INSTRUCTIONS

Universal slide rule
«WIRE» IWA 09102

System: Kohlhase-Heuel

Universal pocket slide rule
«WIRE» ARISTO 40128

System: Kohlhase-Heuel

Published and distributed by
Hermann F. Heuel, Beratender Ing. VBI
Höhenstraße 62, D-8959 Hopfen am See

INSTRUCTIONS

for the

Universal slide rule
«WIRE» IWA 09 102

System: Kohlhase-Heuel

and

Universal pocket slide rule
«WIRE» ARISTO 40 128

System: Kohlhase-Heuel

Published and distributed by

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FOREWORD

With the issue of this instruction book and the newly developed

Universal Pocket Slide Rule "DRAHT" ARISTO 40 128

System: Kohlhase-Heuel

Produced in 1965, having dimensions of 165×75 mm this fulfilled a great wish of my friends, who created the initiative for the development. All technicians in the Home and Foreign wire bar and tube industries are now in a position to determine all factors for wire bar and tube forming on the spot in workshop practice. It is more advantageous than an ordinary slide rule inasmuch as that all calculations can be made by this rule.

Up to now, the only available rule was the

Universal Slide Rule "DRAHT" ARISTO 90 103

System: Kohlhase-Heuel

having dimensions of 320×165 mm and was used specifically in factory offices, but is now no longer available. However, by the middle of 1965, the completely newly developed

Universal Slide Rule "DRAHT" IWA 09 102

System: Kohlhase-Heuel

with dimensions of only 285×76 mm will be available. This one will have many advantages over the ARISTO 90 103 and will actually be cheaper.

Taking into account the precision finish, both rules include all scales, curves and figure tables. By using the instruction book, theoretical and practical knowledge will be surprisingly simple to attain.

Hopfen am See 1978

Your Wire Friend,

Hermann F. Heuel

INTRODUCTION

There are many types of slide rule for the Wire Industry (Bibliographic 1—4). They were inefficient for determining the necessary factors for drawing operations on Iron, Steel and metal wire, Bar and Tube forming so that these slide rules and calculating aids were never fully developed.

Furthermore, for determining and investigating unique factors, one had to refer to the trade literature through the many and often very detailed manuals with graphs, tables, nomograms, diagrams, guides and so forth published by the authors in Bibliographic 5—14. Using these manuals as aids for the purpose of Wire, Bar and Tube forming is often very complicated and time wasting.

Based on these disadvantages the

(a) Universal Slide Rule "WIRE" IWA 09 102
System: Kohlhase-Heuel

and the

(b) Universal Pocket Slide Rule "WIRE" ARISTO 40 128
System: Kohlhase-Heuel

were developed especially to make the technicians' task easier. Both slide rules are used as normal slide rules containing the two units of measurement (metric and inch) for determining and calculating all necessary factors for Wire, Bar and Tube forming. Furthermore, all mathematical problems (apart from trigonometry) multiplication, division, squares, square roots and logarithms can be calculated as with any other slide rule. It is taken for granted that calculations using scales K, A, B, CI, C, D and L are known. If this is not the case, using a slide rule can easily be learnt with a handbook which is obtainable from any slide rule dealer.

It has not been deemed necessary to give clear explanations and mathematical proof on the slide rules (a) and (b) as enough has been given in the trade literature over the past few years. By completing and publishing this instruction book for slide rules (a) and (b) I have satisfied the following world-wide wishes and challenges:

- **Only one instruction book for the complete process of Wire, Bar and Tube forming.**
- **Universally adaptable to the Wire, Bar and Tube forming trade.**
- **Uncomplicated spacing of scales graphs and figures.**
- **Robust and extremely precise construction.**
- **Very clear calculating and result readings.**
- **Extraordinarily simple to use without having knowledge of mathematics.**
- **Easily carried in the pocket.**
- **Factors for wire, bar and tube forming determined practically on the spot on the shop floor.**
- **Usable as an ordinary slide rule.**
- **Usable for both units of measurement (metric and inch) without further calculations.**
- **Slide rules (a) and (b) are protected against damage and dirt by a leather sachet.**

● **By using slide rules (a) and (b) in wire, bar and tube forming, the technicians' task has been much simplified.**

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Description

The symbols and spacing of Scales, Graphs, and Tables for both slide rules (a) and (b) are as follows:

(a) Scales on the Front Side

Cube Scale	**K**	(x^3)	On upper edge of stock.
Drawing Speed Scale	**E**	(m/s) (ft./min.)	
Square Scale	**A**	(x^2)	On upper edge of slide
Square Scale	**B**	(x^2)	
Total area reduction Scale	**G**	(A in %) (R per cent)	On the stock under the plexiglass slide.
Area reduction per single draft scale	**H**	(a in %) (r per cent)	
Drafts table	**H**	(z) (n)	
Reciprocal Scale	**CI**	$\left(\frac{1}{x}\right)$	On bottom edge of slide.
Basic Scale	**C**	(x)	
Basic Scale	**D**	(x_z)	On bottom edge of stock
Log scale	**L**	(lg)	

(b) Scales and Tables on the Reverse Side

Tensile table	**F**	($^{\sigma}B = kp/mm^2$)	On the reverse side.
Total area reduction scale	**G**	(A in %) (R per cent)	In the centre on the reverse side.
Tensile Strength Table	**F1**	($^{\sigma}L = lb./sq. in. \times 10^3$)	On the reverse side

(c) The Slide

The most important part of Slide Rules **(a) and (b)** is the slide. By using this in conjunction with scales, graphs and tables, the first possibilities ever are created for determining and calculating all factors connected with wire, bar and tube forming.

The slide can be moved either to the left or to the right. On the right hand side a line connects **B 100 with CI 1** and on the left, a line connects **B 1 to CI 10.** These hairlines guarantee an extremely precise reading on graph table **H (which contains graphs for the number of drafts z = n = 1 to 30)** at the intersecting points with the horizontal constant area reduction lines **a = r = 10 to 40 %.**

The graph table is to determine the number of drafts and is numbered **1 to 30** at the bottom. The horizontal area reduction lines are numbered **10 to 40 %** at the right hand side.

Intermediate values at the graph intersecting points including **tenths of one per cent,** will have to be estimated.

(d) The Cursor

The cursor for slide rules (a) and (b) acts as a double cursor for the front and reverse sides. Included on the front side are:

(a) the long line **I** in the centre of the cursor,

(b) the short line **II** on the upper left,

(c) the short line **III** on the lower right,

(d) the short line **PS** on the upper right,

(e) the short line **HP** on the right under PS,

(f) the symbol **KW** on the upper cursor edge and

(g) the long line **IV** in the centre of the reverse side of the cursor which coincides with cursor line I on the front side and connects **B 100** to **CI 1** on the right of the slide and **B 1** to **CI 10** on the left.

(e) The Fixed Powers

For ease of operation, the following fixed powers have been marked on the unit scales:

In scale A; B; CI; C and D π = **3,142**

In scale **C c** = **1,128**

In scale **C** c_1 = **3,570**

In scale **C c** = **11,280**

In scale **C F** = **1,273**

In scale **C** F_1 = **4,020**

In scale **C Fyd** = **1,117**

In scale **C** Fyd_1 = **3,531**

In scale **C Fft** = **1,934**

In scale **C** Fft_1 = **6,116**

In scale **C Z** = **0,03937**

The fixed powers **F**; F_1; **Fyd**; Fyd_1; **Fft**; Fft_1; are used for Wire, Bar and Tube forming **with iron and steel** having a weight of **7,85 kp/dm³**.

These symbols may be used for a further twelve metals by using Table 1.

Material	Weight kp/dm³	Fixed Powers F	F_1	Fyd	Fyd_1	Fft	Fft_1
Aluminium	2,70	**6,867**	**2,171**	**1.904**	**6.020**	**1.043**	**3.298**
Lead	11,34	**1,060**	**3,351**	**0.929**	**2.938**	**1.609**	**3.089**
Chromium	7,19	**1,330**	**4,208**	**1.165**	**3.690**	**2.021**	**6.390**
Chrome - Nickel Steel 18/8	7,80	**1,278**	**4,044**	**1.112**	**3.543**	**1.940**	**6.137**
Chromium Steel 13% Cr.	7,70	**1,285**	**4,070**	**1.127**	**3.565**	**1.953**	**6.173**
Copper	8,96	**1,192**	**3,770**	**1.045**	**3.305**	**1.810**	**5.725**
Brass Ms 63	8,53	**1,222**	**3,863**	**1.071**	**3.388**	**1.845**	**5.868**
Brass Ms 80	8,67	**1,212**	**3,832**	**1.063**	**3.360**	**1.840**	**5.820**
Brass Ms 90	8,73	**1,208**	**3,819**	**1.059**	**3.349**	**1.834**	**5.800**
Monel Metal	8,85	**1,199**	**3,793**	**1.052**	**3.326**	**1.821**	**5.760**
Nickel	8,90	**1,196**	**3,782**	**1.048**	**3.315**	**1.816**	**5.744**
Phosphor Bronze	8,82	**1,202**	**3,799**	**1.053**	**3.333**	**1.824**	**5.770**

Adapting these fixed powers for determining and calculating factors in Wire, Bar and Tube forming for use with the materials mentioned in Table 1 will be explained in later examples.

Further symbols have been added at the ends of the scales for ease of operation viz:

1. **lz: lo** = Elongation from starting to finishing length on scale **B left.**
2. **t** = Running time in m/min for a weight or length on scale **B right.**
3. **do** = Starting or exit diameter on scale **C left.**
4. **dh** = Starting patenting diameter on scale **C left.**
5. **dz** = Final or finishing diameter on scale **D left.**
6. **d₁ — dz** = Total draft diameter on scale **C right.**

(f) The most important symbols for Wire and Bar Forming

To differentiate and avoid confusion when setting and reading off, the following symbols for wire and bar forming have been added and should be studied carefully in the following examples.

These symbols come under the headings **0,0 to 0,7** and are as follows:

0,0

(a) **d = mm** or **d = inches**

are for all round wire and bar diameters and read on scales **C** and **D.**

(b) **do = mm** or **do = inches**

are for all round exit or starting diameter for wire and bar and read only on scale **C.**

(c) **d_h = mm or d_h = inches**

are for round starting diameters for patented steel wire and read only on scale C.

(d) **See section "Tube forming" for appropriate symbols for tube diameters.**

0,1

dz = mm or **dn = inches**

are for all round final, intermediate and finishing diameters and read only on scale D.

0,2

(a) **F = mm²** or **F = sq. in.**

are for all round and profile wire or bar cross sectional areas and read on scales A and B.

(b) **Fo = mm²** or **Fo = sq. in.**

are for all round and profile exit or starting cross sectional areas and read only on scale A.

0,3

Fz = mm² or **Fn = sq. in.**

are for all round and profile final, intermediate or finishing cross sectional areas and read only on scale B.

0,4

d1; d2; d3 . . . dz = mm or **d1; d2; d3 . . . dn = in.**

are for all round wire and bar intermediate draft diameters and **read only on scale C.**

0,5

F1; F2; F3 . . . Fz = mm² or **F1; F2; F3 . . . Fn = sq. in.**

are for all round and profile wire or bar intermediate cross sectional areas and read only on scale B.

0,6

All symbols mentioned under **0,0 to 0,5** are diameters and cross sectional areas for determining the factors in two units of measurement (metric and inches).

PRACTICAL EXAMPLES AND SOLUTIONS

0,7 Determine the cross sectional area **F = mm²** or **F = sq. in.** for a round diameter **d = 70,0; 7,00; 0,70** and **0,07 mm** or **d = 2.756; 0.2756; 0.0276** and **0.00276 inches:**

Solution 1 (Metric System)

Slide c = 1,128 on scale C opposite d = 7 (d = mm) on scale D. Opposite B 1 on scale A we read the following:

For **d = 70,00 mm**	**F = 3848**	**mm² cross sectional area**
for **d = 7,00 mm**	**F = 38,48**	**mm² cross sectional area**
for **d = 0,70 mm**	**F = 0,3848**	**mm² cross sectional area**
for **d = 0,070 mm**	**F = 0,003848**	**mm² cross sectional area**

Solution 2 (English System)

Slide **c = 1.128** on scale **C** opposite **d = 2756 (d = inches)** on scale **D.** Opposite **B 1** on scale **A** we read the following:

For **d = 2.756 inches**	**F = 5.97**	**sq. in. Cross sectional area**
for **d = 0.2756 inches**	**F = 0.0597**	**sq. in. Cross sectional area**
for **d = 0.02756 inches**	**F = 0.000597**	**sq. in. Cross sectional area**
for **d = 0.00276 inches**	**F = 0.000006**	**sq. in. Cross sectional area**

Note when using slide rules (a) and (b)

As shown in example **0,7** the position of the decimal point is just as important as an accurate reading when determining a value.

0,8
0,9
Determine the weight G_M **= kp/m;** W_y **= lb./yd.;** W_f **= lb./ft.** and with the same setting the length **L = m/kp; l = yd./lb.** and **l = ft./lb.** for the diameters given in example **0,7.**

Solution 1 (Metric System)

For the diameters given in example **0,7** slide the fixed symbol for the metric system F_1 **= 4.020** on scale **C** opposite 7 (diameter in mm) on scale **D. (Iron and steel material weight = 7,85 kp/dm³** ... for all other metals refer to table 1 for the **F —** values) Opposite B_1 on scale **A** read the weights and opposite **A 100** on scale **B** read the lengths which are as follows:

For **d = 70,00 mm**	G_M **= 30,3**	**kp/m**
for **d = 7,00 mm**	G_M **= 0,303**	**kp/m**
for **d = 0,70 mm**	G_M **= 0,00303**	**kp/m**
for **d = 0,07 mm**	G_M **= 0,00003**	**kp/m**
For **d = 70,00 mm**	**L = 0,0331**	**m/kp**
for **d = 7,00 mm**	**L = 3,31**	**m/kp**
for **d = 0,70 mm**	**L = 331,0**	**m/kp**
for **d = 0,07 mm**	**L = 33100**	**m/kp**

See note under example **0,7.**

Solution 2 (English System)

For the round diameters given in example **0,7** slide the fixed symbol **Fyd = 1.117** opposite **2756** on scale **D** when **lb./yd.** and **yd./lb.** are to be determined. When **lb./ft.** and **ft./lb.** are to be determined, slide **Fft = 1.934** opposite **2756** on scale **D.** (For all other metals refer to the F values in table 1. — **Iron and steel weight is 13231.6 lb./cu. yd.** or **490.1 lb./cu. ft.)** Opposite **B 1** on scale A read the weights and opposite **A 100** on scale **B** read the lengths which are as follows:

For **d = 2.756**	**inches**	W_y =	**60.90**	**lb./yd.**
for **d = 0.276**	**inches**	W_y =	**0.609**	**lb./yd.**
for **d = 0.0276**	**inches**	W_y =	**0.00609**	**lb./yd.**
for **d = 0.00276**	**inches**	W_y =	**0.000061**	**lb./yd.**
For **d = 2.756**	**inches**	**l** =	**0.1064**	**yd./lb.**
for **d = 0.276**	**inches**	**l** =	**1.64**	**yd./lb.**
for **d = 0.0276**	**inches**	**l** =	**164.20**	**yd./lb.**
for **d = 0.00276**	**inches**	**l** =	**16420.00**	**yd./lb.**
For **d = 2.756**	**inches**	W_F =	**20.3**	**lb./ft.**
for **d = 0.276**	**inches**	W_F =	**0.203**	**lb./ft.**
for **d = 0.0276**	**inches**	W_F =	**0.00203**	**lb./ft.**
for **d = 0.00276**	**inches**	W_F =	**0.000020**	**lb./ft.**
For **d = 2.756**	**inches**	**l** =	**0.0493**	**ft./lb.**
for **d = 0.276**	**inches**	**l** =	**4.93**	**ft./lb.**
for **d = 0.0276**	**inches**	**l** =	**492.63**	**ft./lb.**
for **d = 0.00276**	**inches**	**l** =	**49263**	**ft./lb.**

See note under example 0,7.

Careful! When determining the weights and lengths of other metals, place the values for these metals (see table 1) opposite **d = mm** or **d = inches** on scale **D.**

1,0 Determine the circumference **U = mm** or **U = inches** for the diameters given in example **0,7.**

Solution

Slide **C 10** or **C 1** opposite **7 (d = mm)** on scale **D** or opposite **2.756 (d = inches)** on scale **D.** Opposite π = **3.14** on scale **C** read the following on scale **D:**

For **d = 70,00 mm**	**U** =	**219,90**	**mm**
for **d = 7,00 mm**	**U** =	**21,99**	**mm**
for **d = 0,70 mm**	**U** =	**2,20**	**mm**
for **d = 0,07 mm**	**U** =	**0,22**	**mm**
For **d = 2.756 inches**	**U** =	**8.66**	**inches**
for **d = 0.276 inches**	**U** =	**0.866**	**inches**
for **d = 0.0276 inches**	**U** =	**0.0866**	**inches**
for **d = 0.00276 inches**	**U** =	**0.00866**	**inches**

Note: **Example 1,0 is valid for any material of any diameter.**

1,1 Determine the surface area **0 = m²/kp** or **0 = sq. in./lb.** for the diameters given in example **0,7.**

Solution 1 (Metric System)

(a) At the same setting as in example **1,0** place the circumference **U =** mm opposite the in example **0,8** and **0,9** determined weight G_M **= 30,3 kp/m.**

Opposite **C 10,** read the surface areas on scale **D** as follows:

For **d = 70,00 mm**	**O = 0,0073 m²/kp**
for **d = 7,00 mm**	**O = 0,0728 m²/kp**
for **d = 0,70 mm**	**O = 0,728 m²/kp**
for **d = 0,07 mm**	**O = 7,28 m²/kp**

Solution 2 (English System)

(b) Place **C 36 (36 inches = 1 yard)** on scale **C** opposite π **= 3.14** on scale **D.** At this setting move cursor line **I** over **C 2756 (d = inches)** on scale **C.** Place the in example **0,8** and **0,9** determined weight W_y **= 60,9 lb./yd.** under cursor line **I.** Opposite **C 10** read the following:

For **d = 2.756 inches**	**O = 0.00395 sq. yd./lb.**
for **d = 0.276 inches**	**O = 0.0395 sq. yd./lb.**
for **d = 0.0276 inches**	**O = 0.395 sq. yd./lb.**
for **d = 0.00276 inches**	**O = 3.949 sq. yd./lb.**

Solution 3 (English System)

(c) Place **C 12 (12 inches = 1 ft.)** on scale **C** opposite π **= 3.14** on scale **D.** At this setting move cursor line **I** over **C 2756 (d = inches)** on scale **C.** Place the in example **0,8** and **0,9** determined weight W_F **= 20.3 lb./ft.** under cursor line **I.** Opposite **C 10** read the following:

For **d = 2.756 inches**	**O = 0.0355 sq. ft./lb.**
for **d = 0.276 inches**	**O = 0.355 sq. ft./lb.**
for **d = 0.0276 inches**	**O = 3.555 sq. ft./lb.**
for **d = 0.00276 inches**	**O = 35.55 sq. ft./lb.**

1,2 For a cross sectional area **F = 3848 mm²** or **F = 5.965 sq. in.** determine:
(a) The weight G_M **= kp/m** or W_y **= lb./yd.** and W_y **= lb./ft.**
(b) The length **L = m/kp** or **l = yd./lb.** and **l = ft./lb.**

Solution 1 (Metric System)

Move cursor line **I** over the cross sectional area **F = 3848 mm²** on scale **A.**

NOW CAREFULLY EXECUTE THE FOLLOWING SETTING.

Place the fixed symbol F_1 **= 4.020** on scale **C** (for iron and steel) under the bottom right hand cursor line **III.**

Read off as follows:

(a) **Opposite B 1 on scale A the weight** G_M **= 30,30 kp/m**
(b) **Opposite A 100 on scale B the length L = 0,033 m/kp.**

Solution 2 (English System)

Move cursor line **I** over the cross sectional area **F = 5.965 sq. in.** on scale **A.**

NOW CAREFULLY EXECUTE THE FOLLOWING SETTING.

Place the fixed symbol **Fyd_1 = 3.531** on scale **C** (for iron and steel) under the bottom right hand cursor line **III.**

Read off as follows:

(a) **Opposite B 1 on scale A the weight W_y = 60.90 lb./yd.**

(b) **Opposite A 100 on scale B the length l = 0.0164 yd./lb.**

Solution 3 (English System)

With the same setting as before place the fixed symbol **Fft_1 = 6.116** (iron and steel) **under the bottom right hand cursor line III.**

Read off as follows:

(a) **Opposite B 1 on scale A the weight W_F = 20.30 lb./ft.**

(b) **Opposite A 100 on scale B the length l = 0.0493 ft./lb.**

Notes

When determining and calculating larger and especially smaller values with the

(a) **Universal Slide Rule "WIRE" IWA 09 102**

(b) **Universal Pocket Slide Rule "WIRE" ARISTO 80 122**

for wire bar and tube forming, variations may arise through;

1. **Inaccurate estimation.**
2. **Inaccurate placing of decimal point.**
3. **Not adhering to setting instructions.**

The STANDARDWERK für die Fertigung, Kalkulation und Prüfung von Eisen, Stahl und Metalldraht, 1. Auflage 1959, von Fritz Kohlhase, Umfang 377 Seiten, DIN A 5, is recommended for checking purposes.

For practically all diameters **d = mm** or **d = inches** and also for all cross sectional areas, the following values:

1. **Diameter in mm or inches.**
2. **Circumference in mm or inches.**
3. **Cross sectional area in mm² or sq. inches.**
4. **Weights G_M = kp/m; W_y = lb./yd. and W_F = lb./ft.**
5. **Lengths L = m/kp; l = yd./lb. and l = ft./lb.**
6. **Surface area O = m²/kp; O = sq. yd./lb. and O = sq. ft./lb.**
7. **Tensile strengths σ_B = kp/mm², σ_L = lb./sq. in. and σ_L = tons/sq. in.**
8. **Breaking strains P = kp and P = lb.**

with diameters of:

(a) **from 25,00 mm to 0,010 mm or from 0.98425 in. to 0.000394 inches.**

or with cross sectional areas of:

(b) **from 490,873438 mm² to 0,000078 mm² or from 0.760854 sq. in. to 0.00000012 sq. inches.**

can be obtained.

By moving the decimal point it is possible to obtain all necessary values under a ten times smaller diameter in **mm** or **inches,** for a ten times larger diameter, or vice versa.

This also applies to cross sectional areas in **mm²** or **square in.**

Furthermore gauges from **0000000 (7/0) to 50** gauge for determining the values under **1 to 8** with all diameters **d = mm** and **d = inches** of the following are included:

1. **Brown & Sharpe Wire Gauge**
2. **American Steel Wire Gauge — Washbourn & Moen Wire Gauge**
3. **Birmingham Wire Gauge**
4. **Imperial Standard Wire Gauge**
5. **Jauge de Paris 1857**

Especially important are technical translations in:

(a) **German**

(b) **English**

(c) **French**

(d) **Spanish**

The contents of which have advanced the industry by many years.

Apart from materials in **iron and steel** having a **weight of 7,85 kp/dm³**, the contents have been extended to include the diameters (a) and (b) of the most important metals with all factors from 1 to 8.

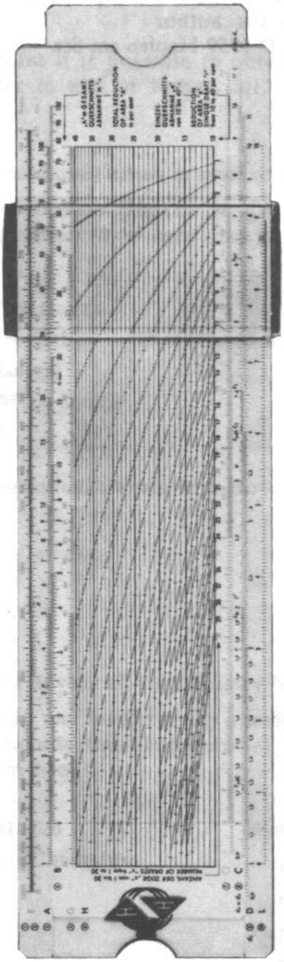
1. **Chrome-Nickel steel 18/8**	**Weight**	**= 7,80 kp/dm³**
2. **Chromium steel 13 % Chromium**	**"**	**= 7,70 kp/dm³**
3. **Nickel**	**"**	**= 8,90 kp/dm³**
4. **Copper**	**"**	**= 8,96 kp/dm³**
5. **Bronze MS 80**	**"**	**= 8,67 kp/dm³**
6. **Phospor-Bronze**	**"**	**= 8,92 kp/dm³**
7. **Aluminium**	**"**	**= 2,70 kp/dm³**

The values for each material given under **1 to 8** can also be obtained in both units of measurement (metric and English) for the diameter under **(a)** and **(b)** including those in **1 to 5 (d = mm** and **d = inches).**

When importing or exporting wire, bar and tube products, it is often necessary to convert from one unit of measurement to the other.

For both units of measurement, all diameters and cross sectional areas can immediately be obtained.

On these grounds the STANDARDWERK is an indespensible aid for finishing, calculating and testing wire and bar in metals given under 1 to 7 and including iron and steel. Obtainable from the author
Hermann F. Heuel, Höhenstraße 63, D-8959 Hopfen am See



INSTRUCTIONS

for

determining the necessary factors for COLD FORMING

and finishing Iron, Steel, and metal

wire with Slide Rules (a) and (b)

THE BASIC SETTING

Every successful cold forming operation on any kind of material is dependant on:

1. Exit diameter **do = mm** or **do = inches** on scale **C.**
2. Exit cross sectional area **Fo = mm²** or **Fo = sq. in.** on scale **B.**
3. Final or finishing diameter **dz = inches** on scale **D.**
4. Final or finishing cross sectional area **Fz = mm²** or **Fn = sq. in.** on scale **A.**

and also by giving each material its most advantageous total cross sectional area reduction **A = %** or **R = per cent.**

The total cross sectional area reduction **A = %** or **R = per cent** must not reach the forming limits and can be selected on scale **G** from **A = R = 0 to 99 %.**

Note especially that the basic setting for all materials is identical and that the following can be obtained:

(a) **B 100 to CI 1** on upper right **A = R = %** on **G**

(b) **B 1 to CI 10** on upper left **A = R = %** on **G**

(c) **do = mm** on scale **C** opposite **dz = mm** on scale **D**

(d) **do = in.** on scale **C** opposite **dn = in.** on scale **D**

(e) $\mathbf{d_h}$ **= mm** on scale **C** opposite **dz = mm** on scale **C**

(f) $\mathbf{d_h}$ **= in.** on scale **C** opposite **dn = in.** on scale **D**

(g) **Fo = mm²** on scale **B** opposite **Fz = mm²** on scale **A**

(h) **Fo = sq. in.** on scale **B** opposite **Fn = sq. in.** on scale **A**

(i) **B 100 to CI 1** on upper right **a = r = %** on **H**

(j) **B 1 to CI 10** on upper left **a = r = %** on **H**

All values from **(a)** to **(p)** in example **1.3** can be obtained with only o n e setting.

Example 1,3

With basic setting, determine all values for cold forming:

(a) Iron wire

(b) Copper wire

(c) Aluminium wire

The total cross sectional area reduction to be **A = R = 86,7 %** the drawing speed **V = 12 m/s** or **V = 2363 ft./min.** for all three materials.

(The choice of materials, the drawing speed and the total cross sectional area reduction have been taken as examples.)

Solution:

Set the right hand connecting line **B 100 to CI 1** or the left hand connecting line **B 1 to CI 10** on the slide over the total cross sectional area reduction

A = R = 86,7 % scale **G.**

Under the connecting line **B 100 to CI 1** on the slide extended to the left, or under the connecting line **B 1 to CI 10** on the slide extended to the right, the following can be read at this setting:

*(a) On scale **G,** total area reduction **A = 86,7 %**

(b) „ „ **G, total area reduction **R = 86,7 per cent**

*(c) „ „ **C,** Exit or starting diameter **do = 5,50 mm**

(d) „ „ **C, Exit or starting diameter **dn = 0.2165 in.**

*(e) „ „ **D,** Final or finishing diameter **dz = 2,00 mm**

(f) „ „ **D, Final or finishing diameter **dn = 0.0787 in.**

(g) Table **H,** at the intersecting points of **a = r = %** (horizontal lines) with **z = n = total number** of drafts (curved lines) read off as follows when forming materials **(a), (b)** and **(c):**

with	**a = r = 39,7 %**	**(per cent),**	**z = n =**	**4**	**drafts**
„	**a = r = 33,2 %**	„ „	**z = n =**	**5**	„
„	**a = r = 28,6 %**	„ „	**z = n =**	**6**	„
„	**a = r = 25,1 %**	„ „	**z = n =**	**7**	„
„	**a = r = 22,4 %**	„ „	**z = n =**	**8**	„
„	**a = r = 20,2 %**	„ „	**z = n =**	**9**	„
„	**a = r = 18,3 %**	„ „	**z = n =**	**10**	„
„	**a = r = 16,9 %**	„ „	**z = n =**	**11**	„
„	**a = r = 15,5 %**	„ „	**z = n =**	**12**	„
„	**a = r = 14,4 %**	„ „	**z = n =**	**13**	„
„	**a = r = 13,5 %**	„ „	**z = n =**	**14**	„
„	**a = r = 12,7 %**	„ „	**z = n =**	**15**	„
„	**a = r = 11,9 %**	„ „	**z = n =**	**16**	„
„	**a = r = 11,1 %**	„ „	**z = n =**	**17**	„
„	**a = r = 10,7 %**	„ „	**z = n =**	**18**	„
„	**a = r = 10,1 %**	„ „	**z = n =**	**19**	„

The choice of **a = r = %** and **z = n = drafts depends** on the material and the diameter **dz = dn = mm** or **inches.**

*(h) Opposite **A 1** on **B,** total elongation factor **E = 7.52**

(i) „ **A 100 on **B,** total elongation factor **E = 7.52**

*(j) „ **B 100** on **A,** total cross sectional area remaining
Qv = 13,3 %

*(k) „ **B 1** on **A,** total cross sectional area remaining
Qv = 13,3 per cent

(l) „ **A = R = 86,7 %** on **A,** total elongation
E — 1 × 100 = 7.52 — 1 × 100 = 652 % (per cent)

*(m) „ **D 1** on **C diameter ratio do/dz = 2.741**

(n) „ **D 10 on **C diameter ratio do/dn = 2.741**

*(o) „ **C 10** on **D diameter ratio dz/do = 0.3643**

(p) „ **C 1 on **D diameter ratio dn/do = 0.3643**

* Slide withdrawn to left.

** Slide withdrawn to right.

For determining the cold forming of the wire in **(a)**, **(b)** and **(c)** mentioned materials, a unit area reduction of **25,1 %** with **z = n = 7 drafts** has been chosen.

Very Important Note:

The Universal basic setting for the total cross sectional area reduction **A = R = 86,7 %** is also valid for cold forming (drawing) from:

1. **do = 0,55 mm** to **dz = 0,20 mm** or
   do = 0.02165 in. to **dn = 0.00787 in.**
2. **do = 0,055 mm** to **dz = 0,020 mm** or
   do = 0.002165 in. to **dz = 0.000787 in.**

and further for bar forming from:

3. **do = 55,00 mm** to **dz = 20,00 mm** or
   do = 2.165 in. to **dn = 0.7874 in.**

and is furthermore valid for all values and fractional values when **do = mm** or **do = inches** on scale **C** opposite values and fractional values **dz = mm** or **dn = inches** on scale **D** when the total cross sectional area reduction **A = R = 86,7 %.** With any other cross sectional area reduction **A = R = %** the diameters will, of course, change. Item 3 is used solely as a setting example.

EXAMPLE 1,4

Determine for example **1,3** the draft diameters **d_1; d_2; d_3—d_7 = dz = mm** or **d_1; d_2; d_3—d_7 = dn = inches** for a unit area reduction of **a = 25,1 %** and **z = r = 7 drafts.**

Solution:

Place the exit or starting diameter **do = 5,5 mm** or **0.2165 inches** opposite **D 10.** At this setting slide cursor line **I across** the intersecting points **z_1; z_2; z_3—z_7** or **n_1; n_2; n_3—n_7** with **a = r = 25,1 %** on table **H.**

Under cursor line **I** read the draft diameters on scale **C,** which are the bearing diameters for **d_1; d_2; d_3—d_7 = dz** or **dn = mm** or **inches.** Further, with the same setting, read the increasing total cross sectional area reduction **A = R = %** under cursor line **I** on scale **G** as follows:

1. Metric System:

   At **z_1, d_1 = 4,75 mm** on **C** and **A = 25,1 %** on **G**

   at **z_2, d_2 = 4,11 mm** on **C** and **A = 44,3 %** on **G**

   at **z_3, d_3 = 3,55 mm** on **C** and **A = 58,2 %** on **G** at z_4, d_4 = **3,07 mm** on **C** and **A = 68,6 %** on **G**

at z_5, d_5 = **2,65 mm** on **C** and **A = 76,5 %** on **G**

at z_6, d_6 = **2,30 mm** on **C** and **A = 82,5 %** on **G**

at z_7, dz = **2,00 mm** on **C** and **A = 86,7 %** on **G**

2. English System:

At n_1, d_1 = **0.1870 in.** on **C** and **A = 25.1 per cent** on **G**

at n_2, d_2 = **0.1618 in.** on **C** and **A = 44.3 per cent** on **G**

at n_3, d_3 = **0.1398 in.** on **C** and **A = 58.2 per cent** on **G**

at n_4, d_4 = **0.1209 in.** on **C** and **A = 68.6 per cent** on **G**

at n_5, d_5 = **0.1043 in.** on **C** and **A = 76.5 per cent** on **G**

at n_6, d_6 = ***0.0906 in.** on **C** and **A = 82.5 per cent** on **G**

at n_7, dn = **0.0787 in.** on **C** and **A = 86.7 per cent** on **G**

At *, move slide to other side.

EXAMPLE 1,5 (Special example)

Determine for example **1,3** the diminishing unit cross sectional area reductions **a = r = % at the draft diameters d_1; d_2; d_3—dz = mm** or **d_1; d_2; d_3—dn = inches.** Starting diameter is **do = 5,5 mm** or **do = 0.2165 inches.** In example **1,3** a unit cross sectional area reduction of **a = r = 25,1 %** for **z = n = 7 drafts** was found.

Solution:

Add to the in example **1,3** determined unit cross sectional area reduction **a = r = 25,1 %** per draft as follows:

At **do to d_1 = mm** or **inches, to a = r = 25,1 + 6,0 = 31,1 %**

at **d_1 to d_2 = mm** or **inches, to a = r = 25,1 + 5,0 = 30,1 %**

at **d_2 to d_3 = mm** or **inches, to a = r = 25,1 + 4,0 = 29,1 %**

at **d_3 to d_4 = mm** or **inches, to a = r = 25,1 + 3,0 = 28,1 %**

at **d_4 to d_5 = mm** or **inches, to a = r = 25,1 + 2,0 = 27,1 %**

at **d_5 to d_6 = mm** or **inches, to a = r = 25,1 + 1,0 = 26,1 %**

at **d_6 to dz = mm** or **inches, to a = r = 25,1 + 0,0 = 25,1 %**

Place the starting or exit diameter **do = 5,5 mm** or **do = 0.2165 inches** opposite **D 10.** Move the cursor line **I** over the intersecting points **z_1; z_2; z_3—z_7 (z = n)** with the above determined unit cross sectional area reduction in table **H.** Under cursor line **I** on scale **C** read off the draft diameters as follow:

do = 5,50 mm to d_1 = 4,55 mm; do = 0.2165 in. to d_1 = 0.1791 in.

d_1 = 4,55 mm to d_2 = 3,82 mm; d_1 = 0.1791 in. to d_2 = 0.1504 in.

d_2 = 3,82 mm to d_3 = 3,28 mm; d_2 = 0.1504 in. to d_3 = 0.1291 in.

d_3 = 3,28 mm to d_4 = 2,84 mm; d_3 = 0.1291 in. to d_4 = 0.1118 in.

d_4 = 2,84 mm to d_5 = 2,49 mm; d_4 = 0.1118 in. to d_5 = *0.0980 in.

d_5 = 2,49 mm to d_6 = 2,22 mm; d_5 = 0.0980 in. to d_6 = 0.0874 in.

d_6 = 2,22 mm to dz = 2,00 mm; d_6 = 0.0874 in. to dn = 0.0787 in.

At * move slide to other side.

The factors **1,0 to 6,0 %** can be selected higher for sharply diminishing unit cross sectional area reductions and lower for more gradual diminishing ones. However, the determined unit cross sectional area reduction **a = r = %** at the final draft **dz = mm or dn = inches,** remains the same.

EXAMPLE 1,6

Determine for example **1.3** (metric system) the running time **t = min/100 kp** or **t = min/100 lb.** (English System) at a drawing speed of **V = 12 m/s** or **V = 2362 ft./min.**

Solution 1 (Metric system)

Place one of the fixed symbols for iron and steel **F = 1.273** or **F_1 = 4.020** (on scale **C**) opposite **dz = 2.00 mm** on scale **D.** At this setting place cursor line **I** over the drawing speed **V = 12 m/s** on scale **E.** Under cursor line **I** read the running time on scale **B** as follows:

(a) **T = 5.60 min./100 kp at V = 12 m/s**

Place the determined running time **t = 5.60 min/100 kp** on scale **B** opposite **60** on scale **A.** Opposite **B 1** on scale **A** read off:

(b) **m = 1070 kp/h**

At the same setting read opposite **A 100:**

(c) **tm = 0,935 h/100 kp**

Solution 2 (English System)

Place one of the fixed symbols for iron and steel **Fft = 1.934** or **Fft_1 = 6.116** (on scale **C**) opposite **dn = 0.0787 inches** on scale **D.** At this seeting place cursor line **I** over the drawing speed **V = 2362 ft./min.** on scale **E.** Under cursor line **I** read the running time on scale **B** as follows:

(d) **t = 2.55 min./100 lb. at V = 2362 ft./min.**

Place the determined running time **t = 2.55 min./100 lb.** on scale **B 1** opposite **60** on scale **A.** Opposite **B 1** on scale **A** read off:

(e) **m = 2350 lb./h.**

At the same setting read opposite **A 100** on scale **B:**

(f) **tm = 0.425 h/100 lb.**

When calculating the efficiency, place the capacity of

(g) **m = 1070 kp/h or m = 2350 lb./h**

opposite **D 10.** Opposite an actual production of

(h) **m = 963 kp/h or m = 2120 lb./h** (taken as an example)

on scale **C, read** on scale **D** the percentage efficiency **Ag** as follows:

(i) **Ag = 0,9 × 100 = 90 %**

at an actual production given in **(h)** opposite the theoretical machine capacity given in **(g)**. Determining and calculating all values under **(a) to (i)** in example **1.6** can be achieved for Copper wire by using the fixed symbols given in table 1:

F = 2.171 or **F₁ = 6.867** (metric system)

Fft = 1.036 or **Fft₁ = 3.298** (English system)

These fixed symbols are placed on scale **C** and placed opposite **dz = 2,00 mm** on scale **D** (metric system) or opposite **dn = 0.0787 inches** on scale **D** (English system)

Further settings and readings are as explained in example **1.6.**

Any selected drawing speed **V = m/s** or **V = ft./min.** can be used with any selected diameter **dz = mm** or **dn = inches** as shown in example **1.6** and all values from **(a)** to **(i)** can be quickly determined.

EXAMPLE 1,7

Determine for a finishing speed of **V = 12 m/s** or **V = 2362 ft./min.** (example **1,3)** the unit draft drawing speed **v = m/s** or **v = ft./min.** for **z = n = 7** drafts.

Solution:

Place **V = 12** or **v = 2362 ft./min.** on scale **B** opposite **A 100.** Then slide cursor line **I** over the intersecting points **z_1; z_2; z_3; z_4; z_5; z_6; z_7; (z = n)** with **a = r = 25,1 %** on table **H** (see e. g. **1,3)**. Under cursor line **I** on scale **B** read the following:

At **z_1 with a = 25,1 %** read **v_1 = 2,11 m/s** on **B**

„ **z_2 with a = 25,1 %** read **v_2 = 2,83 m/s** on **B**

„ **z_3 with a = 25,1 %** read **v_3 = 3,76 m/s** on **B**

„ **z_4 with a = 25,1 %** read **v_4 = 5,01 m/s** on **B**

„ **z_5 with a = 25,1 %** read **v_5 = 6,70 m/s** on **B**

„ **z_6 with a = 25,1 %** read **v_6 = 8,90 m/s** on **B**

„ **z_7 with a = 25,1 %** read **v_7 = 12,00 m/s** on **B**

This reading goes from right to left, from z_7 to z_1.

At n_1 **with r = 25,1 %** read v_1 = **415 ft./min.** on B

„ n_2 **with r = 25,1 %** read v_2 = **552 ft./min.** on B

„ n_3 **with r = 25,1 %** read v_3 = **740 ft./min.** on B

„ n_4 **with r = 25,1 %** read v_4 = **990 ft./min.** on B

„ n_5 **with r = 25,1 %** read v_5 = **1320 ft./min.** on B

„ n_6 **with r = 25,1 %** read v_6 = **1761 ft./min.** on B

„ n_7 **with r = 25,1 %** read v_7 = **2362 ft./min.** on B

This reading goes from right to left, from z_7 to z_1.

These unit draft drawing speeds **V = m/s** or **V = ft./min.**, are dependant on a constant unit cross sectional area reduction **a = r = %** when multi-hole drawing. The accumulation factor has not been taken into account. The calculation can be selected for finishing speeds **v = m/s** and ft./min. as long as the material is formed or drawn with a constant unit cross sectional area reduction **a = r = %.**

EXAMPLE 1,8

Determine for materials e. g. **pure titanium** or for alloy materials having higher quantities of **C; Cr; Ti; Ni; Mo; Nb; Ta; V** or **W**, that, when cold formed at a lower percentage **A = R = %** reach their forming limits, the necessary factors for determining the drawing operations, the necessary annealing stage diameters for similar reductions between the **seperate** annealing stages.

In the example, the various materials will have an exit or starting diameter of **do = 5,5 mm** or **do = 0.2165 inches** and a final diameter of **dz = 0,90 mm** or **dn = 0.0334 inches** so that between the starting and finishing diameters five similar annealing stages as well as the final annealing stage can be given.

At which diameters shall the annealing process occur?

Solution:

Place the exit or starting diameter **do = 5,5 mm** or **do = 0.2165 inches** on scale **C** opposite the final or finishing diameter **dz = 0,90 mm** or **dn = 0.0334 inches** on each scale **D.**

Under the left hand connecting line **B 1 to CI 10** read on table **H,** on scale **G** and on the other scales as follows:

(a) On scale **G,** total cross sectional area reduction **A = R = 97,33.**

(b) On table **H,** at the intersecting points between **a = r = %** (unit cross sectional area reduction) the horizontal lines, with **z = n = total number** of drafts, the curved lines, read off as follows:

a = r =	36,4 % (per cent)	with	z = n =	8 drafts
a = r =	33,1 %	„ „ „	z = n =	9 „
a = r =	30,4 %	„ „ „	z = n =	10 „
a = r =	28,1 %	„ „ „	z = n =	11 „
a = r =	26,1 %	„ „ „	z = n =	12 „
a = r =	24,3 %	„ „ „	z = n =	13 „
a = r =	22,9 %	„ „ „	z = n =	14 „
a = r =	21,5 %	„ „ „	z = n =	15 „
a = r =	20,4 %	„ „ „	z = n =	16 „
a = r =	19,2 %	„ „ „	z = n =	17 „
a = r =	18,3 %	„ „ „	z = n =	18 „
a = r =	17,4 %	„ „ „	z = n =	19 „
a = r =	16,6 %	„ „ „	z = n =	20 „
a = r =	15,9 %	„ „ „	z = n =	21 „
a = r =	15,2 %	„ „ „	z = n =	22 „
a = r =	14,6 %	„ „ „	z = n =	23 „
a = r =	14,0 %	„ „ „	z = n =	24 „
a = r =	13,6 %	„ „ „	z = n =	25 „
a = r =	13,0 %	„ „ „	z = n =	26 „
a = r =	12,6 %	„ „ „	z = n =	27 „
a = r =	12,2 %	„ „ „	z = n =	28 „
a = r =	11,8 %	„ „ „	z = n =	29 „
a = r =	11,4 %	„ „ „	z = n =	30 „

The choice of the unit cross sectional area reduction is dependant on the material and the diameter **dz = dn = mm** or inches. For example **1,8**, a unit cross sectional area reduction of **18,3 %** with **z = n = 18 drafts** for cold forming from an exit diameter of **do = 5,5 mm** or **do = 0.2165 inches** to a finishing diameter **dz = 0,90 mm** or **dn = 0.0334 inches,** has been chosen.

(c) Opposite **A 100** on **B,** total elongation factor **E = 37,3**

(d) „ **B 100** on **A,** total cross sectional area remaining **Qv = 2,67 %**

(e) „ **A = R = 97,33 %** on **A** total elongation **(E = 37,3 — 1 × 100) = E = 37,3 — 1 = 36,3 × 100 = 3630 %** on **B,** when **B 1 to CI 10 is over A = 97,33 % on scale G.**

(f) „ **C 1** on **D,** diameter ratio **(do/dz)** or **(do/dn) = 16,38**

Note: This reading is valid for both units of measurement without moving the slide.

Determine the draft diameters for cold forming **d_1; d_2; d_3 — dz = mm,** or **d_1; d_2; d_3 — dn = inches** and the annealing stage diameters at **d_3; d_6; d_9; d_{12}; d_{15} = mm** or **inches.**

Place **d_o = 5,5 mm** or **d_o = 0.2165 inches** on scale **C** opposite **D 10.** At this setting move cursor line **I** over the intersecting points, **z_1; z_2; z_3 — z_{18}; drafts** or **n_1; n_2; n_3 — n_{18} drafts** at **a = r = 18,3 %** on table **H** and read on scale **C** as follows.

d_o = 5,50 mm to d_1 = 4,96 mm; d_o = 0.2165 in. to d_1 = 0.1953 in.

d_1 = 4,96 mm to d_2 = 4,49 mm; d_1 = 0.1953 in. to d_2 = 0.1768 in.

d_2 = 4,49 mm to d_3 = *4,05 mm; d_2 = 0.1769 in. to d_3 = *0.1594 in.

d_3 = 4,05 mm to d_4 = 3,69 mm; d_3 = 0.1594 in. to d_4 = 0.1453 in.

d_4 = 3,69 mm to d_5 = 3,31 mm; d_4 = 0.1453 in. to d_5 = 0.1303 in.

d_5 = 3,31 mm to d_6 = *3,00 mm; d_5 = 0.1303 in. to d_6 = *0.1181 in.

d_6 = 3,00 mm to d_7 = 2,71 mm; d_6 = 0.1181 in. to +d_7 = 0.1067 in.

d_7 = 2,71 mm to d_8 = 2,45 mm; d_7 = 0.1067 in. to d_8 = 0.0965 in.

d_8 = 2,45 mm to d_9 = *2,21 mm; d_8 = 0.0965 in. to d_9 = *0.0870 in.

d_9 = 2,21 mm to d_{10} = 2,00 mm; d_9 = 0.0878 in. to d_{10} = 0.0787 in.

d_{10} = 2,00 mm to d_{11} = 1,81 mm; d_{10} = 0.0795 in. to d_{11} = 0.0713 in.

d_{11} = 1,81 mm to d_{12} = *1,64 mm; d_{11} = 0.0713 in. to d_{12} = *0.0646 in.

d_{12} = 1,64 mm to d_{13} = 1,48 mm; d_{12} = 0.0646 in. to d_{13} = 0.0583 in.

d_{13} = 1,48 mm to d_{14} = 1,34 mm; d_{13} = 0.0583 in. to d_{14} = 0.0528 in.

d_{14} = 1,34 mm to d_{15} = *1,22 mm; d_{14} = 0.0528 in. to d_{15} = *0.0480 in.

d_{15} = 1,22 mm to d_{16} = 1,10 mm; d_{15} = 0.0480 in. to d_{16} = 0.0433 in.

d_{16} = 1,10 mm to d_{17} = 0,99 mm; d_{16} = 0.0433 in. to d_{17} = 0.0390 in.

d_{17} = 0,99 mm to dz = *0,90 mm; d_{17} = 0.0390 in. to dn = *0.0354 in.

At + move slide to other side.

At * execute annealing treatment.

The annealing stage diameters can also be read under cursor line **I** on scale **C** at the intersecting points **z_3; z_6; z_9; z_{12} and z_{15} = n drafts** with the unit cross sectional area reduction **a = r = 18,3 %** when **d_o = 5,5 mm** or **d_o = 0.2165 inches** is opposite **D 10,** as follows:

At **z_3, d_3 = 4,05 mm** or **d_3 = 0.1594 in.** on **C**

at **z_6, d_6 = 3,00 mm** or **d_6 = 0.1181 in.** on **C**

at **z_9, d_9 = 2,21 mm** or **d_9 = 0.0878 in.** on **C**

at **z_{12}, d_{12} = 1,64 mm** or **d_{12} = 0.0646 in.** on **C** at z_{15}, **d_{15} = 1,22 mm** or **d_{15} = 0.0480 in.** on **C**

at z_{18}, **dz = *0,90 mm** or **dn = *0.0354 in.** on **C**

At * the final annealing.

As in example **1,6** all values from **(a) to (i)** can be **obtained.**
The fixed **F and Fft symbols** are not used in this setting and are left out of table 1. The total annealing stages are given only as an example, the calculations can be achieved for any number.

EXAMBLE 1,9 (Steel wire)

In contrast with all other materials, that on reaching their forming limits have to undergo one or more annealing treatments, carbon steel wire is heated under a continuous process depending on its carbon content, and then quenched in air or in a salt or lead bath.

Determine for **lead patented** steel wire with an exit diameter of **d_h = 5,00 mm** or **d_h = 0.1968 inches** for cold forming to a finishing diameter **dz = 1,775 mm** or **dn = 0.0699 inches,** all necessary factors by using slide rules **(a)** and **(b).** The finished drawing speed to be **V = 7,00 m/s** or **V = 1379 Ft/min.** The tensile strength to reach **$^{\sigma}$B = 200 to 210 kp/mm²** or **$^{\sigma}$L = 292000 to 299000 lb./sq.**

Solution:

With the basic setting, place the patenting diameter **d_h = 5,00 mm** or **d_h = 0.1968 inches** on scale **C** opposite the finishing diameter **dz = 1,775 mm** or **dn = 0.0699 inches** on scale **D.**

Read off under the **right** hand connecting line at * and under the **left** hand connecting line at **, as follows:

*(a) On scale **G** the total cross sectional area reduction **A = 87,4 %**

(b) On scale **G the total cross sectional area reduction **R = 87,4 %**

(c) On table **H** the constant unit cross sectional area reduction **a = r = %** at the intersecting points of the straight lines with the curved lines **z = n = number** of drafts.

a = r = 34,8 % (per cent) with z = n = 5 drafts

a = r = 29,2 % „ „ „ **z = n = 6** „

a = r = 25,5 % „ „ „ **z = n = 7** „

a = r = 22,8 % „ „ „ **z = n = 8** „

a = r = 20,5 % „ „ „ **z = n = 9** „

a = r = 18,7 % „ „ „ **z = n = 10** „

a = r = 17,2 % „ „ „ **z = n = 11** „

a = r = 15,9 % „ „ „ **z = n = 12** „

a = r = 14,8 % „ „ „ **z = n = 13** „

$a = r = 13{,}8\ \%$ (per cent) with $z = n = 14$ drafts
$a = r = 12{,}9\ \%$ „ „ „ $z = n = 15$ „
$a = r = 12{,}2\ \%$ „ „ „ $z = n = 16$ „
$a = r = 11{,}4\ \%$ „ „ „ $z = n = 17$ „
$a = r = 10{,}9\ \%$ „ „ „ $z = n = 18$ „
$a = r = 10{,}3\ \%$ „ „ „ $z = n = 19$ „

*(d) Opposite A 1 on B, total elongation factor E = 7,91
**(e) „ A 100 on B, total elongation factor E = 7,91
*(f) „ B 100 on A, total cross sectional area remaining Qv = 12,6 %
**(g) „ B 1 on A, total cross sectional area remaining Qv = 12,6 %
*(h) „ A = 87,4 % on A, total elongation (E — 1 × 100 = 692 %) on B.
**(i) „ A = 87,4 % on A, total elongation (E — 1 × 100 = 692 %) on B.
*(j) „ D 1 on C, diameter ratio d_h/dz = 2.808
**(k) „ D 10 on C, diameter ratio d_h/dz = 2.808
*(l) „ C 10 on D, diameter ratio dz/d_h = 0,355
**(m) „ C 1 on D, diameter ratio dz/d_h = 0.355

With a similar setting as before, for determining the tensile strength, the Carbon content and the patenting tensile, place cursor line I over the right hand connecting line B 100 to CI 1 or over the left hand connecting line B 1 to CI 10 and read off on the reverse side on table F or F_1 the following values under the cursor line IV:

*(n) On table F under IV, tensile strength $\sigma B = 206$ kp/mm²
**(o) „ „ F_1 under IV, tensile strength $\sigma L = 293$ lb./sq. in.
(p) „ „ F to the right for $\sigma B = 206$ kp/mm² the C content = 0,70 %
(q) „ „ F_1 to the right for $\sigma L = 2931$ lb./sq. in.³ the C content = 0,70 %
(r) „ „ F to the right, the patenting tensile $\sigma B = 120$ kp/mm² (red figures)
(s) „ „ F_1 to the right, the patenting tensile $\sigma L = 171$ lb./sq. in³ (red figures)

Especial Note:

1. Determining factors for **cold forming all materials** by using slide rules **(a)** and **(b)** can be achieved by using the scales and curve table on the **front side** as explained in the examples in this instruction book.
2. All other calculations can be executed on the scales on the **front** of slide rules **(a)** and **(b)**.
3. When cold forming steel wire, the tensile strength, the carbon content, the patenting tensile and the increase in tensile in relation to the total cross sectional area reduction is determined on the **reverse side**, as explained in examples 1,9 to 2,2.

4. The **tensile strength values $^{\sigma}L$ = lb./sq. in.³** are given in a compact form, the given values **$^{\sigma}L$ = lb./sq. in.³** should be multiplied by **1000.**

5. Variations will occur:

   (a) with different chemical combinations, especially with higher or lower **C and Mn contents** in the basis material.

   (b) by using a higher or lower total cross sectional area reduction **A = R = %** and unit cross sectional area reduction **a = r = %** when cold forming from **d_h = mm** or **d_h = inches** to the finishing diameter **dz = mm** or **dn = inches.**

   (c) when the values on tables **F** and **F_1** are used for non lead patented steel wire.

   (d) when, on patenting the thicker diameter **d_h = mm** or **d_h = inches,** an impure, irregular structure is obtained or large perlite particles occur in the structure that will have an adverse effect on the mechanical properties.

   (e) when patenting at diameters **d_h = mm** or **d_h = inches** that have been drawn at a high cold forming degree to the patenting diameter, the patenting tensile **$^{\sigma}B$ = kp/mm²** or **$^{\sigma}L$ = lb./sq. in.** will increase due to the higher conversion rate. The tensile will decrease when the opposite occurs.

6. **Accurate details and finishing methods for lead patented steel wire are described in the handbook:**

„Die Praxis der modernen, rationellen und wirtschaftlichen

Fertigung unlegierter und legierter Stahldrähte"

„Aus der Praxis — für die Praxis"

First printed 1963 from Fritz Kohlhase, Dortmund-Asseln.

EXAMPLE 2,0

Determine when cold forming (Example 1,9) from the **d_h = 5,00 mm** or **d_h = 0.1963 inches** to **dz = 1.775 mm** or **dn = 0.0699 inches,** the draft diameters **d_1; d_2; d_3 — dz = mm** or **d_1; d_2; d_3 — dn = inches,** at the same time the increasing total cross sectional area reduction **A = R = %** and the tensile, starting from the patenting tensile **$^{\sigma}B$ = kp/mm²** or **lb./sq. in.³** on tables **F** and **F_1** on the reverse side.

Considering the variables mentioned under items 1 to 5, the most favourable reduction a = r = 20,5 % (per cent) with **z = n = 9 drafts given in example** 1,9 item C, has been selected for cold forming steel wire, from which the draft diameters dz = mm or dn = inches are determined.

Solution:

Place the patenting diameter d_h = **5,00 mm** or d_h = **0.11968 inches** on scale C opposite **B 10.** At this setting, move cursor line **I continually** over the intersecting points between the curved lines.

z_1; z_2; z_3 — z_9 = } number of
n_1; n_2; n_3 — n_9 = } drafts.

with the horizontal lines.

a = 20,5 % or r = 20,5 per cent.

on table **H.** Under cursor line **I** on the front and the cursor line **IV** on the reverse side read off the following:

(a) **On scale C, the draft diameters d_1; d_2; d_3 — dz = dn = mm or inches which are the diameters.**

(b) **At the same time the increasing cross sectional area reduction A = R = % at each draft z = n = 1 to 9 on G.**

(c) **On table F on the reverse side of slide rules (a) and (b) on the right, the C content = 0,70 % (black figures) patenting tensile $^{\sigma}$B = 120 kp/mm² (red figures — right) and, depending on the drafts, z = 1 to 9, the increasing tensile to the finishing tensile $^{\sigma}$B = kp/mm².**

(d) **On table F_1 on the reverse side of slide rules (a) and (b) the content = 0,70 % (black figures), patenting tensile $^{\sigma}$L = 171 lb./sq. in.³ (red figures right) and, depending on the drafts mo = 1 to 9, the increasing tensile to the finishing tensile $^{\sigma}$L = 293 sq. in.³.**

The following factors are obtained in the scales and tables:

scale C	scale G	table F
d_1 = 4,45 mm;	A = 20,5 %;	$^{\sigma}$B = 131 kp/mm²
d_2 = 3,97 mm;	A = 37,0 %;	$^{\sigma}$B = 141 kp/mm²
d_3 = 3,54 mm;	A = 49,8 %;	$^{\sigma}$B = 150 kp/mm²
d_4 = 3,16 mm;	A = 60,0 %;	$^{\sigma}$B = 157 kp/mm²
d_5 = 2,82 mm;	A = 68,4 %;	$^{\sigma}$B = 164 kp/mm²
d_6 = 2,51 mm;	A = 74,8 %;	$^{\sigma}$B = 173 kp/mm²
d_7 = 2,23 mm;	A = 80,0 %;	$^{\sigma}$B = 182 kp/mm²
d_8 = 2,00 mm;	A = 84,0 %;	$^{\sigma}$B = 193 kp/mm²
dz = 1,775 mm;	A = 87,4 %;	$^{\sigma}$B = 206 kp/mm²

scale C	scale G	table F_1
d_1 = 0.1752 in.;	R = 20.5 p. c.;	$^{\sigma}$L = 186 lb./sq. in.³
d_2 = 0.1563 in.;	R = 37.0 p. c.;	$^{\sigma}$L = 201 lb./sq. in.³
d_3 = 0.1394 in.;	R = 49.8 p. c.;	$^{\sigma}$L = 212 lb./sq. in.³

scale C	scale G	table F_1
d_4 = 0.1244 in.;	R = 60.0 p. c.;	$^{\sigma}L$ = 223 lb./sq. in.³
d_5 = 0.1110 in.;	R = 68.4 p. c.;	$^{\sigma}L$ = 233 lb./sq. in.³
d_6 = *0.0988 in.;	R = 74.8 p. c.;	$^{\sigma}L$ = 246 lb./sq. in.³
d_7 = 0.0878 in.;	R = 80.0 p. c.;	$^{\sigma}L$ = 259 lb./sq. in.³
d_8 = 0.0787 in.;	R = 84.0 p. c.;	$^{\sigma}L$ = 275 lb./sq. in.³
dn = 0.0699 in.;	R = 87.4 p. c.;	$^{\sigma}L$ = 293 lb./sq. in.³

Note:

When setting cursor line **I** over the intersecting points **z = n = 1 to 9** with **a = r = 20,5 %** on table **H,** the result **$^{\sigma}B$ = kp/mm²** will be read on the reverse side on table **F** and **$^{\sigma}L$ = lb./sq. in.³** on table **F_1** under cursor line **IV.** At * move slide to other side.

EXAMPLE 2,1

As in example **1,5,** determine for **1,9** the diminishing unit cross sectional area reduction **a = r = %** for the draft diameters **d_1; d_2; d_3 .... dz = mm** or **d_1; d_2; d_3 .... dn = inches.** Also the increasing cross sectional area reduction **A = R** = % and the tensile strength **$^{\sigma}B$ = kp/mm²** or **$^{\sigma}L$ = lb./sq. in.³.**

Exit or starting diameter is patented steel wire **dh = 5,00 mm** or **dh = 0.1968 inches.** In example **1,9** under **(c) z = n = 9 drafts** with **a = r = 20,5 %** was determined.

Solution:

Add to the in e. g. **1,9** determined unit cross sectional area reduction **(a = r = 20,5 %)** per draft as follows:

At d_h on d_1 = mm or in., to a = r = 20,5 + 8,0 = 28,5 %
" d_1 on d_2 = mm or in., to a = r = 20,5 + 7,0 = 27,5 %
" d_2 on d_3 = mm or in., to a = r = 20,5 + 6,0 = 26,5 %
" d_3 on d_4 = mm or in., to a = r = 20,5 + 5,0 = 25,5 %
" d_4 on d_5 = mm or in., to a = r = 20,5 + 4,0 = 24,5 %
" d_5 on d_6 = mm or in., to a = r = 20,5 + 3,0 = 23,5 %
" d_6 on d_7 = mm or in., to a = r = 20,5 + 2,0 = 22,5 %
" d_7 on d_8 = mm or in., to a = r = 20,5 + 1,0 = 21,5 %
" d_8 on dz = mm or in., to a = r = 20,5 + 0,0 = 20,5 %

Place the exit or starting diameter **d_h = 5,00 mm** or **d_h = 0.1968 inches** opposite **D 10.** Slide cursor line **I over** the intersecting points of the determined unit cross sectional area reductions for the diminishing reduction on table **H.** Under cursor line **I** on the **front** and cursor line **IV** on the **reverse** side, the following factors can be read:

scale C	scale G	table F_1
d_1 = 4,23 mm;	A = 28,5 %;	σB = 136 kp/mm²
d_2 = 3,62 mm;	A = 47,6 %;	σB = 148 kp/mm²
d_3 = 3,14 mm;	A = 60,4 %;	σB = 157 kp/mm²
d_4 = 2,77 mm;	A = 69,3 %;	σB = 165 kp/mm²
d_5 = 2,47 mm;	A = 75,5 %;	σB = 174 kp/mm²
d_6 = 2,23 mm;	A = 80,0 %;	σB = 182 kp/mm²
d_7 = 2,05 mm;	A = 83,2 %;	σB = 191 kp/mm²
d_8 = 1,90 mm;	A = 85,6 %;	σB = 200 kp/mm²
dz = 1,775 mm;	A = 87,4 %;	σB = 206 kp/mm²

scale C	scale G	table F_1
d_1 = 0.1665 in.;	R = 28.5 p. c.;	σL = 193 lb./sq. in.³
d_2 = 0.1425 in.;	R = 47.6 p. c.;	σL = 211 lb./sq. in.³
d_3 = 0.1236 in.;	R = 60.4 p. c.;	σL = 223 lb./sq. in.³
d_4 = 0.1091 in.;	R = 69.3 p. c.;	σL = 235 lb./sq. in.³
d_5 = 0.0972 in.;	R = 75.5 p. c.;	σL = 248 lb./sq. in.³
d_6 = 0.0878 in.;	R = 80.0 p. c.;	σL = 259 lb./sq. in.³
d_7 = 0.0807 in.;	R = 83.2 p. c.;	σL = 271 lb./sq. in.³
d_8 = 0.0748 in.;	R = 85.6 p. c.;	σL = 285 lb./sq. in.³
dn = 0.0699 in.;	R = 87.4 p. c.;	σL = 293 lb./sq. in.³

Note:

When placing cursor line **I** over the intersecting points **z = n = 1 to 9** with **a = r = % diminishing** unit cross sectional area reduction on table **H**, σ**B = kp/mm²** will be read on table F_1 on the reverse side under cursor line **IV.** At move slide over to other side.

EXAMPLE 2,2

Determine for e. g. **1,9** the running time **t = min./100 kp** (metric system) or **t = min./100 lb.** (English system) at a drawing speed **c = 7,0 m/s** or **v = 1379 ft./min.**

Solution 1 (metric system)

Place one of the fixed symbols for iron and steel **F = 1.273** or **F_1 = 4.020** (marked on scale **C**) opposite **dz = 1,775 mm** on scale **D.** At this setting place cursor line **I** over the drawing speed **v = 7,0 m/s** on scale **E.** Under cursor line **I** read the following on scale **B:**

(a) **t = 12.3 min./100 kp at v = 7,0 m/s**

Now place the determined running time **t = 12.3 min./100 kp** on scale **B** opposite **60** on scale **A. Opposite B 1** on scale **A** read off:

(b) **m = 480 kp/h**

With the same setting read opposite A 100 on scale B:

(c) **tm = 0.202 h/100 kp**

Solution 2 (English system)

Place one of the fixed symbols for iron and steel **Fft = 1.934** or **Fft₁ = 6.116** (marked scale **C**) opposite **dn = 0.0699 inches** on scale **D.** At this setting place cursor line **I** over the drawing speed **v = 1379 ft./min.** on scale **E.** Under cursor line **I** read the running time t on scale **B** as follows:

(d) **t = 5.55 min./100 lb. at v = 1379 ft./min.**

Now place the running time **t = 5.55 min./100 lb.** on scale **B** opposite **60** on scale **A.** Opposite **B 100** on scale A read:

(e) **m = 1078 lb./h**

With the same setting read **opposite A 100** on scale **B:**

(f) **tm = 0.960 h/100 lb.**

Now place the theorectical production under (b) **m = 480 kp/h** or the production under (e) **m = 1078 lb./h opposite D 10.** Opposite the actual production on scale **C** read the percentage efficiency **Ag = %** on scale **D** as shown in e. g. **1,6.**

Note:

As seen in e. g.'s **1,9 to 2,2** all necessary factors in steel wire production can be achieved for all diameters **dz = mm** or **dn = inches** with slide rules **(a)** and **(b).**

These calculations take only a small fraction of the time that other calculations take so that time and expense is saved by using these slide rules.

SPECIAL EXAMPLE

(a) We are given a non-slip drawing machine (multiholer with wire accumulation) having **9 holes** and a drawing speed reduction of **25 %.** The reduction of the unit cross sectional area reduction **a = %** to be so that there is only the lowest possible wire accumulation.

Solution

Place the right-hand connecting line **B 100 to CI 1** opposite the intersecting point **z_9 = n_9 drafts** with **a = r = 25,1 %** on table **H.**

All exit diameters **do = mm** or **do = inches** that as factors and fractions on scale **C,** are opposite factors and fractions on scale **D** can be drawn with a much lower wire accumulation on the multihole machine providing the machine is capable of it.

All other factors are determined as in the preceding examples.

(b) A steel wire of unknown diameter having a tensile strength of **$^{\sigma}$B = 190 kp/mm²** or **$^{\sigma}$L = 270 lb./sq. in.³** is to be produced.

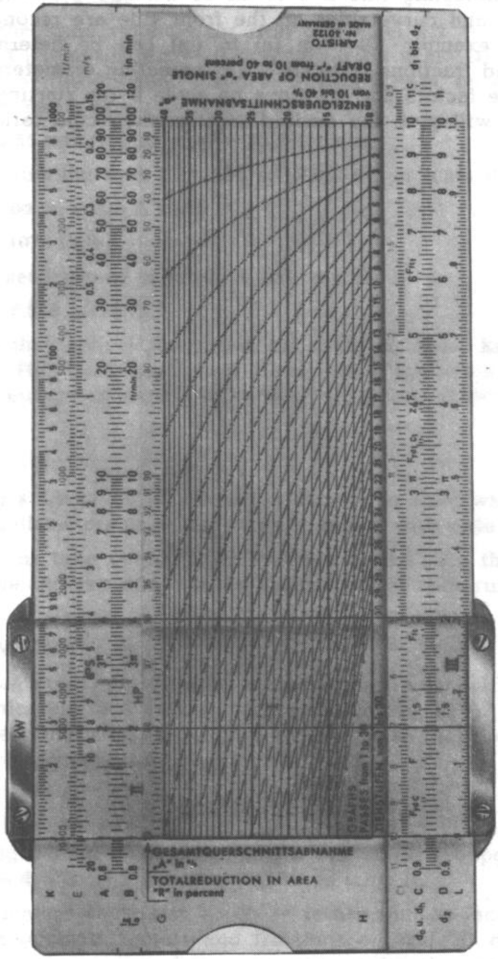
Solution

Place cursor line **IV** on the **reverse** side o v e r ,

(a) Tensile strength σ_B **= 190 kp/mm²** on table **F** or

(b) tensile strength σ_L **= 270 lb./sq. in.²** on table F_1

Then on the **front side,** place the r i g h t hand connecting line **B 100 to CI 1** or the l e f t hand connecting line **B 1 to CI 10** u n d e r cursor line **I.** By this movement, all scales and curvetables on the front side are reconnected so that all factors given in example **1,9** from **(a) to (m)** can be determined. At this setting, all factors and fractions on scale **C** (as patenting diameters d_h **= mm or** d_h **= inches)** opposite factors and fractions on scale **D** (as starting, intermediate and final diameters) will give the desired tensile when cold forming under **(a)** and **(b).**


GESAMTQUERSCHNITTSABNAHME
"A" in %
TOTALREDUCTION IN AREA
"R" in percent

INSTRUCTIONS

for Bar Forming

with

(a) UNIVERSAL SLIDE RULE "DRAHT" IWA 09 102

System: Kohlhase-Heuel

(b) UNIVERSAL POCKET SLIDE RULE "DRAHT" ARISTO 40 128

System: Kohlhase-Heuel

BAR FORMING

Whereas wire forming is usually a multi-draft process **(z = n drafts)**, Bar forming is always a single draft operation on draw benches **(z = n = 1 draft)**.
The reduction from exit diameter **(do = mm or do = inches)** or exit cross sectional area **(Fo = mm² or Fo = sq./in.)** to finishing diameter **(dz = mm or dn = inches)** or finishing cross sectional area **(Fz = mm² or Fn = sq./in.)** is usually expressed in mm or inches.

Round bar forming in coil is a continuous process whereby the basis material, after surface treatment, is drawn, straightened, polished and sheared. All other basis materials in bar form with round or profile sections are drawn on draw benches and, in the case of round bar, simultaneously straightened, polished and sheared in lengths.

It should be noted that when forming thicker materials the energy needed N_A = **PS** or P_{Dr} = **HP** will increase tremendously.

The factors for round steel, Iron and metal bar forming are determined by placing **do = mm** or **do = inches** on scale **C** opposite **dz = mm** or **dn = inches** on scale **D**, as given in the examples on wire forming, but only with **z = n = 1 draft.**

The factors for profile cross sectional areas are determined by placing **Fo = mm²** or **Fo = sq./in.** on scale **B** opposite **Fz = mm²** or **Fn = sq./in.** on scale **A.** Two materials have been chosen at random for the following examples.

Material 1. Free cutting steel **9 SPh 23,** Material No. **10716** with **C = 0,15 %, Mn = 0,50 to 0,90 %; P = 0,026 to 0,125 %; S and Pb = 0,15 to 0,30 %.**

Material 2. High Purity Steel **Ck 60,** Material No. **11221** with **C = 0,57** to **0,65 %; Si 0,15 to 0,35 %; Mn = 0,50 to 0,90 %; P + S = maximum of 0,035 %.**

EXAMPLE 2,3

Determine for forming material **1,** all factors by using slide rules **(a)** and **(b).** Exit cross sectional area to be **Fo = 283,53 mm²** or **Fo = 0.4395 sq./in.** and finished cross sectional area to be **Fz = 254,47 mm²** or **Fn = 0.3944 sq./in.**
Materials having large round or profile sections have been eliminated as they are not cold formed before being descaled and cleaned.

Solution

Make the basic setting by placing **Fo = 283,53 mm²** or **Fo = 0.4395 sq./in.** on scale **B** opposite **Fz = 254,47 mm ²** or **Fn = 0.3944 sq./in.** on scale **A.** This setting is identical for both units of measurement so that the slide need not be reversed.

Under the right hand connecting line **B 100** to **CI 1**, read off as follows on Table **H**, on scale **G** and on the other scales as follows:

(a) On scale **A**, the total cross sectional area reduction **A = R = 10 %**

(b) On Table **H**, unit cross sectional area reduction (reduction per draft)
a = r = 10 %

(c) „ „ **H**, at intersection **z = n = 1** draft with **a = r = 10 %**

(d) Opposite **A 1** on **B**, total elongation factor **E = 1.111**

(e) „ **B 100** on **A**, total remaining cross sectional area **Qv = 90 %**

(f) „ **A = R = 10** on scale A read on scale B:
(E — 1 × 100 %) or **E = 1.111 — 1 = 0.111 × 100 = 11,1 %**
elongation.

(g) „ L_0 = metres on scale **A** read Lz = metres final length on scale **B**
l_0 = yards on scale **A** read ln = yards final length on scale **B**
l_0 = feet on scale **A** read ln = feet final length on scale **B**

To determine the reduction in mm with the same setting, place the top left hand cursor line **II** opposite **Fz = 254,47 : 100 = 2,5447 mm² or Fn = 0.3944 sq./in.** on scale **A.**

Under cursor line **I**, read on scale **C** the diameter **do = 10,00 mm** or **do = 0.7480 inches** and on scale **D** the diameter **dz = 18,00 mm** or **dn = 0.7087 inches.**

EXAMPLE 2,4

Determine all factors for material 2 having sections of **Fo = 63,62 mm²** or **Fo = 0.0986 sq./in.** to **Fz = 50,27 mm²** or **Fn = 0.0779 sq./in.**

Solution

As in e. g. **2,3** place **Fo = 63,62 mm²** or **Fo = 0.0986 sq./in.** on scale **B** opposite **Fz = 50,27 mm²** or **Fn = 0.0779 sq./in.** on scale **A.** Under the right hand connecting line **B 100** to **CI 1**, read on table **H**; on scale **G** and on the other scales as follows:

(a) On scale **A**, total cross sectional area reduction **A = R = 21 %**

(b) On table **H**, unit cross sectional area reduction
a = r = 21 % with z = 1 draft
a = r = 11 % with z = 2 drafts.

(c) Opposite **A 1** on **B**, total elongation factor **E = 1,266**

(d) „ **B 100** on **A**, total remaining cross sectional area **Qv = 79 %**

(e) „ **A = R = 21 %** on scale **A**, read on scale **B** the elongation **(E — 1 × 100)** or
E = 1,266 — 1 = 0,266 × 100 = 26,6 %

(f) Opposite **Lo = metres** on scale **A** read **Lz = metres** final length on scale **B.**

l_0 = yards on scale **A** read **ln = yards** final length on scale **B.**

l_0 = feet on scale **A** read **ln = feet** final length on scale **B.**

To determine the reduction in mm, with the same setting, place the top left hand cursor line **II** over **Fz = 50,27 mm²** or **Fn = 0.0779 sq./in. (set Fn on left under 0.0779)** on scale **A.** Under cursor line **I** read on scale **C** the diameter **do = 9,00 mm** or **do = 0.3543 inches** and on scale **D** the diameter **dz = 8,00 mm** or **dn = 0.3149 inches.**

When cold forming material 2 with **a = r = 11 %** and **z = 2 drafts,** then **Fo = 63,62 mm²** or **Fo = 0.098 sq./in.** on scale **B** is placed opposite **100** on scale **A.** Move cursor line **I** over the intersecting points **z_1** and **z_2 (z = n)** with **a = r = 11 %** on table **H** and read off on scale **B** under cursor line **I** as follows:

for **z_1 = n_1** with **a = r = *21 %** on table **H,** further

for **z_2 = n_2** with **a = r = *21 %** on table **H**

an then on scale **C** under cursor line **I** read off the two single drafts as follows:

F_1 = 56,50 mm² or **F_1 = 0.0870 sq./in.**

F_2 = 50,27 mm² or **F_2 = 0.0779 sq./in.**

Explanation: **a = r = *21 %** is the total cross sectional area reduction. Because the reductions **F_1** and **F_2** set on scales **C and D** are the square roots of the reductions **F_1** and **F_2** on scales **B** and **A,** the above calculations can be achieved.

The values of materials **1** and **2,** the starting and finishing cross sectional areas **Fo = mm²** and **Fz = mm²** or **Fo = sq./in.** and **Fn = sq./in.** are given as examples, but any materials having any starting and finishing areas can be calculated by using slide rules **(a)** and **(b).**

EXAMPLE 2,5

To determine the length **Lo = m; l_0 = yd.** or **l_0 = ft.** for material **1,** place the elongation factor **E = 1.111** and for material **2** the elongation factor **E = 1.266** on scale **B** opposite **A 1.**

Solution

Opposite the starting lengths **Lo = m; l_0 = yd.** or **l_0 = ft.** on scale **A,** the finishing lengths **Lz = m; ln = yd.** and **ln = ft.** are read off on scale **B.**

EXAMPLE 2,6

Determine the weight G_M = **kp/m;** W_y = **lb./yd.** and W_F = **lb./ft.** for the starting cross sectional area **Fo = 283,53 mm²** or **F = 0.4395 sq./in.** and for the finishing cross sectional area **Fz = 254,47 mm²** or **Fn = 0.3944 sq./in.** for material **1** given in e. g. **2,3.**

Solution

Place cursor line **I** over the above mentioned areas on scale **A. Note: The next setting must be carefully followed. Place one of the fixed symbols**

F = 1.273 or **F_1 = 4.020**

Fyd = 1.117 or **Fyd_1 = 3.531**

Fft = 1.934 or **Fft_1 = 6.116**

for materials having a weight γ = **7,85 kp/dm³**, γ = **13231.6 lb./cu. yd.** or γ = **490.1 lb./cu. ft.** on scale **C,** under the bottom right hand cursor line **III.** With slide extended to right read off:

for **Fo = 283,53 mm²**	read G_M = **2,23 kp/m**	opposite	**B 1** on **A.**
" **Fo = 0.4395 sq./in.**	" W_y = **4.487 lb./yd.**	"	**B 1** on **A.**
" **Fo = 0.4395 sq./in.**	" W_F = **1.496 lb./ft.**	"	**B 1** on **A.**

At the same setting, the lengths are read off as follows:

for **Fo = 283,53 mm²**	read **L = 0,4493 m/kp**	opposite	**A 100** on **B.**
" **Fo = 0.4395 sq./in.**	" **l = 0.2229 yd./lb.**	"	**A 100** on **B.**
" **Fo = 0.4395 sq./in.**	" **l = 0.6686 ft./lb.**	"	**A 100** on **B.**

The setting is identical for all areas. With the slide extended to the left a reverse reading applies, under **A 1** on **B kp/m; lb./yd.; lb./ft.** and above **B 100** on **A m/kp; yd./lb.** and **ft./lb.**

Special note.

For other materials, the fixed symbol values are given in table **1** and used as above. In this way all materials depending on the area can have weight and length calculated as with material **1.**

EXAMPLE 2,7

It is allways interesting to the technician to know the net running time **t = min.** for a starting length **Lo = metres;** l_0 = **yards** or l_0 = **feet depending on the drawing speed v = m/s** and **v = ft./min.,** by using slide rules **(a)** and **(b).** Starting (or exit) lengths are taken as:

Lo = 10,00 metres

l_0 = **10.94** yards **(10 m × 1.09364 yd. = 10.94 yd.)**

l_0 = **32.28** feet **(10 m × 3.28080 ft. = 32.28 ft.)**

Solution

For drawing certain bar lengths the drawing speed (taken as an example) will be:

Lo = 10,00 metres at **v = 0,05 m/s** **(0,05 m/s × 60 min. =3,0 m/min.)**

l_0 **= 10.94** yards at **v = 3.28 ft./min.** **(1 m = 1.094 yd. × 3.0 m/min. = 3.28 ft./min.)**

l_0 **= 32.28** feet at **v = 9.84 ft./min.** **(1 m = 3.2808 ft. × 3.0 m/min. = 9.84 ft./min.)**

To determine the running time of a bar length **t = min.** (metric system), place cursor line **I** over **v = 0,50 m/s** for lengths in metres; over **v = 3.28 × 100 = 328 ft./min.** for lengths in yards and over **v = 9.84 × 100 = 984 ft./min.** for lengths in feet on scale **E.** Then place the connecting line **B 100** to **CI 1** under cursor line **I.** Opposite the lengths given in this example, **Lo = 10,00 m;** l_0 **= 10.94 yards** and l_0 **= 32.28 feet** on scale **B,** read the net running time **t = min.** on scale **A** as follows:

At **v = 0,05 m/s** opposite **Lo = 10,00 m** on **B,** read **t = 3.33 min.** on **A.**

„ **v = 3.28 ft./min.** „ l_0 **= 10.94 yd.** on **B,** read **t = 3.33 min.** on **A.**

„ **v = 9.84 ft./min.** „ l_0 **= 32.28 ft.** on **B,** read **t = 3.33 min.** on **A.**

The running time can be determined more easily by placing:

(a) **v = 3.00 m/min.** on scale **B** opposite **A 1**

(b) **v = 3.28 ft./min.** on scale **B** opposite **A 1**

(c) **v = 9.84 ft./min.** on scale **B** opposite **A 1**

At this setting, opposite the lengths **Lo = m;** l_0 **= yd.** and l_0 **= ft.** on scale **B** the same running time on scale **A, (t = 3.33 min.)** when **Lo = 10,00 m;** l_0 **= 10.94 yd.** and l_0 **= 32.28 ft.**

Irrespective of which basis material is to be cold formed, bar forming remains a single draft process and all factors can easily and quickly be determined by using slide rules **(a)** and **(b)** when the following facts are known:

1. **for r o u n d sections d = mm; d = inches.**
2. **for p r o f i l e sections F = mm²; F = sq./in.**

It is to be noted that variations will occur when:

(a) The setting is inaccurate,

(b) Inaccurate reading off or estimating,

(c) Incorrect placing of decimal.

If points **(a)** to **(c)** are adhered to when using slide rules **(a)** and **(b)** bar forming will be more efficient and time will be saved.

INSTRUCTIONS for TUBE FORMING

with

(a) **Universal Slide Rule „DRAHT" IWA 09102**
System: K o h l h a s e - H e u e l

(b) **Universal Pocket Slide Rule „DRAHT" ARISTO 40 128**
System: K o h l h a s e - H e u e l

TUBE FORMING

Tube forming from large down to small diameters is usually achieved by drawing on various types of draw bench.

Tube from various materials is usually drawn through a number of dies until the final or finishing diameter is achieved. When the forming limit is reached — which varies with each material — an annealing process occurs. The processing and the achieving of the most advantageous mechanical properties at the final stage depend on:

(a) the total cross sectional area reduction **A = R = % (per cent)**

(b) the unit cross sectional area reduction (reduction per single draft) **a = r = %**

(c) **z = n = total number of drafts**

(d) the draft diameters **D_1; D_2 — Dz = Dn = mm or inches**

(e) the inner tool or mandrel diameters in **mm** or **inches**

(f) the diameter of the necessary drawing dies in **mm** or **inches**

(g) the annealing treatment.

Determining the necessary factors from **(a)** to **(g)** in both units of measurement by using slide rules **(a)** and **(b)** is explained in the following examples. For the tube forming process, the following symbols — as with wire and bar drawing — have been used:

1. **Do; D_1; D_2 . . . Dz = mm** or **Do; D_1; D_2 . . . Dn = inches** for the external starting, intermediate and final diameters.
2. **di_0; di_1; di_2 . . . di_z = mm** or **di_0; di_1; di_2 . . . di_n = inches.** for the internal starting, intermediate and final diameters.
3. **to; t_1; t_2 . . . tz = mm** or **to; t_1; t_2 . . . tn = inches.** for the starting, intermediate and final wall thickness.

5. Average diameter **Do — to = Dm = mm** or **inches**
   = external diameter — wall thickness.

6. Average diameter **dio + to = Dm = mm** or **inches**
   = internal diameter + wall thickness.

EXAMPLE 1

Tube drawing without inner tool (Hollow drawing)

By this method, the external and internal diameter is reduced by an almost identical amount. The wall thickness can sometimes increase by 5 %, but can also decrease depending on the degree of forming, according to "Siebel und Weber", Stahl und Eisen 55 (1935) S. 331/34. In determining the factors for cold forming, these variations are ignored although practically, they should not be ignored.

Determine all factors for cold forming a tube without mandrel having:

(a) **Do = 35,00 mm** or **Do = 1.378 inches external diameter** to a final or finishing diameter of:

(b) **Dz = 25,40 mm** or **Dn = 100 inches.**

The internal diameter when starting to be:

(c) **di_o = 30,00 mm** or **di_o = 1.181 inches**

having a wall thickness of:

(d) **to = 2,50 mm** or **to = 0.09843 inches.**

The average diameter at **(a)** is:

(e) **Do = 35,00 mm — 2,50 mm = Dm = 32,50 mm**
Do = 1.378 in. — 0.09843 in. = Dm = 1.2796 in.

At the final diameter, the average diameter to be:

(f) **Dz = 25,40 mm — 2,50 mm = Dm = 22,90 mm**
Dn = 1.00 in. — 0.09843 in. = Dm = 0.90157 in.

From which follows the internal diameter **di_z = mm** or **di_n = in.**

(g) **Dm = 22,90 mm — 2,50 mm wall thickness = di_z = 20,40 mm.**
Dm = 0.90157 in. — 0.09843 in. wall thickness **di_n = 0.80314 in.**

Solution

The basic setting is exactly as for wire and bar drawing, by placing:

Do = 35,00 mm on scale **C** opposite **Dz = 25,40 mm** on scale **D** or

Do = 1.378 in. on scale **C** opposite **Dn = 0.09843 in.** on scale **D.**

With this setting, read under connecting line **B 100** with **CI 1** on scale **G,** on table **H** and on the other scales as follows:

1. On scale **G,** total cross sectional area reductions **A = R = 47,30 % (per cent)**
2. On table **H,** at the intersection of **a = r = %** with **z = n** number of drafts:

   (a) **a = r = 27,4 %** with **z = n = 2** drafts

   (b) **a = r = 19,1 %** with **z = n = 3** drafts

   (c) **a = r = 14,9 %** with **z = n = 4** drafts

   (d) **a = r = 12,0 %** with **z = n = 5** drafts

   (e) **a = r = 10,2 %** with **z = n = 6** drafts

   The choice of reduction per draft is dependant on the material.

3. Opposite **A 1.** Total elongation factor **E = 1.899**
4. " **Lo = m** on **A,** after forming **lz = m** is found on **B**
5. " **l_o = yd.** on **A,** after forming **ln = yd.** is found on **B**
6. " **l_o = ft.** on **A,** after forming **ln = ft.** is found on **B**
7. " **A = R = 47,30 %** on **A** read the elongation on **B. (E — 1 × 100 = %) 1,899 — 1 = 0,899 × 100 = 89,9 %**
8. " **D 1** on **C,** read the diameter ratio **(Do/dz)** on **(Do/Dn) = 1,378.**

EXAMPLE 2

Determine the separate external and internal draft diameters for cold forming the tube given in example 1 under **(a)**; ***(c)** and ***(e)**.

Solution

To determine the intermediate values for the separate drafts, place:

(a) **Do = 35,00 mm** or **Do = 1.378 in.** on scale **C**

*(c) **di_0 = 30,00 mm** or **di_0 = 1.181 in.** on scale **C**

*(e) **Dm = 32,50 mm** or **Dm 1.280 in.** on scale **C**

opposite **D 10** on scale **D.**

For cold forming the external diameters **Do = 35,00 mm** or **Do = 1.378 in.** the under 2/b determined unit cross sectional area reduction **a = 19,1 %** with three drafts has been chosen Whilst the choice of **z = 3** drafts is sufficient for **(a)**, for ***(c)** and **(e)**, the unit cross sectional area reductions are determined by the basic setting.

To determine these place:

*(c) **di_0 = 30,00 mm** or **di_0 = 1.181 in.** on scale **C** opposite

(h) **di_z = 20,40 mm** or **di_n = 0.80314 in.** on scale **D** and

*(e) **Dm = 32,50 mm** or **Dm = 1.280 in.** on scale **C** opposite

(g) **Dm = 22,90 mm** or **Dm = 0.90157 in.** on scale **D.**

Under the connecting line **B 100** with **CI 1** at the intersection with **z = 3 drafts** read:

for c on h the unit cross sectional area reduction

a = 22,6 % and for e on g the unit cross sectional area reduction

a = 20,9 %, on table **H.**

In determining the drafts as in **(a)**, **(c)**, and **(e)**, move cursor line **I** continuously across the intersections on table **H** for:

(a) **z_1; z_2; z_3** or **n_1; n_2; n_3** with **a = 19,1 %**

(c) **z_1; z_2; z_3** or **n_1; n_2; n_3** with **a = 22,6 %**

(e) **z_1; z_2; z_3** or **n_1; n_2; n_3** with **a = 20,9 %**

Under cursor line I on scale $\breve{C}$ we read off the following:

(a)	**Do = 35,00 mm;**	**Do = 1.378**	**inches**	starting external diameter
	D_1 = 31,40 mm;	**D_1 = 1.236**	**inches**	First draft diameter
	D_2 = 28,25 mm;	**D_2 = 1.112**	**inches**	second draft diameter
	D_z = 25,40 mm;	**Dn = 1.000**	**inches**	final external diameter
(c)	**di_0 = 30,00 mm;**	**di_0 = 1.181**	**inches**	starting internal diameter
	di_1 = 26,68 mm;	**di_1 = 1.050**	**inches**	first internal diameter

di_2 = 23,20 mm; di_2 = 0.9134 inches second internal diameter

di_z = 20,40 mm; din = 0.8031 inches final internal diameter

(e) **Dm_0 = 32,50 mm; Dm_0 = 1.280 inches**
Dm_1 = 28,98 mm; Dm_1 = 1.140 inches
Dm_2 = 25,75 mm; Dm_2 = 1.014 inches
Dm_z = 22,90 mm; Dmn = 0.9016 inches

} **to to tz = 2,50 mm** or **to to tn = 0.09843 in. remains the same.**

EXAMPLE 3

Depending on the number of drafts **z = n,** the unit cross sectional area reduction (reduction per draft) **a = r = %,** and the exit lengths **L_0 = m; l_0 = yd.** or **l_0 = ft.** determine the final lengths.

1. With **Do = 35,00 mm** and exit length **L_0 = 5,00 m**
2. With **Do = 1.378 in.** and exit length **l_0 = 5.47 yd.**
3. With **Do = 1.378 in.** and exit length **l_0 = 16.40 ft.**

Solution

The elongation from starting, **L = m; l = yd.** and **l = ft.** to finishing diameters is determined as follows:

Place the connecting line **B 100 to CI 1** over the intersection of **z_1 = n_1 = 1 draft** with **a = r = 19,1 %** (as determined in table **H** in example **1** under **2/b**).

With this setting, read off as follows:

1.	Opposite	**L_0 = 5,00 m**	on **A,**	read on	**B, L_1 = 6,18 m**	
	„	**L_1 = 6,18 m**	„ **A,**	„ „	**B, L_2 = 7,64 m**	
	„	**L_2 = 7,64 m**	„ **A,**	„ „	**B, Lz = 9,44 m**	final length
2.	„	**l_0 = 5.47 yd.**	„ **A,**	„ „	**B, l_1 = 6.76 yd.**	
	„	**l_1 = 6.76 yd.**	„ **A,**	„ „	**B, l_2 = 8.37 yd.**	
	„	**l_2 = 8.37 yd.**	„ **A,**	„ „	**B, ln = 10.35 yd.**	final length
3.	„	**l_0 = 16.40 ft.**	„ **A,**	„ „	**B, l_1 = 20.14 ft.**	
	„	**l_1 = 20.14 ft.**	„ **A,**	„ „	**B, l_2 = 25.10 ft.**	
	„	**l_2 = 25.10 ft.**	„ **A,**	„ „	**B, ln = 31.02 ft.**	**final length**

To determine the running time t = min., for the in 1., 2., and 3. determined lengths, refer to section "Bar forming" example 2,6.

Determining the cross sectional are $F = mm^2$; F = sq. in. the weight G_M = kp/m; W_y = lb./yd. and W_F = lb./ft.; the length L = m/kp; l = yd./lb. and l = ft./lb. are given in example 10 in "tube forming".

EXAMPLE 4

Tube drawing with mandrel

Determine all factors for cold forming a tube having:

D_o = 40,00 mm or **D_o = 1.575 in.** starting external diameter

di_o = 34,00 mm or **di_o = 1.339 in.** starting internal diameter

t_o = 3,00 mm or **t_o = 0.1181 in.** starting wall thickness

to the following final dimensions

D_z = 34,00 mm or **D_n = 1.339 in.** final external diameter

di_z = 28,00 mm or **di_n = 1.102 in.** final internal diameter

t_z = 3,00 mm or **t_n = 0.1181 in.** final wall thickness.

The cold forming (drawing) is achieved by using mandrels of various diameters **d = mm** or **d = inches**; depending on **z_1; z_2 .... z_z = n_1; n_2 .... n_n** = number of drafts and also the unit cross sectional area reduction (reduction in area per draft) **a = r = %.** By this process, only the outer and inner dimensions are reduced so that the inner wall retains the same smooth finish as the outer wall.

The wall thickness to to **t_z = mm** or to to **t_n = inches** remains the same throughout all drafts.

Solution

As in example 1, the basic setting is achieved as follows:

1. **D_o = 40,00 mm** or **D_o = 1.575 in.** on scale **C opposite**
   d_z = 34,00 mm or **D_n = 1.339 in.** on scale **D**
2. **di_o = 34,00 mm** or **di_o = 1.339 in.** on scale **C opposite**
   di_z = 28,00 mm or **di_n = 1.1034 in.** on scale **D**
3. **t_o = mm** or **t_o = in.** to **t_z = mm** or **t_n = in.** the wall thickness remaining the same.

Under the connecting line **B 100 to CI 1** read on scale **G,** on Table **H** and on the other scales as follows for No. 1:

1. (a) On scale **G,** the total cross sectional area reduction **A = R = 27,8 %**

   (b) On table **H,** at the intersections of the curved lines **(z = n = drafts)** with the straight lines **(a = r = %)** read the unit cross sectional areas off as follows:

   z_1 = n_1 drafts with a = r = 27,8 %

   z_2 = n_2 „ „ a = r = 15,0 %

   z_3 = n_3 „ „ a = r = 10,1 %

   (c) Opposite **A 1** on **B,** the total elongation factor, **E = 1.382**

   (d) „ **L_o = 5,00 mm** on **A,** a final length of **L_z = 6,83 mm** on **B**

(e) Opposite **l_o = 5.47 yd.** on **A**, **ln = 7.59 yd.** on **B**

(f) 〃 **l_o = 16.40 ft.** on **A**, **ln = 22.78 ft.** on **B**

(g) 〃 **A = R = 27,8 %** on **G**, total elongation

(E = 1.382 — 1 = 0.382 · 100 = 38,2 % on **B**

2. For No. **2**, the total and unit cross sectional area reductions are determined by placing:

di_o = 34,00 mm or **di_o = 1.339 in.** on **C** opposite

di_z = 28,00 mm or **di_n = 1.1034 in.** on **D**.

Under the connecting line **B 100** with **CI 1** read the following:

(i) On scale **G**, the total cross sectional area reduction **A = R = 32,10 %**

(j) On table **H**, at the intersection of **z_3 = n_3** drafts, read **a = r = 12,1 %** unit cross sectional area reduction which was determined under (b) as having **z = n = 3** drafts.

EXAMPLE 5

Determine the draft diameters for forming the tube in Example 4.

Solution

Place for No. **1**:

Do = 40,00 mm or **Do = 1.575 inches** and for No. **2**:

di_o = 34,00 mm or **di_o = 1.339 inches** opposite **D 10**.

At this setting slide cursor line **I** continuously over the intersections of **z = n** = number of drafts of:

1. **z_1** with **a = 10,1 %** or **n_1** with **r = 10.1 per cent**

   z_2 〃 **a = 10,1 %** 〃 **n_2** 〃 **r = 10.1 per cent**

   z_3 〃 **a = 10,1 %** 〃 **n_3** 〃 **r = 10.1 per cent**

2. **z_1** 〃 **a = 12,1 %** 〃 **n_1** 〃 **r = 12.1 per cent**

   z_2 〃 **a = 12,1 %** 〃 **n_2** 〃 **r = 12.1 per cent**

   z_3 〃 **a = 12,1 %** 〃 **n_3** 〃 **r = 12.1 per cent**

Under cursor line **I** on scale **C** read the following:

1. **Do = 40,00 mm** or **Do = 1.575 in. starting external diameter**

   D_1 = 37,80 mm or **D_1 = 1.488 in. first draft diameter**

   D_2 = 35,80 mm or **D_2 = 1.409 in. second draft diameter**

   Dz = 34,00 mm or **Dn = 1.339 in. final draft diameter**

2. di_0 = **34,00 mm** or di_0 = **1.339 in.** starting internal diameter

   di_1 = **31,80 mm** or di_1 = **1.252 in.** first mandrel diameter

   di_2 = **29,80 mm** or di_2 = **1.173 in.** second mandrel diameter

   di_z = **28,00 mm** or di_n = **1.102 in.** final mandrel diameter

The average diameters **Dm = mm** or **Dm = in.** are determined in example 2.

The wall thickness remains the same under this forming process when:

3. **tz = 3,00 mm** or **tn = 0.118 in.** final wall thickness.

EXAMPLE 6

Tube drawing with mandrel

Determine all factors for cold forming a tube having:

1. **Do = 38,00 mm** or **Do = 1.496 in.** external starting diameter

   di_0 = **28,00 mm** or di_0 = **1.102 in.** internal starting diameter

   to = 5,00 mm or **to = 0.1969 in.** starting wall thickness

to the following finished dimensions:

2. **Dz = 25,40 mm** or **Dn = 1.000 in.** final outside diameter

   di_z = **19,40 mm** or di_n = **0.7638 in.** final inside diameter

   tz = 3,00 mm or **tn = 0.1181 in.** final wall thickness

Attention! Contrary to examples 1 to 5, example 6 shows the reduction based on the external diameter **Do = mm** or **Do = inches** and the wall thickness **to = mm** or **to = inches** dependant on the total cross sectional area reduction **A = R = %**, the number of drafts **z = n** and the unit cross sectional area reduction (reduction per draft) **a = r = %**.

Solution

All factors are determined by placing the basic setting of:

1. **Do = 38,00 mm** or **Do = 1.496 in.** on scale **C** opposite

   Dz = 25,40 mm or **Dn = 1.000 in.** on scale **D**

2. di_0 = **28,00 mm** or di_0 = **1.102 in.** on scale **C** opposite

   di_z = **19,40 mm** or di_0 = **0.7638 in.** on scale **D**

3. **to = 5,00 mm** or **to = 0.1969 in.** on scale **C** opposite

   tz = 3,00 mm or t_n = **0.1181 in.** on scale **D.**

Under the connecting line **B 100** with **CI 1** (slide withdrawn to the left) or under the connecting line **B 1** with **CI 10** (slide withdrawn to the right), read on scale **G,** on table **H** and on the other undermentioned scales as follows:

1. (a) On scale **G**, total cross sectional area reduction $A = R = 55{,}40\,\%$

   (b) On table **H**, at the intersections of:

$z = n = 2$ drafts with $a = r = 33{,}1\,\%$ (per cent)
$z = n = 3$ „ „ $a = r = 23{,}6\,\%$ „ „
$z = n = 4$ „ „ $a = r = 18{,}2\,\%$ „ „
$z = n = 5$ „ „ $a = r = 14{,}9\,\%$ „ „
$z = n = 6$ „ „ $a = r = 12{,}6\,\%$ „ „
$z = n = 7$ „ „ $a = r = 10{,}9\,\%$ „ „

The choice of reduction per draft is dependant on the material.

(c) Opposite **A 1 on B**, the total elongation factor $E = 2{,}25$

(d) „ $L_o = m$ on **A**; $Lz = m$ on **B**

(e) „ l_o = yd. on **A**; ln = yd. on **B**

(f) „ l_o = ft. on **A**; ln = ft. on **B**

(g) „ $A = R = 55{,}40\,\%$ on scale **A**, $E = 2{,}25 - 1 = 1{,}25 \times 100 = 125\,\%$ total elongation.

(h) „ **D 1 on C**, diameter ratio (Do/Dz) or (Do/Dn) = 1,495.

Note: Although for forming the outside diameters $z = n = 5$ drafts have been chosen depending on the material, the same drafts will be used for the inside diameters and wall thickness. This is determined by the basic setting as in **1. (a)** and **(b)**. Read off for:

2. (i) On scale **G**, total cross sectional area reduction $A = R = 51{,}90\,\%$

   (j) On table **H**, with $z = n = 5$ drafts, $a = r = 13{,}7\,\%$ reduction per draft

3. (k) On scale **G**, total cross sectional area reduction $A = R = 64{,}0\,\%$

   (l) On table **H**, with $z = n = 5$ drafts, $a = r = 18{,}4\,\%$ reduction per draft

EXAMPLE 7

Determine for example **6** the separate draft diameters.

Solution:

When determining the draft diameters: $D_1; D_2 \ldots . Dz$ = mm; $D_1; D_2 \ldots . Dn$ = in.; $di_1; di_2 \ldots . di_z$ = mm; $di_1; di_2 \ldots . di_n$ = in.; and $t_1; t_2 \ldots . tz$ = mm; $t_1; t_2 \ldots . tn$ = in.: place on scale **C** opposite **D 10** the following:

1. **Do = 38,00 mm** or **Do = 1.496 in.**

2. di_o **= 28,00 mm** or di_o **= 1.102 in.**

3. **to = 5,00 mm or to = 0.1969 in.**

Now slide cursor line **I continuously** over the intersections of:

1. $z_0; z_1; z_2 \ldots z_5 = n_5$ drafts with **a = r = 14,9 %**
2. $z_0; z_1; z_2 \ldots z_5 = n_5$ drafts with **a = r = 13,7 %**
3. $z_0; z_1; z_2 \ldots z_5 = n_5$ drafts with **a = r = 18,4 %**

on table **H,** and read under cursor line **I** on scale **C** the forming drafts as for 1. to 3. as follows:

1. **Do = 38,00 mm** or **Do = 1.496 inches** starting outside diameter
   D_1 **= 35,00 mm** or D_1 **= 1.378 inches** 1st draft diameter
   D_2 **= 32,30 mm** or D_2 **= 1.272 inches** 2nd draft diameter
   D_3 **= 29,80 mm** or D_3 **= 1.173 inches** 3rd draft diameter
   D_4 **= 27,50 mm** or D_4 **= 1.083 inches** 4th draft diameter
   Dz = 25,40 mm or D_5 **= 1.000 inches** finishing outside diameter

2. di_0 **= 28,00 mm** or di_0 **= 1.102 inches** starting inside diameter
   di_1 **= 26,00 mm** or di_1 **= 1.024 inches** 1st mandrel diameter
   di_2 **= 24,20 mm** or di_2 **= 0.9488 inches** 2nd mandrel diameter
   di_3 **= 23,20 mm** or di_3 **= 0.9094 inches** 3rd mandrel diameter
   di_4 **= 21,55 mm** or di_4 **= 0.8484 inches** 4th mandrel diameter
   di_z **= 19,40 mm** or di_n **= 0.7638 inches** finishing inside diameter

3. **to = 5,00 mm** or **to = 0.1969 inches** starting wall thickness
   t_1 **= 4,52 mm** or t_1 **= 0.1780 inches** 1st draft wall thickness
   t_2 **= 4,06 mm** or t_2 **= 0.1598 inches** 2nd draft wall thickness
   t_3 **= 3,68 mm** or t_3 **= 0.1449 inches** 3rd draft wall thickness
   t_4 **= 3,33 mm** or t_4 **= 0.1311 inches** 4th draft wall thickness
   tz = 3,00 mm or **tn = 0.1181 inches** final wall thickness

To determine **Dm = mm** or **Dm = inches,** refer to example 1.

Attention!

To determine the weight G_M **= kp/m;** W_y **= lb./yd.** and W_F **= lb./ft.** as well as the length **L = m/kp; l = yd./lb.** and **l = ft./lb.,** refer to example **10.** When determining these values it is to be especially noted that the setting will differ.

Note:

The reduction per draft **a = r = %** is limited to **10 %** on slide rules **(a)** and **(b)**. In cold forming practice, it does occur (as seen in example 8) that reductions per draft of less than **a = r = 10 %** must be used for determining the factors for which the slide rules can be adapted.

EXAMPLE 8

Tube drawing with Mandrel.

Determine all factors cold forming a tube having:

Do = 30,00 mm or **Do = 1.181 in.** starting external diameter

di_0 = 25,00 mm or **di_0 = 0.9843 in.** starting internal diameter

to = 2,50 mm or **to = 0.0984 in.** wall thickness

to the following finished dimensions:

Dz = 25,40 mm or **Dn = 1.000 in.** external diameter

di_z = 22,40 mm or **di_n = 0.8819 in.** internal diameter

tz = 1,50 mm or **tn = 0.0591 in.** wall thickness

To determine the necessary factors for the tube forming, use the basic setting:

1. **Do = 30,00 mm** or **Do = 1.181 in.** on scale **C**, opposite
   Dz = 25,40 mm or **Dn = 1.000 in.** on scale **D.**
2. **di_0 = 25,00 mm** or **di_0 = 0.9843 in.** on scale **C**, opposite
   di_z = 22,40 mm or **di_n = 0.8819 in.** on scale **D.**
3. **to = 2,50 mm** or **to = 0.0984 in.** on scale **C**, opposite
   tz = 1,50 mm or **tb = 0.0590 in.** on scale **D.**

Under the connecting line **B 100** with **CI 1** (slide withdrawn to the left) or under the connecting line **B 1** with **CI 10** (slide with drawn to the right) read on scale **G**, on table **H** and the other undermentioned scales as follows:

1. (a) On scale **A**, total cross sectional area reduction **A = R = 28,4 %**

   (b) On table **H**, at the intersections of

   z = n = 1 draft with **a = r = 28,4 %**

   z = n = 2 drafts with **a = r = 15,3 %**

   z = n = 3 drafts with **a = r = 10,5 %**

   ***z = n = 4** drafts with **a = r = 7,1 %**

   The undeterminable reduction per draft a = r = % is achieved by dividing the total reduction by z = n = *4 drafts as follows:

A = R = 28,4 % ÷ *4 = 7,10 % reduction per single draft.

(c) Opposite **A 1 on B,** the total elongation factor **E = 1,39**

(d) " **L_0 = m** on **A, Lz = m** on scale **B**

(e) " **l_0 = yd.** on **A, ln = yd.** on scale **B**

(f) " **l_0 = ft.** on **A, ln = yd.** on scale **B**

(g) " **A = R = 28,4 %** on scale **A, E = 1,39 — 1 = 0,39 × 100 = 39 %** elongation on scale **B**

(h) " **D 1** on scale **C,** diameter ratio **(Do/Dz)** or **(Do/Dn) = 1,181.**
Attention! Though the forming of the outside diameters, depending on the material, had been chosen as z = n = *4 drafts, the same number of drafts must be used in forming the inside diameters and the wall thickness.

These are determined by the basic setting as in 1 (a) and (b). Read off as follows:

2. **(i) On scale G, total cross sectional area reduction A = R = 19,8 %**

(j) On table H, at the intersection of (not readable).

The unreadable reduction per draft a = r = % is achieved by dividing the total reduction by z = n = *4 drafts as follows:

A = R = 19,8 % ÷ *4 = 4,95 % reduction per draft.

For the forming of the wall thickness, read off as follows:

3. **(k) On scale G, total cross sectional area reduction A = R = 64,0 %**

(l) On table H, at the intersection of z = r = 4 drafts with a = r = 22,5 %

EXAMPLE 9

Determine for example 8 the unit cross sectional area reductions (reductions per single draft).

Solution

To determine the draft diameters **D1 .... Dz = mm** or **D1 .... Dn = in.** Slide the connecting line **B 100** with **CI 1** continuously over:

***a = r = 7,10 + 7,10 = 14,20 + 7,10 = 21,30 + 7,10 = 28,4 %**

for 1, and for 2 over:

***a = r = 4,95 + 4,95 = 9,90 + 4,95 = 14,85 + 4,95 = 19,8 %**

on scale **G.** Read for 1 opposite **Do = 30,00 mm** or **Do = 1.181 in.** the draft diameter and for 2 read opposite **di_0 = 25,00 mm** or **di_0 = 0.9843 in.** the inside diameter.

For 3, the wall thicknesses are as follows:

1.	D_o	= **30,00 mm** or D_o	= **1.181**	**inches** starting external diameter
	D_1	= **28,90 mm** or D_1	= **1.140**	**inches** 1st draft diameter
	D_2	= **27,60 mm** or D_2	= **1.096**	**inches** 2nd draft diameter
	D_3	= **26,60 mm** or D_3	= **1.050**	**inches** 3rd draft diameter
	D_z	= **25,40 mm** or D_n	= **1.000**	**inches** final external diameter
2.	di_o	= **25,00 mm** or di_o	= **0.9843**	**inches** starting internal diameter
	di_1	= **24,40 mm** or di_1	= **0.9561**	**inches** 1st mandrel diameter
	di_2	= **23,80 mm** or di_2	= **0.9335**	**inches** 2nd mandrel diameter
	di_3	= **23,10 mm** or di_3	= **0.9100**	**inches** 3rd mandrel diameter
	di_z	= **22,40 mm** or di_n	= **0.8819**	**inches** final mandrel diameter
3.	t_o	= **2,50 mm** or t_o	= **0.09843**	**inches** starting wall thickness
	t_1	= **2,20 mm** or t_1	= **0.08661**	**inches** 1st draft wall thickness
	t_2	= **1,93 mm** or t_2	= **0.07598**	**inches** 2nd draft wall thickness
	t_3	= **1,71 mm** or t_3	= **0.06700**	**inches** 3rd draft wall thickness
	t_z	= **1,50 mm** or t_n	= **0.05906**	**inches** final wall thickness

Dm = mm and **Dm = inches** are determined as in example 1.

Note

Examples **1 to 9** have shown the versatility of slide rules **(a)** and **(b)** in the tube forming process. These examples can naturally be adapted to other starting values and all factors can be determined according to them.

Apart from determining the necessary factors for the actual tube forming process, it may be of interest to the tube technician to quickly and accurately calculate any other relevant details.

The tube technician may wish to easily, and without complicated calculations and with the help of slide rules **(a)** and **(b)**, achieve the following:

(a) The weight G_M = **kp/m** and length **L = m/kp**

(b) The weight W_y = **lb./yd.** and length **l = yd./lb.**

(c) The weight W_F = **lb./ft.** and length **l = ft./lb.**

These are explained in the following example:

EXAMPLE 10

Determine for the tube dimensions in example 6 and having:

1. **Do = 38,00 mm** or **Do = 1.496 in.** starting external diameter
di_o = 28.00 mm or **di_o = 1.102 in.** starting internal diameter
to = 5,00 mm or **to = 0.1969 in.** wall thickness

2. **Dz = 25,40 mm** or **Dn = 1.000 in.** finishing external diameter
di_z = 19,40 mm or **di_n = 0.7638 in.** finishing internal diameter
tz = 3,00 mm or **tn = 0.1181 in.** finishing wall thickness

the weights and lengths of tubes having the in 1 and 2 given dimensions out of the following materials:

I. Steel or Iron
II. Copper
III. Aluminium

Solution:

First determine the average diameter **Dm** given in example under solution (e) and (g), as follows:

1. **Do = 38,00 mm — to = 5,00 mm = Dm = 33,00 mm** average starting diameter
2. **Dz = 25,40 mm — tz = 3,00 mm = Dm = 22,40 mm** average finishing diameter
1. **Do = 1.496 in. — to = 0.1969 in. = Dm = 1.2991 in.** average starting diameter
2. **Dn = 1.000 in. — tn = 0.1181 in. = Dm = 0.8819 in.** average finishing diameter

then determine the cross sectional area **F = mm²** or **F sq. in.** by the following equation.

1. $F = Dm \cdot \pi \cdot to$ [mm²]; $F = Dm \cdot \pi \cdot to$ = [sq. in.]
2. $F = Dm \cdot \pi \cdot tz$ [mm²]; $F = Dm \cdot \pi \cdot tn$ = [sq. in.]

Determining the cross sectional area by multiplication is achieved with the following setting:

Place for

1. **to = 5,00 mm** or **to = 0.1969 in.** on scale **CI** opposite
Dm = 33,00 mm or **Dm = 1.2991 in.** on scale **D.**

Or for,

2. **tz = 3,00 mm** or **tn = 0.1181 in.** on scale **CI** opposite
Dm = 22,40 mm or **Dm = 0.8819 in.** on scale **D.**

Note: CI = Reciprocal scale

Opposite π = **3.14** on scale **C** read the following on scale **D:**

1. **F = 518 mm²** or **F = *0.801 sq. in.** (* move slide to other side)
2. **F = 211 mm²** or **F = 0.327 sq. in.**

Then move cursor line I over the determined tube cross sectional area.

1. **F = 518 mm²** or **F = 0.801 sq. in.** on scale **A**
2. **F = 211 mm²** or **F = 0.327 sq. in.** on scale **A.**

Note: Determining the tube cross sectional area is the same for all materials.

At this setting place one of the following fixed symbols under cursor line III at the bottom right hand side of the cursor

I. Iron and Steel tube

F = **1.273** or **F_1** = **4.020**
Fyd = **1.117** or **Fyd_1** = **3.531** } Fixed on scale **C**
Fft = **1.934** or **Fft_1** = **6.116**

II. Copper tube

F = **1.192** or **F_1** = **3.770**
Fyd = **1.045** or **Fyd_1** = **3.305** } given in table 1
Fft = **1.810** or **Fft_1** = **5.725**

III. Aluminium tube

F = **6.867** or **F_1** = **2.171**
Fyd = **1.904** or **Fyd_1** = **6.020** } given in table 1
Fft = **1.043** or **Fft_1** = **3.293**

Note: With the slide withdrawn to the right read:

G_M = kp/m; W_y = lb./yd.; W_F = lb./ft. opposite **B 1**

and at the same time read opposite **A 100:**

L = m/kp; l = yd./lb.; l = ft./lb.

With the slide withdrawn to the left, the reverse is read off. At the above setting, the following results can now be read off:

I. Iron and Steel tube forming

***F** = **518 mm²**	**G_M = 4,066 kp/m**	and	**L = 0,246 m/kp**
***F** = **0.801 sq. in.**	**W_y = 8.197 lb./yd.**	„	**l = 0.122 yd./lb.**
***F** = **0.801 sq. in.**	**W_F = 2.733 lb./ft.**	„	**l = 0.366 ft./lb.**
****F** = **211 mm²**	**G_M = 1,656 kp/m**	„	**L = 0,604 m/kp**
****F** = **0.327 sq. in.**	**W_y = 3.328 lb./yd.**	„	**l = 0.300 yd./lb.**
****F** = **0.327 sq. in.**	**W_F = 1.113 lb./ft.**	„	**l = 0.894 ft./lb.**

II. Copper tube having:

***F** = **518 mm²**	**G_M = 4,641 kp/m**	„	**L = 0,216 m/kp**
***F** = **0.801 sq. in.**	**W_y = 9.356 lb./yd.**	„	**l = 0.107 yd./lb.**
***F** = **0.801 sq. in.**	**W_F = 3.119 lb./ft.**	„	**l = 0.321 ft./lb.**

**F = 211 mm² G_M = 1,891 kp/m and L = 0,529 m/kp

**F = 0.327 sq. in. W_y = 3.812 lb./yd. „ l = 0.262 yd./lb.

**F = 0.327 sq. in. W_F = 1.270 lb./ft. „ l = 0.787 ft./lb.

III. Aluminium tube having:

*F = 518 mm² G_M = 1,399 kp/m „ L = 0,715 m/kp

*F = 0.801 sq. in. W_y = 2.220 lb./yd. „ l = 0.451 yd./lb.

*F = 0.801 sq. in. W_F = 0.940 lb./ft. „ l = 1.064 ft./lb.

**F = 211 mm² G_M = 0,570 kp/m „ L = 1,755 m/kp

**F = 0.327 sq. in. W_y = 1.150 lb./yd. „ l = 0.870 yd./lb.

**F = 0.327 sq. in. W_F = 0.383 lb./ft. „ l = 2.612 ft./lb.

At * weight and length of starting tube ± the reading off accuracy

At ** weight and length of finishing tube ± the reading off accuracy.

With the help of the above examples, all necessary factors can be determined for cold forming tubes in any material from any starting and internal diameter.

When reading off results, the placing of the decimal point is important.

The tube circumference U = mm or U = inches is referred to in example 1,0, the surface area O = m²/kp or O = sq. in./lb. is referred to in example 1,1 (a), (b) and (c).

Examples 2,5 and 2,6 refer to:

(a) the tube lengths in meters, yards or feet after cold forming

(b) the running time t = min. for any given tube length

(a) The universal Slide rule "DRAHT" IWA 09 102,
System: Kohlhase-Heuel
will be obtainable approximately middle of 1965.

(b) The Universal Pocket Slide rule "DRAHT" ARISTO 40 128
System: Kohlhase-Heuel

will be obtainable middle of March 1965.

Obtainable from the technical book and slide rule publishers and distributers:

Hermann F. Heuel, Höhenstraße 63, D-8959 Hopfen am See

The following reports refer to slide rule (a) and (b) for determining all factors for

WIRE, BAR and TUBE FORMING,

in both units of measurement (metric and inches) as shown in the preceding examples.

REPORTS

Rhineland-Westphalian Technical High School at Aachen.

Institute for Industrial Forming

Auf Ersuchen der Firma F. KOHLHASE, Dortmund-Asseln, Wiscelusweg 7, wurde der UNIVERSAL-RECHENSCHIEBER „DRAHT" dem Institut für Bildsame Formgebung der Technischen Hochschule Aachen zwecks Prüfung auf seine Eignung für die Praxis und seine Anwendbarkeit in Forschung und Lehre überreicht.

Der neue Universal-Rechenschieber „DRAHT" von F. Kohlhase bietet dem Hersteller von Draht auf Grund seiner vielfältigen Anwendungsmöglichkeiten eine merkliche Hilfe. Die für die Drahtherstellung notwendigen jedoch zeitraubenden Berechnungen lassen sich bei Anwendung dieses Gerätes in ganz kurzer Zeit lösen.

Die Ermittlung von Zugzahl, Abnahmeverhältnis, Ziehgeschwindigkeit, Laufzeit, Durchsatz usw. kann sicher und schnell erfolgen. Es läßt sich z. B. für jeden einzelnen Zug bei Festsetzung der Abnahmestufung die jeweils zu erwartende Festigkeit in Abhängigkeit vom C-Gehalt, der Gesamtquerschnittsabnahme und der Patentierfestigkeit sofort ablesen. Dies möge an einem Beispiel näher erläutert werden:

Es ist ein Stahldraht herzustellen, der einen Enddurchmesser von $d_z = 0{,}95$ mm haben soll bei einer Zugfestigkeit $\sigma_B = 220$ kp/mm². Als Ausgangsmaterial steht ein Walzdraht $d_0 = 5{,}0$ mm mit einem C-Gehalt von 0,70 % zur Verfügung.

Mit nur einer Schieberstellung läßt sich folgendes ermitteln: Gesamtquerschnittsabnahme A = 90 % bei z = 9 Zügen mit jeweils a = 22,5 % Einzelquerschnittsabnahme. Der Enddrahtdurchmesser, $d_z = 0{,}95$ mm entspricht einem Patentierungs- oder Härtedrahtdurchmesser $d_h = 3{,}0$ mm bei einer Patentierfestigkeit $\sigma_B = 120$ kp/mm². Die Verlängerung beträgt $l_z/l_0 = 10$.

Der neue Rechenschieber erlaubt auch, neben der Stufung jeweils gleicher Einzelabnahmen, unterschiedliche Einzelquerschnittsabnahmen je Zug (sowohl steigend wie auch fallend) zu ermitteln.

Arbeitsbedarf und Leistungsaufnahme bei Einzelzug wie bei Mehrfachzug sind mit den gefundenen Werten und an Hand der auf der Rückseite des Schiebers angegebenen Formeln leicht zu bestimmen. Darüber hinaus erfüllt der Universal-Rechenschieber alle üblichen Funktionen eines gewöhnlichen Rechenschiebers. Er bietet weiterhin den Vorteil, sämtliche Berechnungen im metrischen und im Zoll-System durchzuführen, die für die Herstellung von Metalldrähten aus Aluminium, Blei, Chrom, Chromnickelstahl 18/8, Chromstahl 13 % Cr, Kupfer, Messing MS 63, MS 80 und MS 90, Monelmetall, Nickel und Phosphorbronze notwendig sind. Dieses dürfte für alle Betriebe von größtem Wert sein, die ein weites Exportprogramm zu erfüllen haben.

Die neu eingeführte auswechselbare Spezialzunge enthält auf einer Seite die Tabelle mit den Zug- und Patentierfestigkeiten $^{\sigma}$B kp/mm², auf der anderen Seite σL lb./sq. in. × 10³. Auf dem Stabkörper unter der Spezialzunge sind die spezifischen Gewichte und die festen F-Marken aufgetragen, was ein Suchen und Nachschlagen erübrigt.

Das Ausmaß des Rechenschiebers erlaubt es allerdings nicht, ihn ständig bei sich zu tragen. Dieser Nachteil — wenn man ihn als solchen bezeichnen will — wird aber durch seine universelle Anwendungsmöglichkeit und die dabei größere Ablesegenauigkeit wieder aufgehoben. Nach dem Studium der ausführlichen und mit vielen praktischen Beispielen versehenen Anleitung dürfte die Handhabung des neuen Rechengerätes keinerlei Schwierigkeiten mehr bereiten.

Auf Grund einer ausführlichen eigenen Prüfung dieses Rechenschiebers bei der Anwendung auf praktische Betriebsfälle kann versichert werden, daß seine leichte und schnelle Handhabung eine enorme Zeitersparnis bei seiner Anwendung mit sich bringt, so daß es zu wünschen wäre, daß sich der Universal-Rechenschieber in der Praxis weitgehend einführt.

Dipl.-Ing. K. Becker, Assistent im Institut für Bildsame Formgebung, Aachen.

gez. i. V. Prof. Dr.-Ing. E. h. Eilender.

Aachen, den 4. 2. 1959

GUTACHTEN

Dr.-Ing. Anton F. Mohrnheim, P. Eng. Associate Research,

Prof. of Metallurgy, University of Rhode Island, USA

Betr.: Universal-Rechenschieber „DRAHT" Aristo 90 103, System Kohlhase.

Der oben angeführte Rechenstab ist ein neuzeitliches, bequemes und nützliches Hilfsmittel für die gesamte Eisen-, Stahl- und Metalldrahtindustrie. Er ist vielseitig, übersichtlich und trägt die Merkmale gründlicher deutscher Präzisionsarbeit.

Rationelle Betriebsführung, erhöhte Anforderungen an mechanische Eigenschaften von Metallen sowie moderne Hochleistungs-Mehrfachziehmaschinen verlangen bei der Kaltverformung von Draht die Berechnung der Einzel- und Gesamtdrahtziehvorgänge und der Kalkulation. Meine langjährigen Erfahrungen in verschiedenen Metallwerken lehrten mich, daß beim Drahtziehen im allgemeinen zu wenig gerechnet und zu viel kostspielig und zeitraubend „ausprobiert" wird.

Es ist deshalb begrüßenswert, daß diese rechnerischen Manipulationen bei der Fertigung von Draht mit obigem Rechenstab schnell, mühelos und bei leichtester Handhabung ausgeführt werden können.

Die konsistent und kontinuierliche Durchführung von Berechnungen für die Fertigung von Draht ist m. E. von allen verantwortlichen Büro- und Betriebsangestellten durch alle Arbeitsstufen in einer fortschrittlichen Drahtindustrie eine wirtschaftliche und technische Notwendigkeit. Der Rechenstab ist der gesamten Drahtindustrie dafür als praktisches Hilfsmittel empfohlen.

Kingston, R. I. 16. Januar 1959.

gez. Dr. Anton F. Mohrnheim.

NOTIZEN

Druck: Paul Meier, Inhaber W. Schüler, 5800 Hagen 5