

## NAVIGATIONAL CALCULATING TOOLS

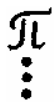
### DESIGNATION AND DEVICE OF THE NAVIGATIONAL SLIDE RULE NL-10M

The navigational slide rule **NL-10M** is a calculating tool for pilots and navigators and is intended for fulfilling the necessary calculations in the preparation of the flight and in-flight calculations.

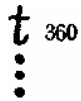
It is arranged according to the principle of the usual calculating slide rule and makes it possible to replace multiplication and division of numbers with simpler actions - by addition and subtraction of the scale sections which express on a specific scale the logarithms of these numbers.

The navigational slide rule consists of housing, cursor and boning rod. On the housing and the cursor are substituted the scales, indices, formulas and inscriptions (Fig. 47).

### SIGNS AND INDICES ON THE RULE



= **3.14** - length of the circle diameter ratio; it is located on scale 1 and it can be used for the solution of the problems connected to **определением** of the circle length;



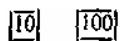
- It is located on scale 1. It serves for determining the time of the aircraft turn to 360°;




- It is located on scale 2 and identified by a red paint. It's used to transfer speeds expressed in km/h into speeds expressed in m/s and vice versa, it corresponds to division of 36;



- It is located on scale 2 and identified by a red paint. It serves for the solution of the problems connected with flight time determination, passed distance and ground speed, corresponds to the division of 60 min or 1 h (60 s or 1 min);



- They are located on scale 2 and they can be used as the initial or final primes of the scale;

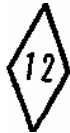
 - It is located by red paint on scale 4 and serves for the solution of problems regarding aircraft turn radius;



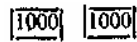
- It is located on scale 4. It corresponds to division of  $45^\circ$  and is used for the solution of the problems to enter the trigonometric angular functions;



- It is located on the cursor under scale 7 and serves for the solution of problems regarding the indications of barometric altimeters in flight up to an altitude of 12000 m;



- It is located on scale 12 and serves for the solution of problems regarding the indications of barometric altimeters in flight for altitudes more than 12000 m;



- They are located on scales 14 to 15 and serve for the designation of the decimal intervals of the scales. They are used for multiplication and division of numbers;

$10^\circ$  - On scale 4. It's used during the solution of problems regarding the time of the aircraft turn to  $360^\circ$ .

### SCALES ON THE RULE

**1, 2** - For calculating the flight time, ground speed and the solution of multiplication and division problems;

**1a** - For calculating turn parameters;

**4, 5, 8** - For determining the trigonometric angular functions, the solution of vector triangled by the theorem of sines and calculation of turn radius (bank angle);

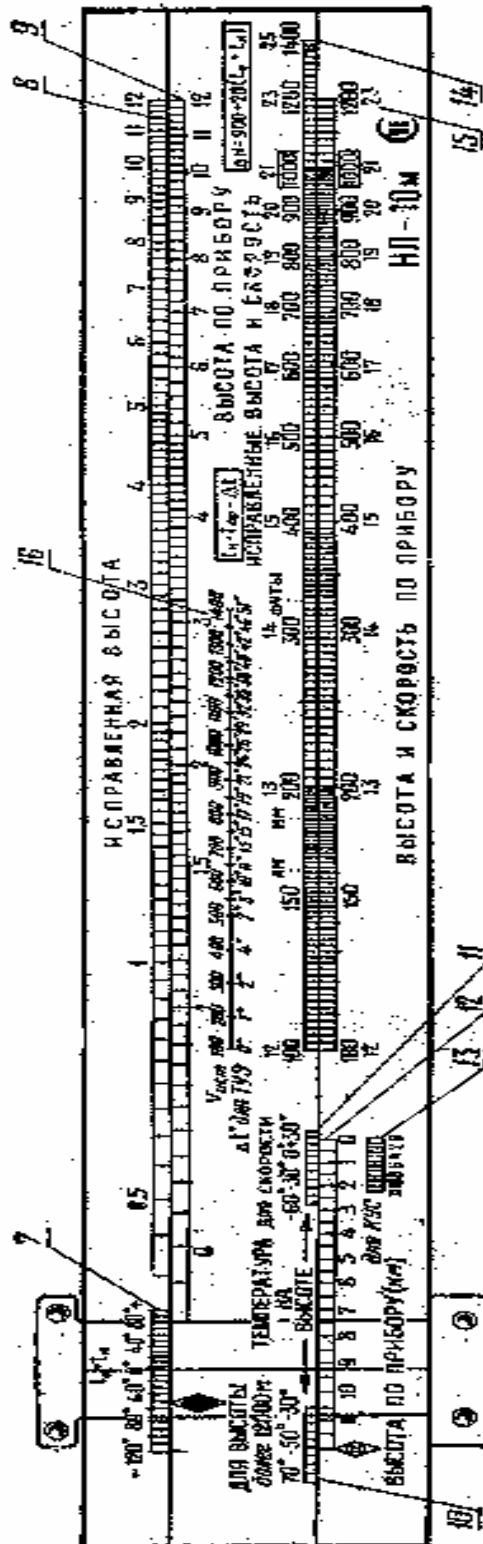
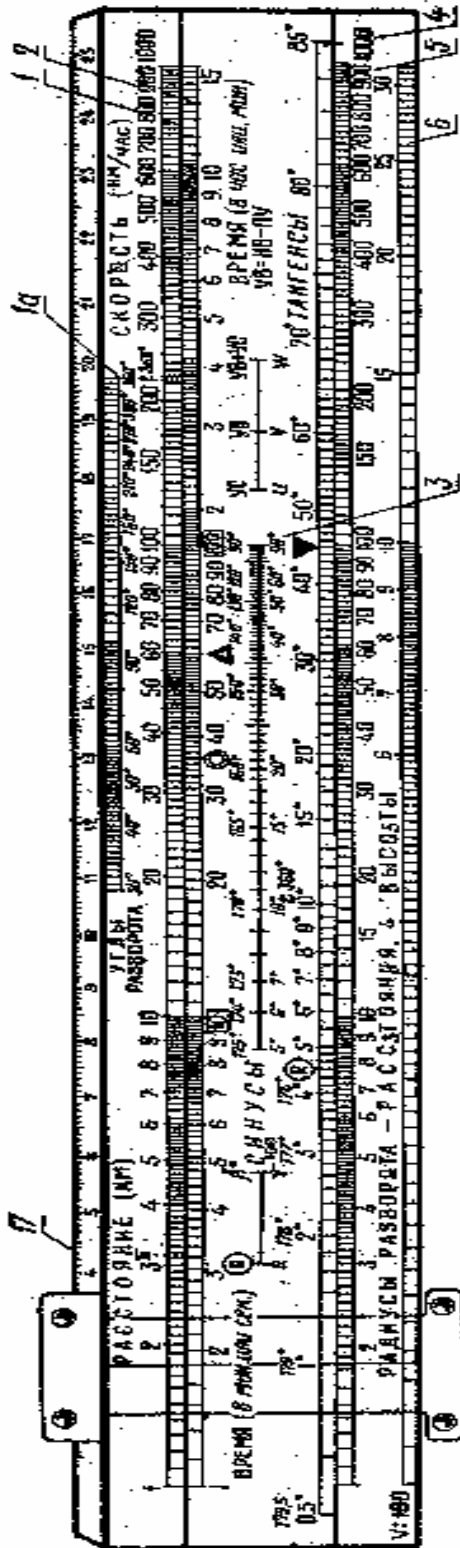


Fig. 47

Рис. 47. Навигационная линейка НЛ-10М

**6** - For squaring and extraction of square roots (together with scale 5 or 1 and 2);

**7, 8, S** - For the re-computation of flight altitude with  $N < 12000$  m;

**12, 14, 15** - For the re-computation of flight altitude with  $N > 12000$  m;

**12, 13, 14, 15, 16** - For the re-computation of airspeed;

**17** - For measuring the distances on the map.

Below are examined solutions of problems with the aid of navigational slide rule **NL-10M**.

### CONVERSION OF SPEEDS EXPRESSED IN KM/H INTO SPEEDS EXPRESSED IN M/S AND VICE VERSA

*Order conversion of speeds expressed in km/h into speed expressed in the m/s:*

Move the cursor to place the round index on the scale 1 that corresponds to the given speed in km/h to count off according to the scale 1 against the index  $\overline{10}$ , the desired speed in m/s.

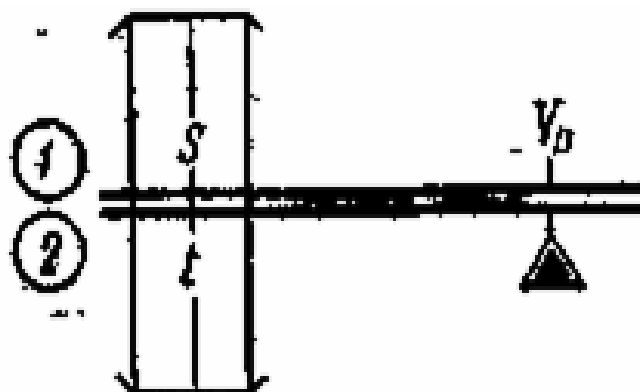
*Order conversion of speeds expressed into the m/s into the speeds expressed in the km/h:*

Move the cursor to place the index  $\overline{10}$  on the scale 1 that corresponds to the given speed in the m/s to count off according to the scale 1 against the round index the desired speed in km/h.

### CALCULATION OF GROUND SPEED ACCORDING TO THE PASSED DISTANCE AND FLIGHT TIME

*Order of solution:*

Place the boning rod according to scale 1 that corresponds to the passed distance of **5np** (Fig. 48);



*Fig 48 Calculation of ground speed according to the passed distance and flight time on NL-10.*

Move the cursor to place it under the boning rod of the scale 2 that corresponds to flight time ( $t$ ) to count off according to the scale 1 against the triangular index the desired ground speed ( $V_{II}$ ) in km/h.

*Examples:*

1. Given:  $S=115$  km;  $t=16$  min of 30 s. Result:  $V_{II} = 420$  км/ч.
2. Given:  $S=74$  km;  $t=27$  min of 30 s. Result:  $V_{II} = 162$  км/ч.

### **CALCULATION OF THE PASSED DISTANCE ACCORDING TO THE GROUND SPEED AND FLIGHT TIME**

*Order of the solution:*

Move the cursor to place the triangular index against the scale 1 that corresponds to the ground speed in km/h; place the mark of boning rod according to scale 2 that corresponds to the flight time to count off on the boning rod on scale 1 the desired distance in km.

*Examples:*

1. Given:  $V_{II} = 510$  км/ч;  $t=7$  min of 15 s. Result:  $S = 62$  km
2. Given:  $V_{II} = 124$  км/ч;  $t=8$  min of 35 s. Result:  $S = 7.7$  km

**Note:** If the flight time is measured in seconds, then it is necessary to place the round index against the ground speed value; the distance in this case will be expressed in the meters.

## CALCULATION OF FLIGHT TIME ACCORDING TO THE PASSED DISTANCE AND GROUND SPEED

*Order of the solution:*

Move the cursor to place the triangular index against the scale 1 that corresponds to ground speed; place the boning rod according to scale 1 that corresponds to the passed distance in km on scale 2 on the boning rod to count off the desired flight time.

*Example:*

Given:  $S=146$  km;  $V_{\Pi} = 350$  км/ч. Result:  $t=25$  min.

**Note:** If the passed distance is measured in the meters, then it is necessary to establish round index against the value of ground speed; flight time in this case will be expressed in seconds.

## CALCULATION OF COURSE CORRECTION ACCORDING TO DISTANCE AND LATERAL DEVIATION

*Order of the solution:*

Move the cursor to place the triangular index against the scale 5 which corresponds to the passed distance (Fig. 49a);

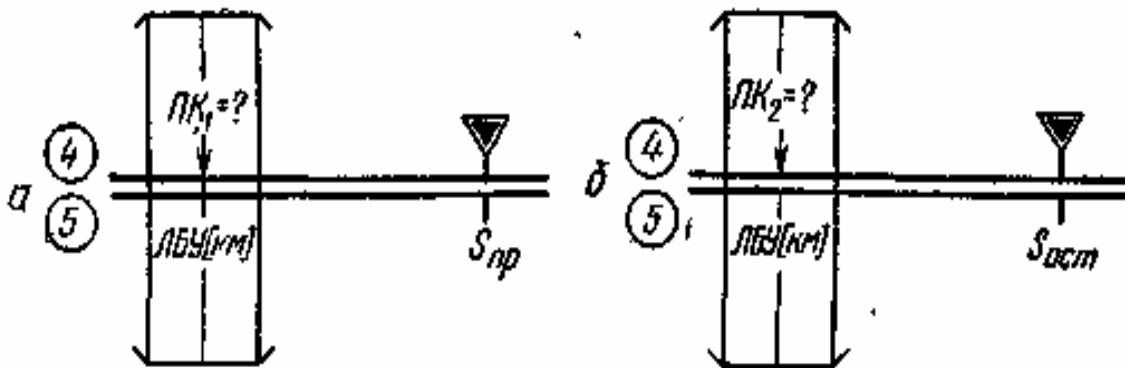


Fig. 49 Calculation of correction into the course on distance and lateral deviation for NL-10M.

Place the boning rod according to scale 5 that corresponds to lateral deviation in km to count off on the boning rod for scale 4; first course correction (for the output in parallel to specified track). Move the cursor to place the triangular index against the scale 5 that corresponds to the remained distance (see fig 49b) to count off on the boning rod for scale 4, second course correction, to accumulate

the first and second corrections. Sum will be the complete correction into the course.

*Example:*

Given:  $S_{np} = 65$  km;  $ЛБУ = 8$  km;  $S_{oct} = 90$  km. Result:  $ПК_1 = 7^\circ$ ;  $ПК_2 = 5^\circ$ ;  $ПК_{полн} = 12^\circ$ .

**Note:** If the lateral deviation in degrees is known and unknown the lateral deviation in the kilometers, then the problem of the definition of additional correction into course for the target approach **ППМ** is solved; then, as shown in Fig. 49, with the only difference that first against the boning rod (see Fig. 49a), we read the desired value not  $БУ^\circ$ , and we already calculate additional correction into the course from  $ЛБУ$  in km, as shown in Fig. 49b.

*Example:*

Given:  $S_{np} = 73$  км;  $БУ^0 = ПК^0 = 10^0$ ;  $S_{oct} = 125$  км. Result:  $ЛБУ = 13$  км;  $ПК_{доп} = ПК_2 = 6^0$ ,  $ПК_{полн} = БУ^0 + ПК_{доп} = 16^0$ .

The sign of correction into the course is determined according to the rule: if aircraft was deflected to the left, then the sign of correction is plus (+), if to the right, then the sign of correction is minus (-).

### **CALCULATION OF THE DRIFT ANGLE OF GROUND SPEED ACCORDING TO THE KNOWN WIND**

*Order of the solution:*

Place the boning rod according to scale 5 division that corresponds to the airspeed (Fig. 50), move the cursor to bring the scale 3 division under the boning rod that corresponds to wind angle  $УВ$ . If  $УВ$  is concluded within limits of 5 to  $90^0$  or 90 to  $175^0$  on scale 4 division or if  $УВ$  is concluded within limits of 0 to  $-5^0$  or  $175^0$  to  $-180^0$ .

**Note:** Wind angle is determined from the formula, placed to the right of scale 3:  $УВ = \delta - ПУ$  (wind direction minus track angle). It is necessary to count always less than  $180^0$ ; if it is more than  $180^0$ , it should be taken addition to  $360^0$  to establish boning rod to the scale division 5, which corresponds to speed of wind ( $W$ ), to count off on the boning rod on scale 3 (if drift angle is less than  $5^0$ , then according to scale 4) the desired drift angle  $УС$ .

To accumulate arithmetically wind angle and drift angle (with the wind angles less than  $90^0$ ) or to obtain their difference (with the wind angles more than  $90^0$ ), place the boning rod according to the scale 3 division that corresponds to the

sum  $YB + YC$  or the difference  $YB - YC$  to count off on the boning rod on scale 5 the desired ground speed  $V_{\Pi}$ .

*Examples:*

1. Given:  $V_{\text{ист}} = 620 \text{ км/ч}$ ;  $W = 120 \text{ км/ч}$ ;  $\delta = 152^\circ$ ;  $\text{МПУ} = 120^\circ$ . Result:  $YB = 32^\circ$ ;  $YC = +6^\circ$ ;  $V_{\Pi} = 720 \text{ км/ч}$ .

2. Given:  $V_{\text{ист}} = 280 \text{ км/ч}$ ;  $W = 45 \text{ км/ч}$ ;  $YB = 155^\circ$ . Result:  $YB = +4^\circ$ ;  $V_{\Pi} = 237 \text{ км/ч}$ .

**Note:** 1. Sign of removal will be minus (-) if  $YB$  is undertaken as addition to  $360^\circ$ . In the remaining cases the sign of removal will be plus (+).  
2. When  $YC$  will come out small (less than  $0.5^\circ$ ), it must be counted as equal 0, a  $V_{\Pi}$  calculated from the formula  $V_{\Pi} = V_{\text{ист}} \pm W$ .

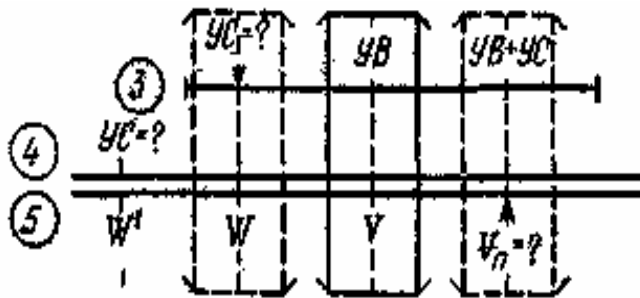


Fig. 50 Calculation of the drift angle and  $\Pi Y$  speed on the NL-10M

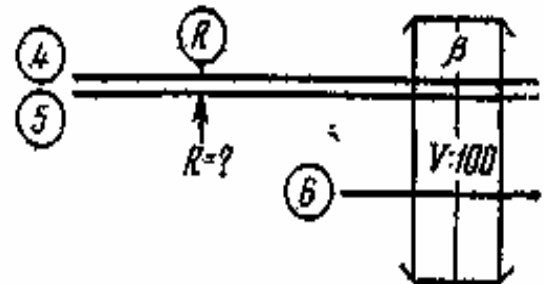


Fig. 51 Determination of the turn radius from the bank angle and the turn speed on NL-10M

### DETERMINATION OF TURN RADIUS FROM THE BANK ANGLE AND SPEED OF TURN

*Order of the solution:*

Place the boning rod according to scale 6 division that corresponds to the aircraft flight speed ( $V$ ) in km/h (Fig. 51). Move the cursor to place it under the boning rod the scale 4 division that corresponds to the aircraft bank angle ( $\beta$ ) to count off according to scale 5 against the index the desired value of aircraft turn radius ( $R$ ) in km or m (the key for the solution of this problem is placed on the rule to the left of scale 3).

**Note:** The established value can be reduced 10 or 100 times.

Examples:

1. Given:  $V = 650 \text{ км/ч}$ ;  $\beta = 15^\circ$ . Result:  $R = 12.4 \text{ км}$ .
2. Given:  $V = 140 \text{ км/ч}$ ;  $\beta = 20^\circ$ . Result:  $R = 420 \text{ м}$ .

### DETERMINATION OF THE TIME OF THE AIRCRAFT TURN WITH THE ASSIGNED RADIUS AND SPEED OF THE TURN

Order of the solution:

Place the boning rod according to scale 1 division that corresponds to the aircraft flight speed ( $V$ ) in km/h (Fig. 52). Move the cursor to place it under the boning rod the scale 2 division that corresponds to the turn radius ( $R$ ) to count off according to scale 2 against index  $t_{360}$  the desired time of aircraft turn on  $360^\circ$

Examples:

1. Given:  $V = 700 \text{ км/ч}$ ;  $R = 8.5 \text{ км}$ . Result:  $t_{360} = 4 \text{ min. } 35 \text{ s}$ .
2. Given:  $V = 240 \text{ км/ч}$ ;  $R = 1500 \text{ м}$ . Result:  $t_{360} = 2 \text{ min. } 22 \text{ s}$ .

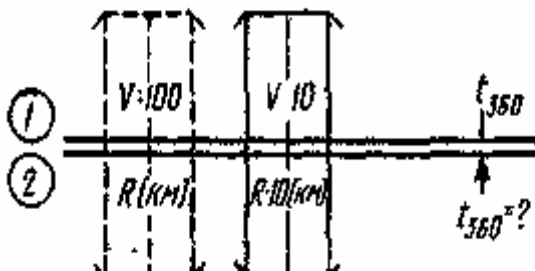


Fig. 52 Determination of the time of turn with the assigned radius and the speed of turn on NL-10M

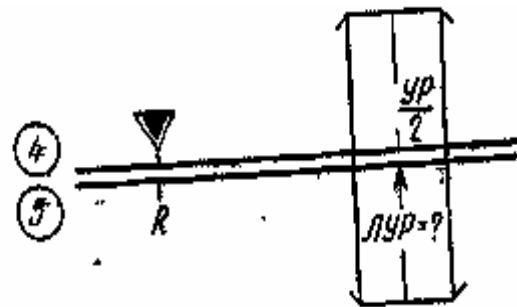


Fig. 53 Determination of linear lead of turn on NL-10M

**Note:** 1. With the turn radius to 10 km to decrease the speed 10 times and to establish in the second interval of scale 1; radius of turn to increase 10 times and to establish in the second interval of scale 2.

2. With the radius of turn is more than 10 km the speed to decrease 100 times and to establish in the first interval of scale 1, and radius of turn 3 km to establish in the first interval of scale 2.

## DETERMINATION OF LINEAR LEAD OF THE TURN

*Order of solution:*

Move the cursor to place the triangular index against the scale 5 division that corresponds to the radius value of turn (**R**) (Fig. 53); place the boning rod according to scale 4 division that corresponds to one-half angle of the aircraft turn ( $\frac{1}{2} \text{YP}$ ) to count off on the boning rod the desired value of linear lead of the turn (**JYP**).

*Example:*

Given:  $\text{YP}=120^\circ$ ;  $\text{R} = 9 \text{ км}$ . Result:  $\text{JYP}= 15.6 \text{ км}$ .