problems involving multiplication, division, squares, square roots, cubes, cube roots, logarithms and trigonometric functions can be easily solved.

3. All scales and tables are engraved to ensure a lifetime of accurate readability.

4. As with all circular slide rules, the answer can never be off scale.

The size of the instrument is such that it will fit easily into a shirt pocket. For the measurement of small lengths, inch and centimeter scales are provided on the front face. The instrument is made of plastic and can be safely washed with lukewarm water and mild soap.

USE OF CONVERSION TABLES

Many reference and conversion tables and frequently used data are included on three surfaces of the instrument for the user's quick reference. Note that there are stars on the face of the instrument and on the sliding insert near the AREA table. By keeping the two stars in the same relative position, the user's speed will be enhanced as he becomes familiar with the locations of the various tables of the instrument.

Each conversion table consists of a matrix of numbers which are the multiplication factors for converting from one unit of measurement to another.

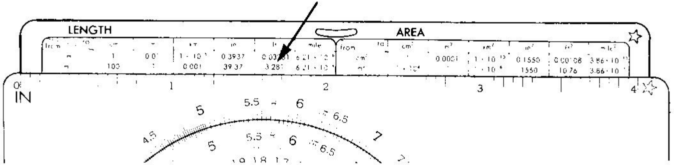


Figure 1

Example: Convert 3 meters into feet (Figure 1)

Procedure: Pull the sliding insert out to the left. On the front of this insert the LENGTH table can be found. Pull the insert out to the **m** row in the **from** column. Locate the **ft** column in the **to** row. The number found in the **m** row and the **ft** column is 3.281. When 3 is multiplied by 3.281, the answer 9.843 is the number of feet in 3 meters.

For convenience in writing and manipulation, numbers are often expressed in the tables as factors of the appropriate power of 10, for instance:

1.23×10^{6} denotes 1,230,000

1.23×10^{-6} denotes 0.00000123

Squares and cubes are expressed by exponents of 2 and 3.

UNITS OF FORCE AND MASS

The tables have been compiled with a view toward eliminating any possible confusion between force and mass. Wherever confusion might arise, an "f" to indicate force, or an "m" to indicate mass is used. For example, gf represents grams force and lbm represents pounds mass. Since the use of g and kg as units of mass is very common, it was not deemed necessary to add "m" after them when so used.

A special force table is also included in which the units of force, mass, acceleration and the conversion factor g_c are listed. This conversion factor is used with Newton's Law in the form $F=ma/g_c$. For example to calculate the gravitational force exerted on a pound mass (1 lbm) at a location where the gravitational acceleration is 30.0 ft/sec^2:

$$F=\frac{ma}{g_c}=\frac{1\ \text{lbm} \times 30.0\ \text{ft/sec}^2}{32.17\ \text{lbm ft/lbf sec}^2}=0.9325\ \text{lbf}$$

At or near sea level, where the earth's gravitational acceleration is 32.17 ft/sec^2, a one pound mass will be attracted to the earth by a one pound force, i.e., its weight will be 1 lbf.

Even when the conversion factor has a magnitude of 1, its use makes Newton's Law dimensionally consistent. For example, to determine the mass of an object whose weight is 2 newtons in a gravitational field of 5 meters/second^2:

$$m=\frac{Fg_c}{a}=\frac{2\ \text{newtons} \times 1\ \text{kg m/newton sec}^2}{5\ \text{m/sec}^2}=0.4\ \text{kg}$$

ABBREVIATIONS

a—acceleration
abs—absolute
acc.—acceleration
alt.—altitude
amp—ampere
atm—atmosphere
AWG—American Wire Gauge
B&S—Brown and Sharp
bbl—barrel
Br.—British
Btu—British thermal unit
c—speed of light
cal—calorie
cap—capacity
cent.—center
cgs—centimeter, gram, second unit
cir—circular
cm—centimeter
comp.—complex
coul—coulomb
db—decibels
deg.—degree
°C—degree Centigrade
°F—degree Fahrenheit
°K—degree Kelvin
°R—degree Rankine
dist.—distance
e—electric
E—potential in volts
elect.—electron
elem. ch.—elementary charge
emf—electromotive force
emu—electromagnetic unit
equiv—equivalent
esu—electrostatic unit
F—force
fl—fluid
ft—foot
fus.—fusion
g—gram mass
g_c—conversion factor in Newton's Law
g_0—gravitational acceleration at sea level
gal—gallon
gf—gram force
grav.—gravitational
Hg—mercury
hp—horsepower

h parameters—hybrid parameters
hr—hour
H_2O—water
I—current in amperes
in—inch
kg—kilogram mass
kgf—kilogram force
km—kilometer
kw—kilowatt
lbf—pound force
lbm—pound mass
lit—liter
ln—logarithm base e
log—logarithm base 10
m—magnetic
m—mass
m—meter
min—minute
mks—meter, kilogram, second unit
mks (nr)—non rationalized mks
mks (r)—rationalized mks
mm—millimeter
mmf—magneto-motive force
mph—miles per hour
mult—multiplier
no.—number
nos.—numbers
nt.—newton
oz—ounce mass
P—power
pos.—positive
press.—pressure
pt—pint
π—ratio of circumference of a circle to its diameter
quad.—quadrant
qt—quart
r—radius
R—radian
rad.—radian
sec—second
S_n—sum of n terms
stand.—standard
temp.—temperature
tol—tolerance
trans.—transverse
vap.—vaporization
vert.—vertex
w—weber
yd—yard

INSTRUCTIONS FOR THE BEGINNER

CIRCULAR SLIDE RULE

The slide rule is a mechanical equivalent of a table of logarithms. The addition or subtraction of scale lengths corresponding to logarithms of numbers results in the multiplication or division of these numbers.

Although slide rules are available in many forms, such as cylindrical, spiral or linear, the circular slide rule is the simplest and most convenient to use.

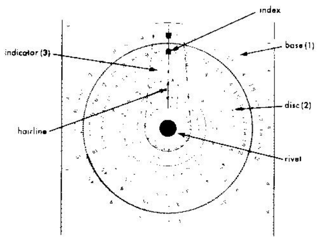


Figure 2

The circular slide rule has three major elements, the base (1), the disc (2) and indicator (3) (or cursor) attached to the base by a rivet (see Figure 2). The hairline is inscribed on the indicator. Index marks and are located at the beginning of the C and D scales.

SCALE DIVISIONS

Many frequently encountered mathematical problems can be solved easily on the circular slide rule, such as those involving multiplication, division, proportions, combined multiplication-division, squares and square roots, cubes and cube roots, logarithms and trigonometric functions.

First it is necessary to become acquainted with the scale divisions on the slide rule. This can best be illustrated by a careful inspection of the C and D scales, which are those most frequently used.

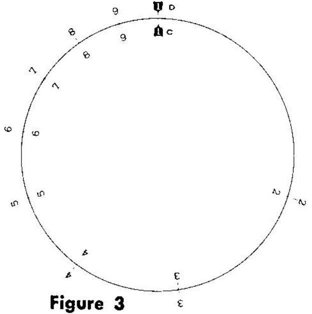


Figure 3

There are 10 primary divisions on the C and D scales (see **Figure 3**), further sub-divided into fractional elements. The numbers of the primary divisions increase clockwise and the spaces between them grow smaller. This space variation is because of the logarithmic nature of the scale. More specifically, the distance from 1 to 2 represents the logarithm of 2, the distance from 1 to 3, the logarithm of 3, etc.

The space between the primary divisions 1 and 2 is divided into tenths (see Figure 4) and these secondary divisions are further subdivided into tenths, totaling 100 divisions between primary divisions 1 and 2. Each of the finest subdivisions, therefore, has the value of 1/100 or 0.01.

Primary divisions 2 and 3, 3 and 4, and 4 and 5 are divided into tenths (see Figure 4), but their secondary divisions are subdivided into fifths, giving each of the finest subdivisions the value of 1/50 or 0.02.

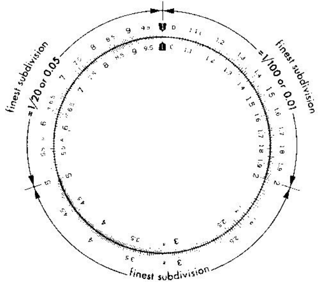


Figure 4

Primary divisions 5 and 6, etc., up to 9 and 10 are each divided into ten secondary divisions (see Figure 4). These secondary divisions are subdivided into two parts giving each of the finest subdivisions the value of 1/20 or 0.05.

LOCATING NUMBERS ON THE SCALES

The decimal point has no bearing upon the position of the number on the slide rule scale. Thus 0.00128, 1.28, 1280, etc., are located at the same position on the scales.

To use the slide rule it is necessary to understand the term "significant digit of a number." The "first significant digit" is the first digit in a number that is not zero. The "first significant digit" in the number 0.00128, 1.28 or 1280 is therefore 1. If the "first significant digit" is 1, then the number will be located on the slide rule scale between the primary divisions 1 and 2. If the "first significant digit" is 2, then the number will be between primary divisions 2 and 3, and so on up the scale.

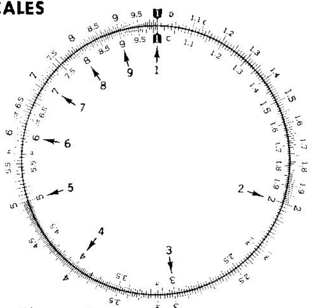


Figure 5

Single-digit numbers fall on primary divisions (see Figure 5). Two-digit numbers fall on the secondary divisions (see Figure 6). Three-digit numbers fall on or within the subdivisions of the secondary divisions.

Example: To locate 2.68

Procedure: Move the indicator to primary division 2 (which is the "first significant digit"). Digit 6 is the sixth secondary division to the right of primary division 2. Since the finest subdivisions have a value of 0.02 each, digit 8 is the fourth finest subdivision to the right (see Figure 7).

When the number is not found to fall exactly on a division, it is necessary to interpolate visually between divisions. For example, 2.87 is located one-half of the way from 2.86 to 2.88 as shown in Figure 7.

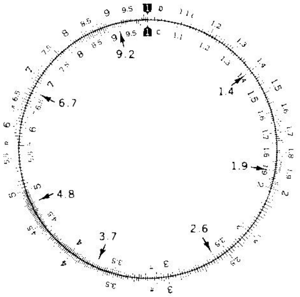


Figure 6

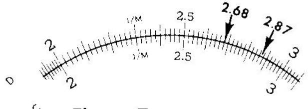


Figure 7

By visual interpolation between the finest divisions, it is possible to locate a number to 4 significant figures between 1 and 2 and to 3 significant figures between 2 and 10.

DECIMAL POINTS

During slide rule calculations, numbers should be set on the slide rule without regard to decimal points.

When answers are obtained on the slide rule, the correct position of the decimal point must be determined separately. Often this is immediately apparent, i.e., 2 x 32.0 is easily understood to be 64.0 and not 6.40 or 640. For complicated calculations, the location of the decimal point is determined by doing the calculations mentally in steps with rounded-off figures. For example, to determine the decimal point for the calculation 899 x 21.0÷342, note that 899/342 is between 2 and 3. When this is multiplied by 21.0 or the rounded-off figure of 20, the answer must be greater than 10 and less than 100; thus, the position of the decimal in the answer is after the second digit.

USE OF CIRCULAR SLIDE RULE

The slide rule has D, C, CI, L, A, S, T and K scales. The C, D, and CI scales are used for multiplication and division. Scales A and C are used to calculate squares and square roots, and K and C scales are used for cubes and cube roots. Logarithms are obtained with the L and C scales. The remaining scales, S and T, are used in conjunction with the D, C, and CI scales to obtain and manipulate trigonometric functions. The circular slide rule is used in much the same manner as the conventional straight slide rule.

In order to simplify explanation of the use of the circular slide rule the following symbols are used in the booklet:

↗ .... setting of the scales
↑ .... setting of the indicator
* .... answer

Letters designating scales are imprinted in red on the indicator. These letters will be helpful to the user in locating the scales. Note that these letters are positioned over the numerical figures in the respective scales, rather than over the divisions, for ease in reading the divisions.

MULTIPLICATION

Example: 1.8 x 2.5=4.5 (Figure 8)

Procedure: Locate 1.8 on the D scale, and line up the index on the C scale with it. Set the indicator to 2.5 on the C scale. The indicator shows the answer 4.5 on the D scale.

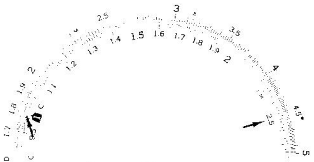


Figure 8a

Figure 8a shows the detailed subdivisions while 8b is shown schematically. For greater clarity, schematic diagrams are used for all subsequent examples.

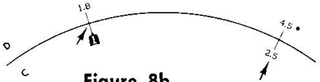


Figure 8b

Example: 3 x 2=6, 3 x 5=15, 3 x 7=21 (Figure 9)

Procedure: Locate 3 on the D scale, and line up on the C scale with it. Set the indicator to the values 2, 5 and 7 on the C scale, and read the answers 6, 15 and 21 respectively, on the D scale.

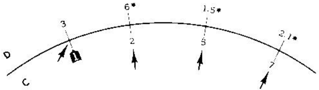


Figure 9

Example: 3 x 4 x 5=60 (Figure 10)

Procedure: Locate 3 on the D scale, and line up 4 on the CI scale with it. Move the indicator to 5 on the C scale, which gives the answer 60 on the D scale.

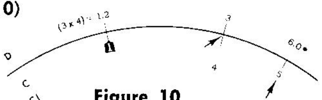


Figure 10

DIVISION

Example: 850÷25=34 (Figure 11)

Procedure: Locate 850 on the D scale, and line up 25 on the C scale with it. The index on the C scale points to answer 34 on the D scale.

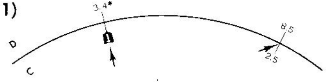


Figure 11

Example: 850÷25÷8=4.25 (Figure 12)

Procedure: Locate 850 on the D scale and line up 25 on the C scale with it. Move the indicator to 8 on the CI scale and read the answer 4.25 on the D scale.

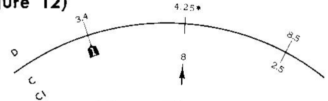


Figure 12

MULTIPLICATION AND DIVISION

Example: $3 \times 6 \div 5 = 3.6$ (Figure 13)

Procedure: Locate 3 on the D scale and line up 5 on the C scale with it. Set the indicator to 6 on the C scale. Read answer 3.6 on the D scale.

Figure 13

PROPORTIONS

Example: 2.4:5=x:8 x=3.84 (Figure 14)

Procedure: Locate 2.4 on the D scale and line up 5 on the C scale with it. Set the indicator to 8 on the C scale and read answer 3.84 on the D scale.

Figure 14

SQUARES AND SQUARE ROOTS

Example: $3^2=9$ (Figure 15)

Procedure: Set the indicator to 3 on the C scale. Read the answer 9 on the A scale.

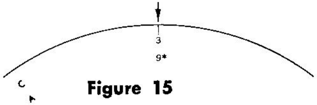
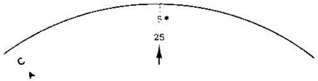


Figure 15

Example: $\sqrt{25}=5$ (Figure 16)

Procedure: Set the indicator to 25 on the A scale. Read the answer 5 on the C scale.

Figure 16

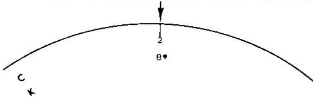


CUBES AND CUBE ROOTS

Example: $2^3=8$ (Figure 17)

Procedure: Move the indicator to 2 on the C scale. Read the answer 8 on the K scale.

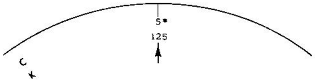
Figure 17



Example: $\sqrt[3]{125}=5$ (Figure 18)

Procedure: Move the indicator to 125 on the K scale. Read the answer 5 on the C scale.

Figure 18



LOGARITHMS

Example: log 78 = 1.892 (Figure 19)

Procedure: Set the indicator to 78 on the C scale. The mantissa 0.892 is read on the L scale. Since the characteristic number is 1, the logarithm of 78 is 1.892.

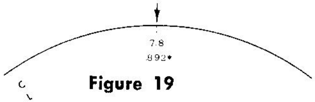


Figure 19

POWERS

Example: $(2)^4 = 16.0$ (Figure 20)

Procedure: Set the indicator to 2.0 on the C scale. Read log 2.0 = 0.301 on the L scale. Line up the index on the C scale with 0.301 on the D scale. Move the indicator to 4 on the C scale and read 4 log 2.0 = 1.204 on the D scale. This is the log of the answer since log $(2.0)^4 = 4$ log 2.0; therefore, set the indicator to 0.204 on the L scale. The answer 16.0 is read on the C scale.

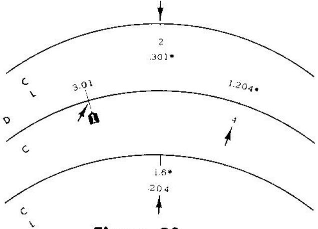


Figure 20

NOTE: Only the mantissas of logarithms are found on the L scale. The characteristic, in this case 1, is used to locate the decimal.

SINES AND COSINES

The S scale is used to determine sines of angles between 6 and 90 degrees. Since the cosine of an angle is equal to the sine of its complement, i.e. cos $\theta = \sin(90 - \theta)$, these same scales can be used to find cosines of angles. For convenience when working with cosines, the complements of the angles are shown in orange on the S scale.

Example: sin 30° = 0.500 (Figure 21)

Procedure: Set the indicator to the black 30° marking on the S scale. The answer 0.500 is read on the C scale.

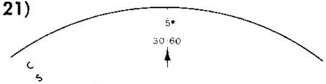


Figure 21

Example: cos 40° = 0.766 (Figure 22)

Procedure: Set the indicator to the orange 40° marking on the S scale. The answer 0.766 is read on the C scale.

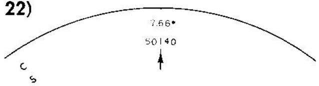


Figure 22

TANGENTS AND COTANGENTS

The tangent scale, T, is used to determine tangents of angles from 6 to 45 degrees, and 45 to 84 degrees. Between 6 and 45 degrees the angles are in black on the T scale and their tangents are found on the C scale (also black). Between 45 degrees and 84 degrees the angles are in orange on the T scale and their tangents are found on the CI scale (also orange).

Example: Tan $42^\circ = 0.900$ (Figure 23)

Procedure: Set the indicator to the black 42° marking on the T scale. Answer 0.900 is read on the C scale.

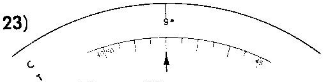


Figure 23

Example: Tan $60^\circ = 1.732$ (Figure 24)

Procedure: Set the indicator to the orange 60° on the T scale. The answer 1.732 is read on the CI scale.

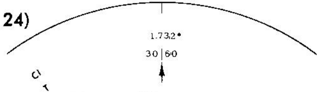


Figure 24

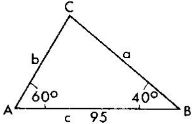
The cotangent of an angle θ is obtained by determining the tangent of $(90-\theta)$. Thus the cotangent 48° and the contangent 30° are obtained by determining tan 42° and tan 60° as in the preceding examples.

TRIANGLES

Problems involving triangles can be solved easily on this slide rule. The slide rule is particularly well suited for Sine Law calculations:

Sine Law: $\dfrac{a}{\sin A} = \dfrac{b}{\sin B} = \dfrac{c}{\sin C}$ where $A+B+C=180^\circ$

Example: Find a and b in following triangle:



$$\frac{a}{\sin 60^\circ} = \frac{b}{\sin 40^\circ} = \frac{95}{\sin[180-(60+40)]}$$

$a=83.5$; $b=62$ (Figure 25)

Procedure: Locate 95 on the D scale, and line up 80° on the S scale with it. Set the indicator to 60° and 40° on the S scale, and read the answers 83.5 and 62 respectively, on the D scale.

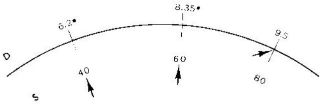


Figure 25

COORDINATE CONVERSIONS

A very important use of this slide rule is the conversion between rectangular and polar coordinate forms of complex numbers.

Example: $3 + j4 = 5 \angle 53^\circ$ *(Figure 26)

Procedure: Line up the index on the C scale with the larger rectangular component (4 in this example) on the D scale. Set the indicator to the other component on the D scale (3 in the example). Determine mentally whether the angle will be larger or smaller than 45°. If larger, read the angle (53°) using the orange numerals on the T scale. If smaller, read the black numerals on the T scale. Next, without moving the indicator, rotate the S scale until the angle just determined (orange 53°) falls under the hairline on the S scale. The magnitude of this number, 5, can now be read on the D scale opposite the index on the C scale.

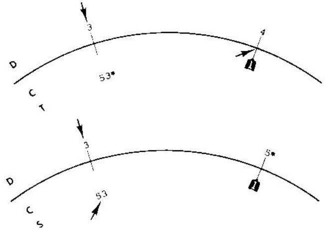


Figure 26

*Note: $5 \angle 53^\circ$ represents a vector of magnitude 5 at an angle of 53° with the plus x axis.

Example: $4 + j3 = 5 \angle 37^\circ$ (Figure 27)

Procedure: Line up on the C scale with 4 on the D scale. Set the indicator to 3 on the D scale. Since the angle is less than 45°, read the black numerals on the T scale, 37°. Next, without moving the indicator, rotate the S scale until the angle just determined (black 37°) falls under the hairline on the S scale. The magnitude of the number, 5, can now be read on the D scale opposite on the C scale.

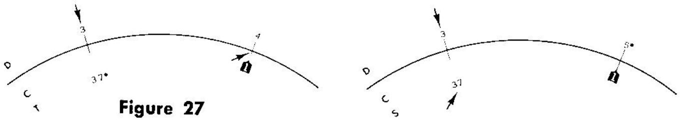


Figure 27

Example: $15\angle 30^\circ = 13.0 + j7.5$ (Figure 28)

Procedure: Line up on the C scale with 15 on the D scale. Set the indicator to the angle designated on the S scale (30°). Use black numerals if the angle is smaller than 45°, orange if the angle is larger than 45°. The smaller rectangular component ($j7.5$) now lies under the hairline on the D scale. Next, without moving the indicator, rotate the T scale until the angle on the T scale (same number and color as just read) falls under the hairline. The larger component 13.0 now is on the D scale opposite on the C scale.

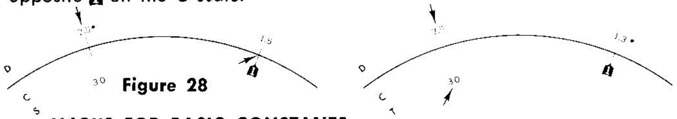


Figure 28

MARKS FOR BASIC CONSTANTS

The C, D, CI and A scales of the circular slide rule include several locating marks to facilitate computations involving frequently used basic constants. On the C, D, CI and A scales appear the mark "π" at 3.142 and a tick mark designating $\pi/4$ at 0.7854. The mark "2π" at 6.283 appears on the C, D and CI scales. The use of these marks makes it unnecessary to recall the numerical values when multiplying or dividing by π, 2π or $\pi/4$, and also insures a more accurate setting.

Three other marks are also provided on the slide rule. They are summarized as follows:

Mark	Scales	Numerical value	Usage
c	D	$\sqrt{4/\pi} = 1.128$	To find the area of a circle with a given diameter. **Procedure:** Line up diameter on the C scale with mark "c" on the D scale. Move the indicator to on the D scale. The answer is found on the A scale.
1/M	C, D, CI	2.3026	To convert $\log_{10} x$ to $\log_e x$, i.e., $\log_e x = 2.3026 \log_{10} x$
R	C, D, CI	57.296°	To convert angles from radians to degrees or vice versa. **Procedure:** Line up on the C scale with "R" on the D scale. Opposite any value on the C scale in radians read same angle in degrees on the D scale.

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AUTO-CAL

Combination slide rule-mileage calculator and 22-year calendar in leather case with key ring

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