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CONTENTS

1 LABORATORY WORK №1. TOLERANCES, FITS, QUALITIES

1.1 The purpose of work

The purpose of work is to study the tolerance and fit systems, calculations of the tolerances, determination of the fits.

1.2 General notes

1.2.1 The tolerances

The tolerance *(IT, T)* is difference in dimension between admissible maximums and minimums.

The maximum and minimum dimensions are two values of dimensions between which there is real dimension (*D*) (figure 1.1).

The nominal dimension (D_{nom}) is the base dimension, determined for product allowing for its functional parameters, and usually is zero calculation reference of deviations.

The dimension deviation is algebraic difference between the dimension and its nominal value.

The high limited deviation (*ES, es*) is algebraic difference between the maximum dimension of hole or shaft and its nominal value.

$$ES = D_{\max} - D_{nom},$$

$$es = d_{\max} - D_{nom}.$$

The low limited deviation (*EI, ei*) is algebraic difference between the minimum dimension of hole or shaft and its nominal value.

$$EI = D_{\min} - D_{nom},$$

$$ei = d_{\min} - D_{nom}.$$

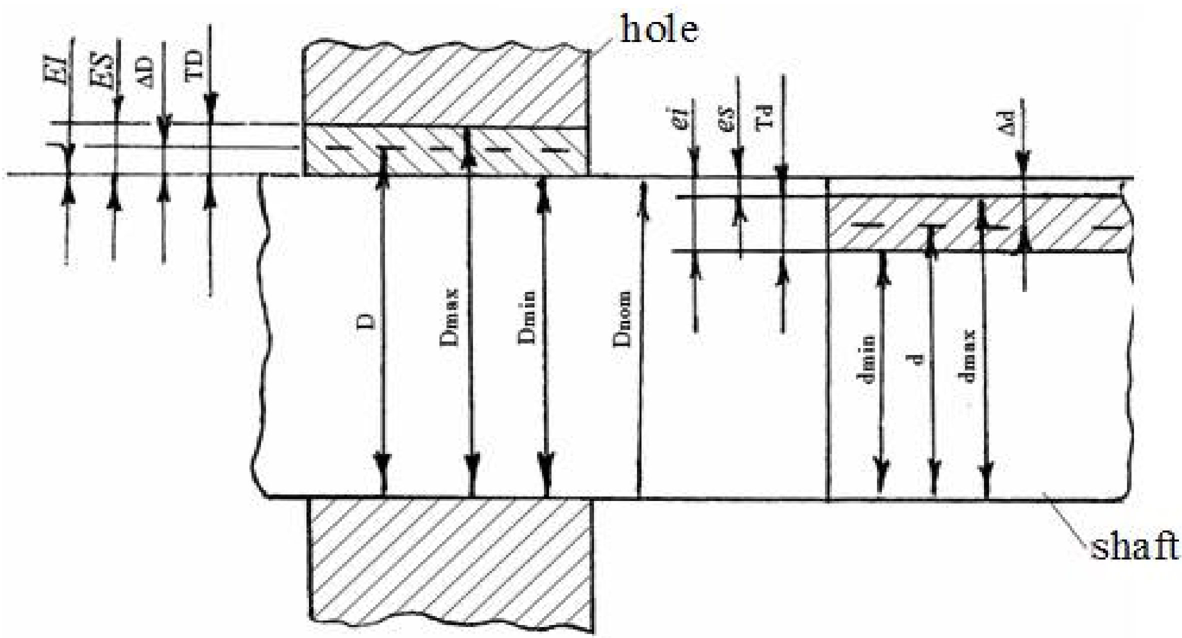


Figure 1.1 – The schema of fields of the tolerances and the limited deviations also the dimensions of hole or shaft

The real deviation (D) is difference between the minimum dimension of hole or shaft and its nominal value.

$$\Delta = D - D_{nom}.$$

The field of the tolerances can been schematically shown by rectangles, high and low sides of them correspond to high and low limited deviations (figure 1.2).

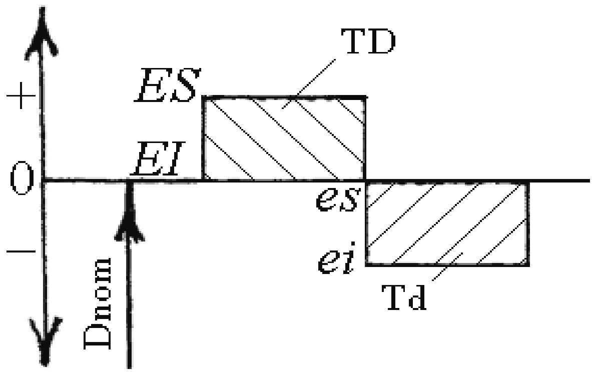


Figure 1.2 – The schematic showing of fields of the tolerances of hole or shaft

1.2.2 The fits

The fit is specification of detail joints, that determined by values gotten clearances and interferences.

There are such three forms of fits: with clearance, interference and transient ones.

The clearance fit is the fit that has always guaranteed clearance (*S*).

$$S_{\max} = D_{\max} - d_{\min},$$

$$S_{\min} = D_{\min} - d_{\max}.$$

The interference fit is the fit that has always guaranteed interference (N).

$$N_{\max} = d_{\max} - D_{\min},$$

$$N_{\min} = d_{\min} - D_{\max}.$$

The transient fit (P) is the fit that can has clearances and interferences.

The tolerance of fit (T) is account of the tolerances of hole or shaft.

$$T = TD + Td.$$

The tolerance of fits with clearances, interferences and transient fits can been calculated by formulas:

$$TS = S_{\max} - S_{\min},$$
$$TN = N_{\max} - N_{\min},$$
$$TP = S + N.$$

1.2.3 The qualities

The qualities are the complex of tolerances described the constant relative accuracy of nominal (rated) values with data range (for example, from 1 up to 500 mm).

The basis of tolerances and fits are 20 qualities 01; 0; 1 – 18. The qualities from 01 up to 4 are used for producing of the precise details and measuring devices, the qualities from 5 up to 14 – for assembles of details (fits) and qualities from 14 up to 18 - for producing of the details, which will not use for assembles.

On the drawings is usually written letter, which mean choosing fit and after it – number, which determines number of the quality. For example, Ø10H7 – for hole, Ø10h7 – for shaft, Ø10$\frac{H7}{h7}$ - for assembles (fits).

1.3 The steps of work execution

According to given variant (table 1.1) from tables 1.2 and 1.3 it is necessary to choose the nominal values and admissible deviations of the hole and shaft (*ES, EI, es, ei*), after that their limited values ($D_{\max}, D_{\min}, d_{\max}, d_{\min}$) and fits (*TD*, *Td*).

Then it is necessary to draw schematically the tolerances fields of hole and shaft (figure 1.1), to determine the created fit (with clearance, interference and transient ones).

On the scheme to show all created clearances and interferences, after that to calculate their limited values and fit tolerance.

1.4 The example

The assemble of hole and shaft (Ø100 $\frac{E6}{j_S 6}$), both are produced by sixth quality. From tables 1.2 and 1.3 it is determined for the hole Ø100 a high limit deviations is equal to *ES* = +0.94, and low one – *EI* = +0.072.

For the shaft a high limit deviations is equal to *es* = +0.011, and low one *ei* = - 0.011.

Let us calculate limited values of hole and shaft, also their tolerances.

$$D_{\max} = D_{nom} + ES,$$
$$D_{\max} = 100 + 0,094 = 100,094.$$

$$D_{\min} = D_{nom} + EI,$$
$$D_{\min} = 100 + 0,072 = 100,072.$$

$$TD = D_{\max} - D_{\min},$$
$$TD = 100,094 - 100,072 = 0,022.$$

$$d_{\max} = D_{nom} + es,$$
$$d_{\max} = 100 + 0,011 = 100,011.$$

$$d_{\min} = D_{nom} + ei,$$
$$d_{\min} = 100 - 0,011 = 99,989.$$

$$Td = d_{\max} - d_{\min},$$
$$Td = 100,011 - 99,989 = 0,022.$$

Let us draw the scheme of tolerance distribution of hole and shaft, and also fit created by its (figure1.3).

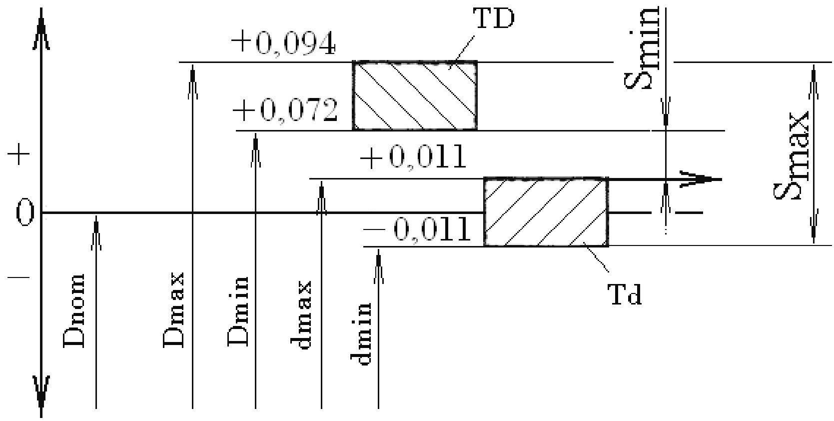


Figure1.3 – The schema of fields of the tolerances

You can see on figure 1.3 the limited values of hole (100,094 – 100,072) are more than limited values of shaft (100,011 – 99,989), and therefore the clearance will be inside assemble. It means appearance of the fit with clearance (*S*).

Let us calculate it’s limited values and show them by arrowed lines on scheme.

$$S_{\max} = D_{\max} - d_{\min},$$
$$S_{\max} = 100,094 - 99,989 = 0,105.$$

$$S_{\min} = D_{\min} - d_{\max},$$
$$S_{\min} = 100,072 - 100,011 = 0,061.$$

Let us calculate fit tolerances (*TS*).

$$TS = S_{\max} - S_{\min},$$
$$TS = 0,105 - 0,061 = 0,044.$$

Table 1.1 – The variants of work

Number of variant	The range of sizes (mm)	The fits and qualities
1	2	3
1	5	$\frac{H6}{h5}, \frac{H7}{h7}, \frac{H8}{r6}$
2	10	$\frac{H8}{s7}, \frac{H9}{d8}, \frac{H11}{j_S14}$
3	15	$\frac{H6}{d8}, \frac{H12}{r6}, \frac{H14}{j_S16}$
4	20	$\frac{H11}{d11}, \frac{H8}{u8}, \frac{H14}{j_S16}$
5	25	$\frac{H15}{j_S15}, \frac{H8}{s7}, \frac{H14}{j_S16}$
6	30	$\frac{H16}{j_S15}, \frac{H6}{n6}, \frac{H7}{j_S6}$
7	35	$\frac{H8}{s7}, \frac{H9}{f9}, \frac{H7}{j_S6}$

Continuation of table 1.1

1	2	3
8	40	$\frac{H6}{h6}, \frac{H8}{u8}, \frac{H7}{n6}$
9	45	$\frac{H16}{h14}, \frac{H8}{s7}, \frac{H14}{j_S16}$
10	50	$\frac{H9}{h6}, \frac{H6}{r6}, \frac{H11}{j_S14}$
11	55	$\frac{M5}{h5}, \frac{E6}{d8}, \frac{J_S5}{u8}$
12	60	$\frac{P5}{j_S6}, \frac{N5}{u8}, \frac{F5}{r6}$
13	65	$\frac{D9}{h14}, \frac{N6}{h7}, \frac{R7}{f7}$
14	70	$\frac{Z8}{d11}, \frac{R7}{d8}, \frac{F5}{h11}$
15	75	$\frac{M5}{h11}, \frac{H11}{u8}, \frac{E6}{f9}$
16	80	$\frac{K7}{n6}, \frac{Z8}{h7}, \frac{N5}{d9}$
17	85	$\frac{P5}{d9}, \frac{F5}{n6}, \frac{E6}{j_S16},$
18	90	$\frac{G6}{j_S15}, \frac{H9}{j_S6}, \frac{J_S5}{r6}$
19	95	$\frac{H11}{h14}, \frac{J_S5}{u8}, \frac{N6}{h5}$
20	100	$\frac{K7}{j_S6}, \frac{E6}{n6}, \frac{N6}{d9}$

Table 1.2 – The admissible deviations, tolerances and qualities for the nominal value range of the shafts

Number of variant	The range of sizes (mm)	The tolerances					
1	2	3	4	5	6	7	8
1	5	*h5*	0 -0,005	*r6*	+0,023 +0,015	*h7*	0 -0,012
2	10	*s7*	+0,038 +0,023	*d8*	-0,040 -0,062	j_s14	+0,180 -0,180
3	15	*d8*	-0,050 -0,077	*r6*	+0,034 +0,023	j_s16	+0,550 -0,550
4	20	*u8*	+0,074 +0,041	*d11*	-0,065 -0,195	j_s16	+0,650 -0,650
5	25	*s7*	+0,056 +0,035	j_s15	+0,420 -0,420	j_s16	+0,650 -0,650
6	30	*n6*	+0,028 -0,015	j_s6	+0,006 -0,006	j_s15	+0,420 -0,420
7	35	j_s6	+0,008 -0,008	*s7*	+0,068 +0,043	*f9*	-0,025 -0,087
8	40	*h6*	0 -0,016	*n6*	+0,033 +0,017	*u8*	+0,099 +0,060
9	45	*s7*	+0,068 +0,043	j_s16	+0,800 -0,800	*h14*	0 -0,620
10	50	*h6*	0 -0,016	*r6*	+0,050 +0,034	j_s14	+0,310 -0,310
11	55	*h5*	0 -0,013	*d8*	-0,100 -0,146	*u8*	+0,133 +0,087
12	60	j_s6	+0,010 -0,010	*r6*	+0,060 +0,041	*u8*	+0,133 +0,087

Continuation of table 1.2

1	2	3	4	5	6	7	8
13	65	*h7*	0 -0,030	*f7*	-0,030 -0,060	*h14*	0 -0,740
14	70	*d8*	-0,100 -0,146	*h11*	0 -0,190	*d11*	-0,290 -0,480
15	75	*u8*	+0,148 +0,102	*f9*	-0,104 -0,178	*h11*	0 -0,190
16	80	*n6*	+0,039 +0,020	*h7*	0 -0,030	*d9*	-0,100 -0,174
17	85	*n6*	+0,045 +0,023	*d9*	-0,120 -0,207	j_s16	+1,100 -1,100
18	90	j_s6	+0,011 -0,011	*r6*	+0,073 +0,051	j_s15	+0,700 -0,700
19	95	*h5*	0 -0,015	*u8*	+0,178 +0,124	*h14*	0 -0,87
20	100	*n6*	+0,045 +0,023	*d9*	-0,120 -0,207	j_s6	+0,011 -0,011

Table 1.3 – The admissible deviations, tolerances and qualities for the nominal value range of the holes

Number of variant	The range of sizes (mm)	The tolerances					
1	2	3	4	5	6	7	8
1	5	*H6*	+0,008 0	*H7*	+0,012 0	*H8*	+0,018 0
2	10	*H8*	+0,022 0	*H9*	+0,036 0	*H11*	+0,090 0
3	15	*H6*	+0,011 0	*H12*	+0,180 0	*H14*	+0,430 0
4	20	*H8*	+0,033	*H11*	+0,130	*H14*	+0,520
5	25	*H8*	+0,033	*H14*	+0,520	*H15*	+0,840

Continuation of table 1.3

1	2	3	4	5	6	7	8
6	30	*H6*	+0,013	*H7*	+0,021	*H14*	+0,520
7	35	*H7*	+0,025	*H8*	+0,039	*H9*	+0,062
8	40	*H6*	+0,016	*H7*	+0,025	*H8*	+0,039
9	45	*H8*	+0,039	*H14*	+0,620	*H16*	+1,600
10	50	*H6*	+0,016	*H11*	+0,160	*H9*	+0,062
11	55	J_S5	+0,006 -0,006	*M5*	-0,006 -0,019	*E6*	+0,079 +0,060
12	60	*N5*	-0,015 -0,028	*P5*	-0,027 -0,040	*F5*	+0,043 +0,030
13	65	*N6*	-0,014 -0,033	*R7*	-0,030 -0,050	*D9*	+0,174 +0,100
14	70	*F5*	+0,043 +0,030	*R7*	-0,042 -0,061	*Z8*	-0,172 -0,218
15	75	*M5*	-0,006 -0,019	*E6*	+0,079 +0,060	*H11*	+0,190
16	80	*N5*	-0,015 -0,028	*K7*	+0,090 -0,021	*Z8*	-0,172 -0,218
17	85	*F5*	+0,051 +0,036	*P5*	-0,032 -0,047	*E6*	+0,094 +0,072
18	90	J_S5	+0,008 -0,008	*G6*	+0,034 +0,012	*H9*	+0,087
19	95	J_S5	+0,008 -0,008	*N6*	-0,016 -0,038	*H11*	+0,220
20	100	*E6*	+0,094 +0,072	*N6*	-0,016 -0,038	*K7*	+0,010 -0,025

2 LABORATORY WORK №2. CALCULATION OF DIMENSION CIRCUITS

2.1 The purpose of work

The purpose of work is to study basis of the manufacture precision also technological methods of precision control of the details and assemblies of electric apparatus, rational choice of design and technological decisions.

2.2 General notes

2.2.1 The dimension circuits

The dimension circuit is complete circuit of dimensions, which determine the precision of relative placing of axis and surfaces of one or several details within assembly joint.

The dimension circuit, which determines the precision of relative placing of axis and surfaces of one detail, is called the detail dimension circuit. The dimension circuit, which determines the precision of relative placing of axis and surfaces of several details within assembly joint, is called the assembly dimension circuit.

Each dimension circuit has one circuit called locked one. All others have name of circuit components.

The circuit components are divided into magnifying and diminishing ones. The magnifying circuit is the part at increasing of which the locked circuit is increased too. The diminishing circuit is the part at increasing of which the locked circuit is decreased. The arrow is marked over sign (in case of magnifying circuit - from left to right and in case of diminishing circuit – from right to left).

2.2.2 Calculation of dimension circuits

The tasks of the verification and design calculations are decided by calculation circuits. The task of the **verification** calculation is determination of nominal size of the locked circuit and it tolerance accordingly to data nominal sizes and tolerances of circuit components.

The task of the **design** calculation is determination of nominal sizes and tolerances of the circuit components accordingly to data nominal sizes and tolerances of circuit components.

The calculation dimension circuits are realized by two methods: maximum-minimum method and probability one. The maximum-minimum method is used for calculation of dimension circuits at individual and small-lot production, and probability one – at quantity and mass production.

The verification calculation of dimension circuits by **maximum-minimum method** begins from determination of nominal size of locked circuit (A_Δ):

$$A_\Delta = \sum_{j=1}^{n} \overrightarrow{A_j} - \sum_{j=n+1}^{n+p} \overleftarrow{A_j},$$

where n – is the number of magnifying circuit;

p – is the number of diminishing circuit..

As a rule during calculation of dimension circuit it is used the half values of the tolerance fields $TA_j / 2$ and coordinate of middle tolerance field of circuit $E_c(A_j)$.

When one of limit deviation of component size is equal to zero, its tolerance is equal to absolute value of second deviation, and coordinate of middle tolerance field is equal to half value of this tolerance with sign, which has second deviation.

After determination these values it is calculated the tolerance TA_Δ and coordinate of middle tolerance field of locked circuit $E_c(A_\Delta)$:

$$TA_\Delta = \sum_{j=1}^{m-1} TA_j, \tag{2.1}$$

where TA_j – are tolerances of all circuit components;

m-1 = n+p.

$$E_c(A_\Delta) = \sum_{j=1}^{n} E_c(\overrightarrow{A_j}) - \sum_{j=n+1}^{n+p} E_c(\overleftarrow{A_j}).$$

The high and low limit deviations of locked circuit are determined by formulas:

$$E_s(A_\Delta) = E_c(A_\Delta) + TA_\Delta / 2,$$
$$E_i(A_\Delta) = E_c(A_\Delta) - TA_\Delta / 2.$$

The correctness of calculations can be checked by formulas:

$$A_\Delta^{\max} = \sum_{j=1}^{n} \overrightarrow{A_j^{\max}} - \sum_{j=n+1}^{n+p} \overleftarrow{A_j^{\min}},$$
$$A_\Delta^{\min} = \sum_{j=1}^{n} \overrightarrow{A_j^{\min}} - \sum_{j=n+1}^{n+p} \overleftarrow{A_j^{\max}}.$$

The probability method of calculation also is beginning from determination of nominal size of locked circuit, coordinate of middle tolerance field of component circuits. After that it is calculated the tolerance TA_Δ :

$$T_\Delta = \frac{1}{k_\Delta} \sqrt{\sum_{j=1}^{m-1} TA_j^2 \cdot k_j^2}\ , \qquad (2.2)$$

where k_Δ, k_j – are coefficients of relative dispersion (0,9 – 1,4).

The coordinate of middle tolerance field of locked circuit $E_c(A_\Delta)$ and the high and low limit deviations of locked circuit are determined by formulas of maximum-minimum method.

During design calculation the nominal value and limit deviations of locked circuit are given. At these values the nominal sizes of circuit components and their tolerances.

Data tolerance of locked (output) series is distributed among component series according to formulas (2.1) and (2.2). Then it is set limited deviations of dimensions of component series correspondingly to tolerances of component series dimensions.

After that correspondingly to tolerance values and coordinates of the tolerance field middle of the component series $E_c(A_j)$ it is determined a calculated tolerance value and limited deviations of locked series, and then compared with data values.

The calculations are continued until data and calculated values will be equaled.

2.3 The example

2.3.1 The task of verification calculation

The nominal values and limited deviations of the base shell of frequency converter (figure 2.1) are given:

$$N_1 = 2{,}3 \pm 0{,}04;$$
$$N_2 = 0{,}8 \pm 0{,}04;$$
$$N_3 = 1{,}2 \pm 0{,}04;$$
$$N_4 = 9{,}3^{+0{,}12}_{+0{,}04}.$$

The task is to determine nominal size, tolerance values and limited deviations of locked series.

Let us determine nominal size of locked series:

$$N_\Delta = \sum_{j=1}^{n} \overrightarrow{N_j} - \sum_{j=n+1}^{n+p} \overleftarrow{N_j},$$
$$N_\Delta = N_4 - (N_1 + N_2 + N_3) = 9{,}3 - (2{,}3 + 0{,}8 + 1{,}2) = 5.$$

Let us determine tolerance values of locked series by **the maximum-minimum method**:

$$TN_\Delta = \sum_{j=1}^{m-1} TN_j,$$
$$TN_\Delta = 0{,}08 + 0{,}08 + 0{,}08 + 0{,}08 = 0{,}32.$$

Let us determine the coordinate of the tolerance field middle of the locked series $E_c(N_\Delta)$:

$$E_c(N_\Delta) = \sum_{j=1}^{n} E_c(\overrightarrow{N_j}) - \sum_{j=n+1}^{n+p} E_c(\overleftarrow{N_j}),$$

$$E_c(N_\Delta) = E_c(N_4) - [E_c(N_1) + E_c(N_2) + E_c(N_3)] = 0,08 - 0 = 0,08.$$

Let us determine high and low limited deviations of the locked series:

$$E_s(N_\Delta) = E_c(N_\Delta) + TN_\Delta / 2,$$

$$E_i(N_\Delta) = E_c(N_\Delta) - TN_\Delta / 2.$$

$$E_s(N_\Delta) = 0,08 + 0,32 / 2 = 0,24,$$

$$E_i(N_\Delta) = 0,08 - 0,32 / 2 = -0,08.$$

The correctness of determination can be checked by formulas:

$$N_\Delta^{\max} = \sum_{j=1}^{n} \overrightarrow{N_j^{\max}} - \sum_{j=n+1}^{n+p} \overleftarrow{N_j^{\min}},$$

$$N_\Delta^{\min} = \sum_{j=1}^{n} \overrightarrow{N_j^{\min}} - \sum_{j=n+1}^{n+p} \overleftarrow{N_j^{\max}}.$$

$$N_\Delta^{\max} = 9,42 - (2,26 + 0,76 + 1,16) = 5,24,$$

$$N_\Delta^{\min} = 9,34 - (2,34 + 0,84 + 1,24) = 4,92.$$

Therefore: $N_\Delta = 5_{-0,08}^{+0,24}$ mm.

Let us determine tolerance values of locked series by **the probability method:**

$$TN_\Delta = \frac{1}{k_\Delta}\sqrt{\sum_{j=1}^{m-1} TN_j^2 \cdot k_j^2}$$

Let us take into account $k_\Delta = k_j = 1$.

$$TN_\Delta = \sqrt{4 \cdot (0,08)^2} = 0,16\,.$$

Let us determine the coordinate of the tolerance field middle of the locked series $E_c(N_\Delta)$:

$$E_c(N_\Delta) = E_c(N_4) - [E_c(N_1) + E_c(N_2) + E_c(N_3)] = 0,08 - 0 = 0,08.$$

Let us determine high and low limited deviations of the locked series:

$$E_s(N_\Delta) = E_c(N_\Delta) + TN_\Delta / 2;$$
$$E_i(N_\Delta) = E_c(N_\Delta) - TN_\Delta / 2.$$
$$E_s(N_\Delta) = 0,08 + 0,16/2 = 0,16;$$
$$E_i(N_\Delta) = 0,08 - 0,16/2 = 0.$$

Therefore: $N_\Delta = 5^{+0,16}$ mm.

2.3.2 The task of design calculation

The dimension value between support basis flange and slot ($N_\Delta = 5,0^{+0,16}$) of the indicated base shell of frequency converter (figure 2.1) are given.

The task is to determine nominal sizes of it dimension components and their tolerances.

After analyzing of the design (construction) of product and requirements to it during operation let us give as the component sizes of base shell such nominal values:

$$N_1 = 2{,}3;$$
$$N_2 = 0{,}8;$$
$$N_3 = 1{,}2;$$
$$N_4 = 9{,}3\ .$$

After that let us determine the designed size of locked series and compare it with given value:

$$N_\Delta = \sum_{j=1}^{n} \overrightarrow{N_j} - \sum_{j=n+1}^{n+p} \overleftarrow{N_j}\ ,$$

$$N_\Delta = 9{,}3 - (2{,}3 + 0{,}8 + 1{,}2) = 5{,}0\ .$$

The received result indicates correctness of calculated value of locked series at correctly determined sizes of component series and therefore coincides with given values.

Let us determine the limited deviations of the locked series accordingly to given value of deviation of it size:

$$E_s(N_\Delta) = 0{,}16; \qquad E_i(N_\Delta) = 0; \qquad E_c(N_\Delta) = 0{,}08.$$

After a new analyzing of the design (construction) of base shell and requirements to it during operation let us divide a given value of the tolerance field for the locked series between the component series:

$$T_c N_j = 0{,}04\ .$$

Let us give high and low limited deviations of the N_4 section of the dimension series:

$$E_s(N_4) = 0{,}1; \qquad E_i(N_4) = 0{,}06; \qquad E_c(N_4) = 0{,}08.$$

In a practicable manufacture the highest limiting deviations are assigned, when obtaining of some detail dimensions become complicated because of different conditions.

Let us take limiting deviations for other component series equal to:

$$E_s(N_{1-3}) = +0,02; \qquad E_i(N_{1-3}) = -0,02; \qquad E_c(N_{1-3}) = 0.$$

Let us calculate design tolerance of locked (output) series by design values of component series tolerances:

$$TN_\Delta = \sum_{j=1}^{m-1} TN_j,$$

$$TN_\Delta = 0,04 \times 4 = 0,16.$$

Design value of locked (output) series tolerance coincides with a given one that is the evidence of correct choice of design values of component series tolerances.

Let us determine coordinate of tolerance zone midpoint of locked (output) series $E_c(N_\Delta)$:

$$E_c(N_\Delta) = E_c(N_4) - [E_c(N_1) + E_c(N_2) + E_c(N_3)] = 0,08 - 0 = 0,08.$$

Let us determine lower and upper limiting deviations of locked (output) series:

$$E_s(N_\Delta) = E_c(N_\Delta) + TN_\Delta / 2;$$
$$E_i(N_\Delta) = E_c(N_\Delta) - TN_\Delta / 2.$$
$$E_s(N_\Delta) = 0,08 + 0,16 / 2 = 0,16;$$
$$E_i(N_\Delta) = 0,08 - 0,16 / 2 = 0.$$

That is $N_\Delta = 5^{+0,16}$ mm.

Set and calculated values coincide with each other.

2.4 The task

2.4.1 The task of checking calculation of dimension circuits

To perform a task by a variant, that is shown in the table 2.1.

Nominal dimensions and limiting deviations of component dimensions of transformer current-carrying terminal (figure 2.2) are given. The task is to calculate the nominal dimension, tolerance, admissible limiting deviations of dimensions between right face of a flange and the place of terminal fixed key installation for providing complete interchangeability when current transformer rated up to 500 kV is designed.

Then it is required to make dimension circuit, determine component augmenting and reductive series and also locked (output) series for solving of a given problem.

The next step is to perform the same calculations for details represented on figures 2.3-2.6.

2.4.2 The task of designed calculation of dimension circuits

Nominal dimension and tolerance for center-to-center dimension of a flange of transformer current-carrying terminal (figure 2.2) are set. It is needed to calculate the nominal dimensions, tolerances, admissible limiting deviations on component dimensions of one side of a flange of current-carrying terminal.

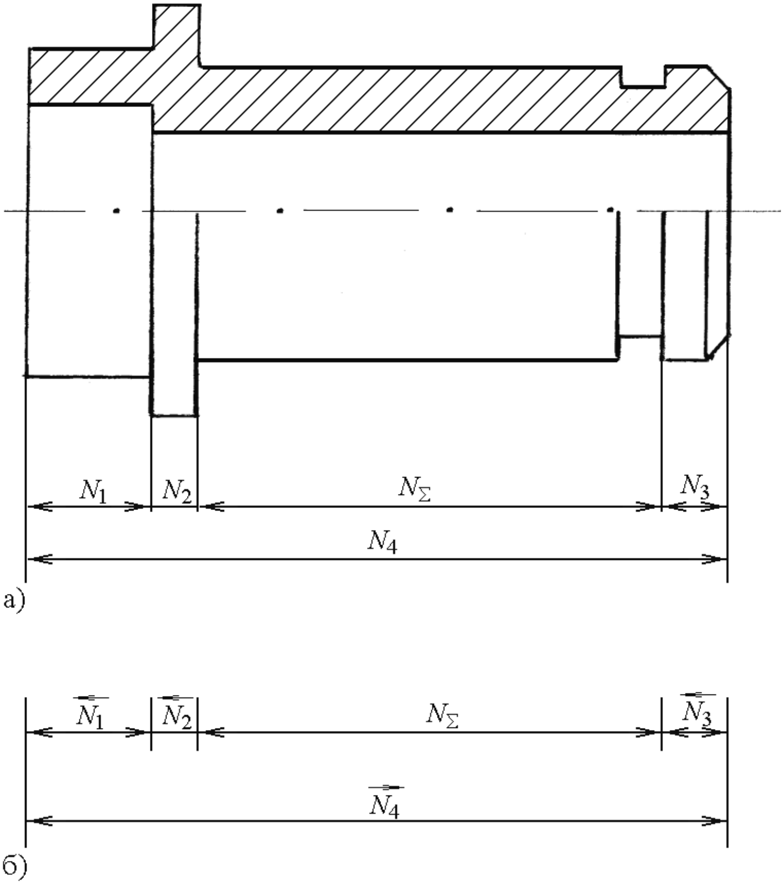
Then it is necessary to perform the same calculations for details represented on figures 2.3-2.6.

Table 2.1 – Table of variants

№ of variant	Type of calculation	The method of calculation	№ of figure	Given data	Unknown data
1	2	3	4	5	6
1	Checking	Max – min	2.2	$N1=244_{-0,85}$; $N2=44^{+0,62}$; $N4=87^{+0,43}$; N5=105±1,1	N3
2	Checking	Probable	2.2	$N1=244_{-0,85}$; $N2=44^{+0,62}$; $N4=87^{+0,43}$; N5=105±1,1	N3
3	Designed	Max – min	2.2	$N7=72^{+0,20}$	N8, N9
4	Designed	Probable	2.2	$N7=72^{+0,20}$	N8, N9
5	Checking	Max – min	2.3	$N1=189_{-0,7}$; $N2=35^{+2,5}$; N8=134±0,04	N5
6	Checking	Probable	2.3	N1=189-0,7; N2=35+2,5; N8=134±0,04	N5
7	Designed	Max – min	2.3	N2=35+2,5	N1, N8, N5
8	Designed	Probable	2.3	N2=35+2,5	N1, N8, N5
9	Checking	Max – min	2.4	N1=900±1; N2=50+0,4; N3=50+0,4	N4

Continuation of table 2.1

1	2	3	4	5	6
10	Checking	Probable	2.4	N1=900±1; N2=50+0,4; N3=50+0,4	N4
11	Designed	Max – min	2.4	N6=12+0,43	N1, N5, N7
12	Designed	Probable	2.4	N6=12+0,43	N1, N5, N7
13	Checking	Max – min	2.5	N1=10-0,4; N3=30±0,5; N4=100±0,8	N2
14	Checking	Probable	2.5	N1=10-0,4; N3=30±0,5; N4=100±0,8	N2
15	Designed	Max – min	2.5	N5=4-0,12	N6, N7
16	Designed	Probable	2.5	N5=4-0,12	N6, N7
17	Checking	Max – min	2.6	N1=36-0,62; N3=30-0,15; N4=1±0,3	N2
18	Checking	Probable	2.6	N1=36-0,62; N3=30-0,15; N4=1±0,3	N2
19	Designed	Max – min	2.6	N6=10+0,08	N5, N7, N8
20	Designed	Probable	2.6	N6=10+0,08	N5, N7, N8



а – base shell of frequency converter;
б – dimensional circuit

Figure 2.1 – Base shell and its dimension circuit

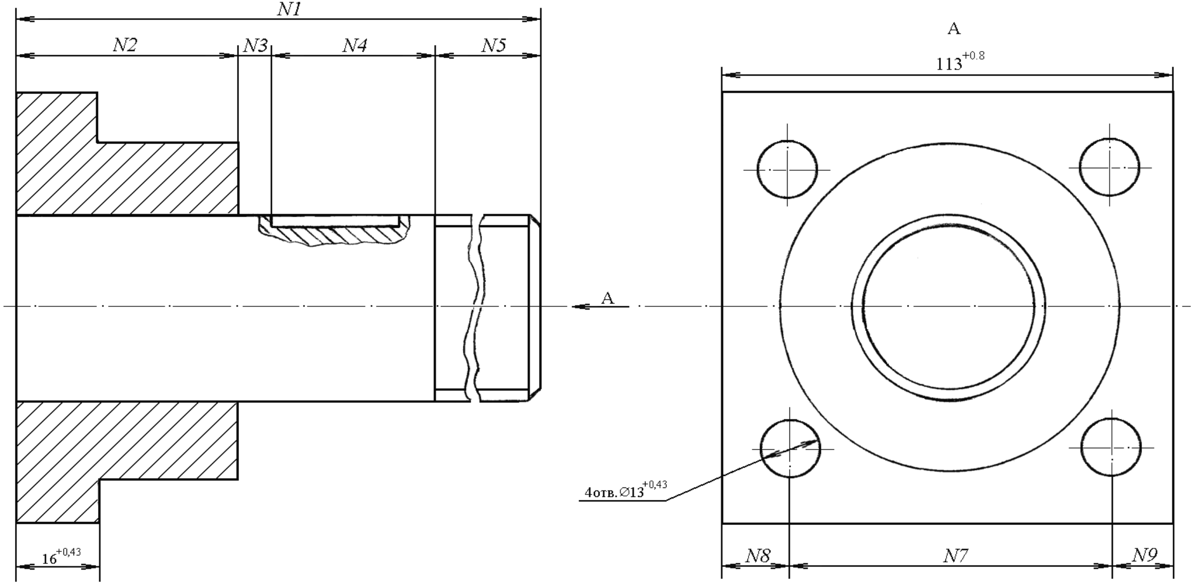


Figure 2.2 – Current-carrying terminal of current transformer rated up to 500kV

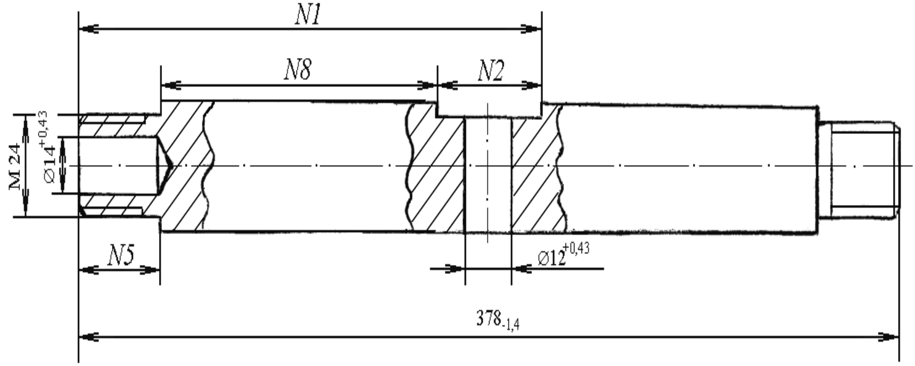


Figure 2.3 – Core

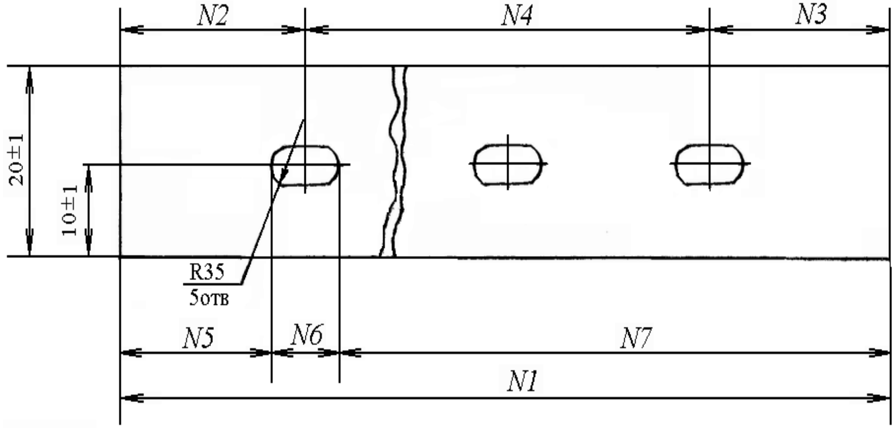


Figure 2.4 – Sheet

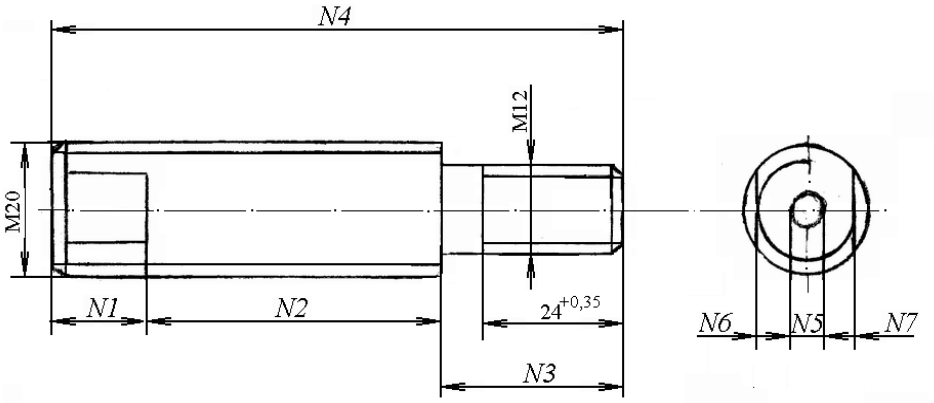


Figure 2.5 – Axe

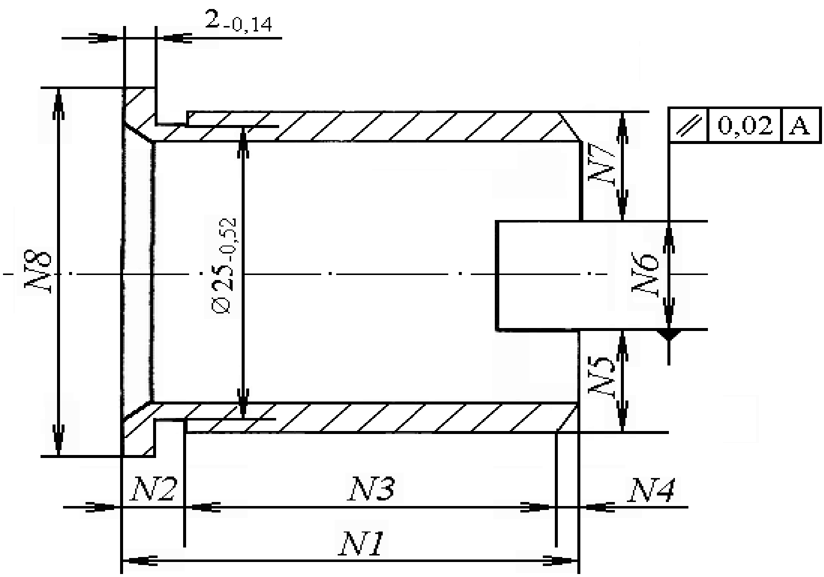


Figure 2.6 – Bushing

3 LABORATORY WORK №3. STUDY OF TECHNOLOGICAL PROCESSES OF EAs MANUFACTURES

3.1 The purpose of the work

The purpose is studying of technological processes of EAs manufacture, its details and assemblies, equipment and facility, being used.

3.2 General notes

Electric apparatus manufacture is a field of general machine building with technology similar to electric machine building but with its peculiarities.

Those particulars are that in the fact electric apparatus manufacture besides metals science as constructional materials comprises itself technology of metal-conductors with electric insulation and without it, as well as technology of magnetic and electric insulation materials.

These technological processes of general machine manufacture (ferrous and nonferrous casting, forging, all types of mechanical processing and welding, soldering, pressing, heat treatment, electrodepositing, assembling, painting) are inherent only to electrotechnical products (cold sheet pressing of electrotechnical steel, sheets varnishing, magnetic core assembling, winding and impregnation of coils and windings).

Engineering operation, reliability and durability of electrical apparatus depend on quality of these processes being realized.

Materials for EAs manufacture are various: electrotechnical copper windings, laminated electrotechnical steel, impregnating varnishes and compounds, coating enamels and electric insulating materials (paper, cardboard, varnished fabric, glass fabric, Mylar films and strips, layered plastic, plastic, mica, asbestos).

Wide classification of designing products also is a feature of electric apparatus manufacturing.

Technological process is a part of production process that contains consecutive change of sizes, shape and exterior view or interior properties of object being designed and it’s managing.

Technological operation is a completed stage of technological process that is realized at one operation place.

Equipment is devices or mechanisms where the basic or auxiliary operations on products manufacture are realized.

Facility is a replacing part of equipment, devices for reliable fastening, correct arrangement or control of tools or details.

3.3 The order of work succession

3.3.1. Study technological processes in electric apparatus manufacture in succession and according to the literature presented below (process content is set by a teacher).

3.3.2 Describe the basic technological operations, from which studied technological processes are made up.

3.3.3 Present a description of basic equipment and facility being applied in studied technological processes.

3.4 Technological processes content

3.4.1 Mechanical machining of EAs materials and details. [2], p.15…81; [3], p. 114…137, 163…200.

3.4.1.1 Cutting of billets from profiled roll, detachable machines. Cutting of billets from rolled sheet (guillotine shears, plasma-arc cutting, gas-laser cutting).

3.4.1.2 Casting into sandy-argillaceous and shell molds. Casting into metal molds (under pressure, with counter pressure). Centered casting. Casting by heated models.

3.4.1.3 Billets manufacture under the pressure. Free forging and equipment being used. Basic forging operations. Hot volumetric pressing and applied equipment. Billets and details manufactured by the methods of powder metallurgy, technology bases and advantages.

3.4.1.4 Cold sheet pressing, field of application, technology bases.

3.4.1.5 Typical methods of details processing by the cutting. Basic notes and definitions.

3.4.2 Technology of springs manufacture [2], p.82…91; [3], p.200…210.

3.4.2.1 Spring assessment in electric apparatus manufacture. Materials that are used for springs manufacture, its features and field of application.

3.4.2.2 Manufacture of twisted cylindrical springs.

3.4.2.3 Manufacture of spiral stripped springs.

3.4.2.4 Manufacture of flat laminated springs.

3.4.3 Technology of magnetic cores and coils manufacture. [2], p.34…37, 138…167; [3], p. 210…267, 280…303.

3.4.3.1 Magnetic cores application in electric apparatus manufacture. Types of magnetic cores, main requirements to magnetic cores. Materials for magnetic cores manufacture.

3.4.3.2 Technology of solid (not laminated) magnetic core fabrication (for DC electromagnets) from rolled and rounds rolling.

3.4.3.3 Technology of laminated magnetic core manufacture. Particulars of plates pressing process.

3.4.3.4 Technology of pressed magnetic core manufacture.

3.4.3.5 Technology of DC magnets manufacture.

3.4.3.6 Technology of coils manufacture.

3.4.3.7 Classification and designed features of coils. Main requirements to coils.

3.4.4 Technology of current-carrying details, contacts and contacting materials manufacture. [1], p. 172…224; [2], p. 104…115; [3], p.210…228.

3.4.4.1 Technology of current-carrying junctions. Constructional forms and materials.

3.4.4.2 Technology of contacts manufacture. Design-technological classification of contacts and contacting details.

3.4.4.3 Contacts manufacture by the methods of powder metallurgy.

3.4.4.4 Technology of switching contacts from arc-resistant composites fabrication.

3.4.4.5 Technology of fixing of contacts plates to contacts base.

3.4.5 Technology of electric insulation and ceramic details manufacture. [1], p. 254…287; [2], p. 129…137, 168…175; [3], p.303…373.

3.4.5.1 Technology basis of transformation plastics into products. Brief characteristic of plastics, basic components. Thermoset and thermoplastic plastics.

3.4.5.2 Manufacture of details from thermosetting plastics.

3.4.5.3 Manufacture of details from thermoplastic plastics.

3.4.5.4 Manufacture of details from layered plastics.

3.4.5.5 Polymeric insulation materials. Manufacture technology of glass plastic profiles by discontinuous drawing.

3.4.5.6 Manufacture of cast epoxy insulation. Types and features of cast insulation in EAs. Equipment and facility for manufacturing of cast insulation. Technology of epoxy casting.

3.4.5.7 Manufacture of apparatus details from ceramic. Ceramic types.

3.4.5.8 Main operations of typical technological process of details manufacture from ceramic.

3.4.6 Technology of resistors manufacture. [3], p. 268…280.

3.4.6.1 Fields of resistors application in electric apparatus manufacture. Classification of resistor elements by design-technological features. Using materials and its characteristics.

3.4.6.2 Technology of wiring and stripping frameless elements of resistors.

3.4.6.3 Manufacture of zigzag resistors elements.

3.4.6.4 Technology of wiring and stripping elements of resistors with rigid frame.

3.4.6.5 Technology of stamping resistor elements.

3.4.6.6 Technology of cast iron resistors elements.

3.4.7 Technology of protection coating. [2], p. 116…128; [3], p.373…396.

3.4.7.1 Preparation of details surface for deposition (mechanical, chemical and electrochemical processing).

3.4.7.2 Technology of galvanic coatings.

3.4.7.3 Technology of chemical coatings.

3.4.7.4 Technology of paint-and-lacquer coating.

3.4.8 Technology of assembly and types of interchangeability. [1], p.309…313; [2]; p. 189…210; [3], p. 396…439.

3.4.8.1 Assembly units (parts, units, blocks) of electric apparatus and its interconnection. Technological scheme of assembly. Types of works connected with electric apparatus assembly.

3.4.8.2 Assembling methods and respective types of interchangeable details.

3.4.8.3 Organizational assembly forms.

3.4.8.4 Stationary assembly, it types, fields of application, features. Movable assembly, its features, fields of application.

3.4.8.5 Basic operations of EAs assembly.

3.4.9 Technical inspection of EAs quality. [1], p. 314…348; [3], p.439...448.

3.4.9.1 Types of technical inspection (incoming, functional and acceptance inspection)

3.4.9.2 Methods of technical inspection. Total and selective inspections.

3.4.9.3 Measurement and control instrumentation.

3.4.9.4 Types of EAs checking tests, its designation and estimated results.

4 LABORATORY WORK №4. MAKING UP OF ROUTE AND OPERATION SHEETS OF TECHNOLOGICAL PROCESS

4.1 The purpose of the work

To get practical skills of route and operation sheets design and making up for technological processes.

4.2 General notes

Rote sheet (RS) is a constituent and integral part of technological documents set that is designed for technological processes. Design rules of RS and its making up are determined according to the ГОСТ 3.1118-82.

During operational description of technological process rout sheets are the main document, where address information (number of the shop, area, workplace, operation and so on), operation name, designation of appropriate documents, technological equipment, labour costs and so on are shown.

During operational description of technological process for single, typical or group processes accord to the standard it is allowable to use form 2 (as a first page – titular) and form 1 б (as the next pages of technological sheet).

Information is entered to the RS line-by-line by several types of lines. Own service digit correspond to every type of a line.

Service digits are designated by capital letters of Russian alphabet and stand before the number of correspondent line.

Service digits and information content are shown in the table 4.1.

In RS forms (2 and 1б) there is reference designation of columns, to which the information, presented in the table 4.2 is correspond.

Because of the fact, that ГОСТ 3.1118-82 is Russian so symbolism is given by the letters of Russian alphabet.

During succession of the work it is allowable not to fulfill the columns that are designated as (*).

The whitening of main sings are according to ГОСТ3.1103-82.

Operational sheet (OS) is designed and made up for the next operations: assembling, welding, soldering, riveting, impregnation, drying, realization of fitter's works and others. OS is executed accord to requirements of ГОСТ 3.1407-86.

The standard provides documentation design during serial and mass types of production.

Technological sheets are called as operational ones (OS).

Sheets of the forms 1 and 1a are made up accord to the standard mentioned above and also it is allowable to use blank of route sheets (RS) of forms 2 and 1б accord to the ГОСТ 3.118-82.

Particular forms 3 and 3a of operational sheets accord to the ГОСТ 3.1407-86 with horizontal arrangement of anchoring field are applied for welding.

Using form RS as operational sheet it is should to write down in the lower angle by the fraction reference designation of appropriate type of document, the function of which these designations execute; for example, RS/OS.

Transitions in operational sheets should be written clear and compactly.

On the lines with service designations O transition writing is started from an imperative verb.

If the facility, tools, instrumentations are used in transition execution it is should to point it on the next row to which the service digit T is assigned.

And it should be pointed with complete data by designations according to respective standards and technical conditions to these devices.

Table 4.1 – Service digits

Designation of service digit	Information content that is entered to the columns arranged in the rows.
1	2
А	Number of the shop; number of the area; number of workplace, where operation is performed; number of operation; operation name; documentation name, according to which operation is performed.
Б	Code, equipment name and information about labour costs.
К	Information about kitting of articles (assembly unit) by component parts with denoted names of details, assembly units, designations; designation of subdivision, from which component parts; normalization units; its quantity per article and cost standard are come in.
М	Information about basic material being used and outgoing billet, information about auxiliary and component materials, being used, with indication of material name and code, designation of subdivisions, from which materials are come in, the code of normalization unit value, its quantity per article and cost standard.
О	Operation content (transition).
Т	Information about technological facility being used when operation is performed.

Table 4.2 – Reference designations of columns

Name (reference designation)	Service digit	Information content
1	2	3
Уч.	А	The number (code) of an area, conveyor, current line and so on.
РМ	А	The number (code) of workplace.
Опер.	А	The number of operation (process) in technological production sequence (taking into account control and displacement).
Code, equipment designation	Б	Code or abbreviated equipment designation or its model. Information is shown by information separator.
УМ	Б	Mechanization level.
Проф .	Б	Profession code by classifier – ДК06-95.
Р	Б	The type of the work, needed for operation performing.
УТ*	Б	The code of working conditions by classifier and the code of standard type.
КОИД	Б	The number of details, producing simultaneously when one operation is performed, when displacement (transportation) is realized the details number in container (package) is pointed out.
ЕН	Б, К, М	Standardization unit, on which cost standard or time standard, for example 1; 10; 100 is established.
ОП*	Б	Amount of production batch in pieces.

Continuation of table 4.2

1	2	3
Кшт.	Б	The factor of piece time at multipress maintenance.
Тпз	Б	The standard of preparatory final time per operation.
ОПП*	К, М	Designation of subdivision (staff, cabin and so on), from where component details, assembly units or materials are come in.
ЕВ	К, М	The code of detail, billet, material unit value (mass, length, square and so on).
КИ	К, М	The number of details, assembly units being used at assembly.
Н.расх.	К, М	Material cost standard.
Тшт.	Б	The standard of piece time per operation. Instead of Тпз for research samples Тшт.к (the standard of piece-calculated time) can be specified, and instead of Тшт.к - estimation on standardization unit.
Document designation	А	Designation of documents (assembly drawing and so on) and instruction of labor safety, being used when given operation is performed.

Writing of information in columns concerning such service digits as А, Б, К/М, Т is realized according to requirements of ГОСТ 3.118-82 with taking into consideration such additions:

– it should to point references on technological constructions (TC) that are used in a column “Document designation” and instructions on labour safety (ILS);

– kind of welding current is additionally pointed in a column “Code, equipment designation” for welding operations;

– columns with labor expenses aren`t fulfilled, except columns "Тпз", "Тшт.", the content of which should have data of total, auxiliary and main time;

– for the rows with symbols К/М the information about component assembly units of an article (assembly units) is pointed at first, and then the information about basic and auxiliary materials that being used during operation is pointed. For introduction of changes it is necessary to leave the empty row between information about component parts of an article and data about basic and auxiliary materials for operation, and also before the content of the first transition;

– for welding and soldering operations it should to point the grade and thickness of material after details and assembly units designation, and in the columns with information about materials it should to note about materials for welding and soldering, that is: adding material, solder, gases, flux and other.

– description of transients content in operations is executed in rows that marked with service digit О along all length of a row with ability to transit the information into the next rows;

Information about facility being applied at operation execution is written in such succession:

– devices;

– auxiliary tools;

– cutting tools;

– hand tools;

– special tools;

– measurement instrumentation.

Writing of information about facility is realized along the whole row length with hyphen to the next rows with separating of every facility type by a sign “;”.

If some facility from mentioned above is not used, so the next one is written by a sequence.

With a purpose of exclusion of information duplication general data from technological facility that being used through all operation is pointed after description of first transition content. Parameters of technological modes are pointed in a row having service digit P.

Sequence of writing of technological modes parameters for welding and soldering is presented in ГОСТ 3.1407-86.

Form and sizes of welded and soldered joints are presented as standard designations. If articles have great quantity of components and materials, than only the number of assembly drawing is pointed, and these data is pointed in it specification.

Then only the ordered list of auxiliary materials that are not pointed in specification is pointed in a row M.

Transitions and operations are designed according to requirements of ГОСТ 3.1703-79 for fitting and fitting-assembly works; for soldering and tinning is according to ГОСТ 3.1704-81; for welding is according to ГОСТ3.1705-81.

Data for fulfillment of M and T columns may be chosen according to [11] and [12].

4.3 The order of work succession

4.3.1 Make up the route sheet on technological process of article manufacture or assembly according to drawing, accord to your variant (writing of each operation should be separated from the next by empty row).

4.3.2 Provide the transport facilities between operations and point them in sheets.

4.3.3 Design the description of one of the technological process operation according to teacher assignment for serial production type.

4.3.4 Made up operation sheet according to design technological process.

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