I. KAMENICHNY

A SHORT HANDBOOK OF HEAT TREATMENT

PEACE PUBLISHERS MOSCOW

I. KAMENICHNY

A SHORT HANDBOOK OF HEAT TREATMENT

PEACE PUBLISHERS
Moscow

TRANSLATED FROM THE RUSSIAN BY I. SAVIN
DESIDNED BY V. NOVOSELOVA

CONTENTS

PREFACE

The present handbook aims at giving the operating personnel of heat-treatment shops a reference book which would serve to overcome difficulties arising in everyday practice.

The handbook describes heat-treatment charts, heat-treatment procedures for tools, parts of lathes, automobiles, and agricultural machinery.

In addition the handbook deals briefly with the following subjects: quality control of metals before and after heat-treatment; heat-treatment and case-hardening of steel; heat-treatment of cast iron, non-ferrous metals, and alloys. The book also contains some practical hints on safety engineering.

Chapter I

PHYSICAL CHARACTERISTICS

1. MECHANICAL CHARACTERISTICS

Term	Definition
Deformation	Change of shape or dimensions of a body without alteration of its mass
Elastic deformation	Deformation of a body which occurs when a force is applied, and which disappears upon removal of the force
Permanent deformation	The part of the deformation which remains after the stress is removed
Strength	Ability of a material to withstand stresses without rupturing
Elasticity	Property of a material to recover its original configuration when the forces are removed
Ductility	Property of a material to withstand considerable permanent deformations without fracturing
Brittleness	Property of a material to fracture without noticeable plastic deformation
Resilience	Work required for rupturing a sample
Hardness	Property of a material to resist indentation by some other body
Fatigue	Development and propagation of cracks in a material as a result of a great number of repeated alternating stresses
Endurance	Property of a material to withstand rupturing by fatigue stresses
Creep	Property of a material to flow gradually and continuously under constant stress, especially at elevated temperatures
Wear	Gradual reduction of the size of a part as a result of friction

Continued

Term	Definition
Wear resistance	Property of a material to resist wear
Strain hardening	Change in properties and structure of a metal due to deformation
Limit of proportionality σ_p, kg/mm²	Highest stress prior to which deformation increases proportionally to the load applied
Elastic limit σ_e, kg/mm²	Stresses at which permanent elongation is negligible (up to 0.02%)
Yield point σ_s, kg/mm²	Least strain at which the sample flows without noticeable increase in stress
Tensile strength, σ_b kg/mm²	Highest stress preceding fracture of a sample
Elongation δ, in %	The ratio of the increase in length of a sample, produced by tensile stresses, to its original length
Relative reduction in area ψ, in %	The ratio of the reduction of area at the point of fracture of a sample to its original cross-section area
Specific resilience a_k, km/cm²	The ratio of the work required to rupture a sample to the cross-sectional area at the point of fracture
Endurance limit σ_w, kg/mm²	Highest stress which a metal can withstand without evidence of fatigue failure
Creep limit σ_c, kg/mm²	Highest stress at which the rate of creep or total creep, in a given time interval, does not exceed a specified value

2 THERMAL CHARACTERISTICS

Term	Definition
Calorie (cal)	The amount of heat required to raise the temperature of 1 gram of water 1°C
Kilocalorie (kcal)	The amount of heat required to raise the temperature of 1 kilogram of water 1°C
Heat capacity C, cal/°C	The amount of heat required to raise the temperature of a material 1°C
Specific heat c, cal/g·degrees C	The amount of heat required to raise the temperature of 1 gram of a material 1°C

Continued

Term	Definition
Heat conductivity	The ability of a body to conduct heat from one part to the other, as well as to an adjacent body when in physical contact with the latter
Convection	Transfer of heat by the flow of a heated agent (air, water, etc.)
Heat radiation	Transfer of heat by heat rays emitted by an incandescent (hot) body
Calorific power Q, kcal/kg	The amount of heat generated by burning 1 kg of a fuel
Temperature t	The thermal condition of a body
Absolute zero	Temperature equal to —273.2°C
Thermodynamic temperature scale, °K	Temperature expressed in terms of degrees Centigrade and referred to absolute zero as a standard
Coefficient of linear expansion, mm/m·degrees C or cm/cm·degrees C	Increment of length per unit of length for a temperature rise of 1°C

3. ELECTRICAL CHARACTERISTICS

Term	Definition
Electric current	The flow of electrons along a conductor
Current I, amperes	The quantity of electricity passing through a conductor in 1 second
Resistance R, ohms	The ability of a material to impede the flow of electric current
Resistivity ρ, ohm·mm²/m	The resistance of a conductor 1 m in length, 1 mm² in cross-section, at 20°C
Voltage E, volts	The difference of electrical potential across the terminals of a conductor
Power P, watts	The work performed when 1 ampere flows through a potential difference of 1 volt

4. SOME PROPERTIES OF ELEMENTS AND MATERIALS DEALT WITH IN HEAT-TREATMENT OF METALS

Material	Formula	Specific gravity	Melting or fusing point, °C
	Solids		
Aluminium	Al	2.7	658
Ammonium chloride	NH_4Cl	1.53	—
Antimony	Sb	6.68	630
Asbestos	—	2.4-2.55	1480-1510
Barium	Ba	3.5	850
Barium chloride	$BaCl_2$	3.86	962
Beryllium	Be	1.82	1350
Birch	—	0.51-0.77	—
Bismuth	Bi	9.8	271
Bone	—	1.7	—
Borax (anhydrous)	$Na_2B_4O_7$	2.37	711
Boron	B	2.32	2300
Brass	—	8.1-8.6	880-910
Bronze, aluminium	—	7.7	—
Bronze, phosphorus	—	8.8	950-970
Bronze, tin	—	8.7	—
Brick	—	1.4-2.0	—
Cadmium	Cd	8.64	321
Calcium	Ca	1.55	850
Calcium carbide	CaC_2	2.22	2300
Caliche (sodium nitrate)	$NaNO_3$	2.26	308
Carboloys, BK type	—	14.3-14.9	—
Carboloys, TK type	—	9.5-11.0	—
Charcoal, lumps	—	0.4	—
Charcoal, crushed	—	1.4-1.5	—
Chromium	Cr	6.92	1615
Clay, dry	—	1.8	—
Coal	—	1.2-1.5	—
Cobalt	Co	8.9	1490
Coke, lumps	—	0.6	—
Coke, crushed	—	1.25-1.4	—
Copper	Cu	8.92	1083
Corundum	Al_2O_3	3.9-4.0	About 2050
Diamond	C	3.51	3500
Duralumin	—	2.6-2.8	—
Fireclay (chamotte)	—	1.8-2.2	—
German silver	—	8.5	1100
Glass	—	2.4-2.6	—
Gold	Au	19.3	1063
Graphite	C	2.25	—
Grey cast iron	—	7.0-7.2	—
Ice at 0°C	—	0.917	—

Continued

Material	Formula	Specific gravity	Melting or fusing point, °C
Iridium	Ir	22.42	2450
Iron	Fe	7.86	1535
Iron carbide	Fe_3C	7.4	—
Lead	Pb	11.34	327
Magnesium	Mg	1.74	651
Malleable cast iron	—	7.2-7.6	—
Manganese	Mn	7.2	1260
Molybdenum	Mo	10.2	2625
Nickel	Ni	8.9	1452
Niobium	Nb	8.4	2500
Oak	—	0.7-1.0	—
Potassium nitrate (niter)	KNO_3	2.11	333
Phosphorus, yellow	P	1.82	44
Pine	—	0.31-0.76	—
Platinum	Pt	21.45	1774
Potassium	K	0.86	62
Potassium cyanide	KCN	1.52	634
Potassium ferricyanide	$K_3Fe(CN)_6$	1.93	—
Potassium ferrocyanide	$K_4Fe(CN)_6$	1.85	—
Potassium hydrate	KOH	2.04	360
Rhodium	Rh	12.5	1966
Salt, common (sodium chloride)	NaCl	2.16	800
Sand, dry	—	1.4-1.6	—
Silicon	Si	2.4	1420
Silicon carbide (carborundum)	SiC	3.17	2700 min
Silver	Ag	10.5	961
Soda ash	Na_2CO_3	2.53	851
Soda, caustic	NaOH	2.13	318
Sodium	Na	0.97	97
Sodium cyanide	NaCH	—	564
Steel, carbon	—	7.7-7.85	—
Steel, grade P9	—	8.25	—
Steel, grade P18	—	8.8	—
Sulphur	S	1.92-2.07	115-119
Tellurium	Te	6.24	452
Tin	Sn	7.28	232
Titanium	Ti	4.5	1800
Tungsten	W	19.3	3370
Tungsten carbide	WC	15 7	2777
Vanadium	V	5.87	1720
Wood, air-dry	—	—	—
Zinc	Zn	7.14	419

Continued

Material	Formula	Specific gravity	Melting of fusing point, °C
	Liquids		
Benzene	—	0.88	—
Gasoline	—	0.7-0.75	—
Glycerine	—	1.26	—
Hydrochloric acid	HCl	1.19	—
Kerosene	—	0.8-0.82	—
Machine oil	—	About 0.9	—
Mercury	Hg	13.55	—39
Nitric acid	HNO_3	1.5	—
Petroleum	—	0.89 max	—
Sulphuric acid	H_2SO_4	1.84	—
Water at 4°C	H_2O	1.0	—

Note. Specific gravities and melting points of alloys are approximate and may vary depending on the composition.

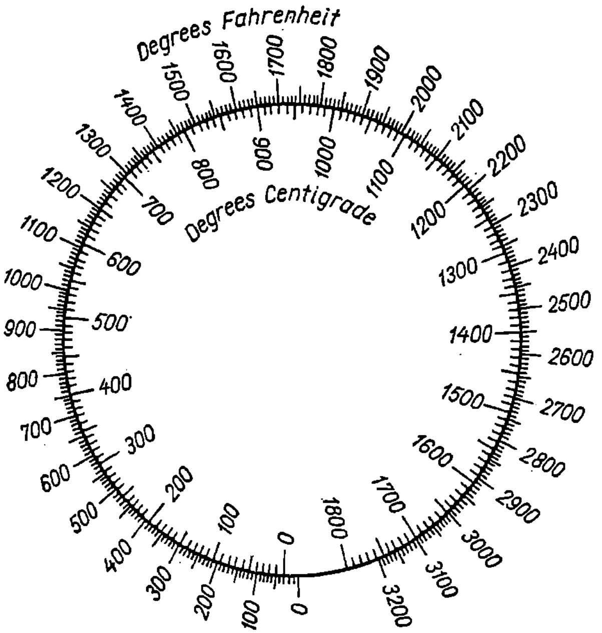


Fig. 1. Conversion of degrees Centigrade to degrees Fahrenheit

Chapter II

QUALITY CONTROL OF METALS

1. HARDNESS TESTS

Hardness may be measured by various methods, depending on the condition of the metal (hardened, annealed, etc.), and on the size of the specimen.

Brinell hardness test. This method is chiefly used to test rolled and forged pieces, castings, as well as dies and tools whose hardness does not exceed 450 units.

The Brinell hardness number (abbreviated to H_B and expressed in kg/mm^2) is determined by forcing a hardened ball 10.5 or 2.5 mm in diameter into the metal being tested under a load of 15.6 to 3,000 kg in a special press (see Table 1).

When testing specimens for hardness the following conditions are to be ensured:

1. The point of indentation should be free from scale and/or decarburised layers.

2. Rounded surfaces should be so machined as to present a plane to the indentor (a flat should be filed).

3. If the bottom or lateral walls are strained following indentation, the test should be repeated by the use of a ball of a smaller diameter and an appropriate load.

4. This method cannot be used to determine the hardness of carburised or nitrided surfaces.

5. The centre of the impression should be situated at least one ball diameter from the edge of the specimen, and at least two diameters from an adjacent impression.

The diameter of the impression is measured by means of a special magnifying glass, and the hardness number is then read in the table.

When testing for hardness with a 5-mm ball the actual diameter of the impression is to be multiplied by 2; when a 2.5-mm ball is used, the result is to be multiplied by 4.

Example:

Ball diameter	5 mm	2.5 mm
Load	750 kg	187.5 kg
Impression diameter	1.8 mm	1.1 mm
Multiplication	1.8×2= =3.6 mm	1.1×4= =4.4 mm
These diameters correspond to the following hardness numbers (see Table 2)	286	187

Table 1

Specimen Thickness and Load Application Time in Brinell Hardness Test

Material	Hardness number H_B	Specimen thickness, mm	Ball diameter, mm	Load *P*, kg	Load application time, sec
Ferrous metals	150-450	Over 6 3-6 Below 3	10 5 2.5	3,000 750 187.5	10 10 10
	Below 150	Over 6 3-6 Below 3	10 5 2.5	1,000 250 62.5	10 10 10
Copper, brass, bronze, magnesium- and aluminium-base alloys	35-130	Over 6 3-6 Below 3	10 5 2.5	1,000 250 62.5	30 30 30
Aluminium, antifriction alloys	8-35	Over 6 3-6 Below 3	10 5 2.5	250 62.5 15.6	60 60 60

Table 2

Conversion of Hardness Numbers and Their Correlation with Tensile Strength

Brinell hardness number		Rockwell hardness number			Diamond pyramid hardness number, H_V	Shore scleroscope hardness number, H_S	Tensile strength, kg/mm^2		
		Scale							
Impression dia., mm	Hardness number	C	A	B			Carbon steel	Chromium steel	Nickel and chrome nickel steel
2.2	780	72	89	—	1,224	—	—	—	—
2.25	745	70	87	—	1,116	—	—	—	—
2.3	712	68	86	—	1,022	—	—	—	—
2.35	682	66	85	—	941	90	—	—	—
2.40	653	64	84	—	868	86	—	—	—
2.45	627	62	83	—	804	84	—	—	—
2.50	601	60	82	—	746	81	—	—	—
2.55	578	58	81	—	694	78	—	—	—
2.60	555	56	79	—	649	75	—	—	—
2.65	534	54	78	—	606	71	—	—	—
2.70	514	52	77	—	587	69	—	—	—
2.75	495	50	76	—	551	66	178	173	168
2.80	477	49	76	—	534	65	172	167	161
2.85	461	48	75	—	502	64	165	—	—
2.90	444	46	74	—	473	61	160	156	—
2.95	429	45	73	—	460	59	155	150	146
3.00	415	44	72	—	435	58	149	145	141
3.02	409	43	72	—	423	57	147	143	139
3.05	401	42	71	—	412	56	144	139.5	136.5
3.10	388	41	71	—	401	55	139.5	136	132
3.15	375	40	70	—	390	53	135	131.5	127.5
3.20	363	39	70	—	380	52	130.5	127	123.5
3.25	352	38	69	—	361	51	126.5	123.0	119.5
3.30	341	37	68	—	344	50	122.5	119.0	116.0
3.35	331	36	68	—	335	49	119.5	116.5	113.0
3.40	321	35	67	—	320	48	115.5	112.0	109.0
3.45	311	34	67	—	312	47	111.5	108.5	105.5
3.50	302	33	67	—	305	46	108.5	105.5	102.5
3.55	293	31	66	—	291	43	105.5	102.5	100.0
3.60	286	30	66	—	285	42	103.0	100.5	97.5
3.65	277	29	65	—	278	41	99.5	97.0	94.0
3.70	269	28	65	—	272	40	97.0	94.0	91.5
3.75	262	27	64	—	261	39	94.5	92.0	89.5

Table 2 continued

Brinell hardness number		Rockwell hardness number			Diamond pyramid hardness number, H_V	Shore scleroscope hardness number, H_S	Tensile strength, kg/mm²		
Impression dia, mm	Hardness number	Scale C	Scale A	Scale B			Carbon steel	Chromium steel	Nickel and chrome-nickel steel
3.80	255	26	64	—	255	38	92.0	89.0	86.5
3.85	248	25	63	—	250	37	89.5	87.0	84.5
3.90	241	24	63	100	240	36	87.0	84.5	82.0
3.95	235	23	62	99	235	35	84.5	82.5	80.5
4.00	228	22	62	98	226	34	82.5	80.0	77.5
4.05	223	21	61	97	221	33	80.0	77.5	76.5
4.10	217	20	61	97	217	33	78.0	76.0	74.0
4.15	212	19	60	96	213	32	76.0	74.0	72.0
4.20	207	18	60	95	209	32	74.5	72.5	70.5
4.25	202	16	59	94	201	31	72.0	71.0	68.5
4.30	196	15	58	93	197	31	70.5	68.5	66.5
4.35	192	15	58	92	190	30	69.0	67.0	65.0
4.40	187	—	57	91	186	—	67.5	65.5	63.5
4.45	183	—	56	89	183	—	66.0	64.0	62.5
4.50	179	—	56	88	177	—	64.0	62.5	60.5
4.55	174	—	55	87	174	—	62.5	61.0	59.0
4.60	170	—	—	86	171	—	61.0	59.5	58.0
4.65	166	—	—	85	165	—	60.0	58.5	57.0
4.70	163	—	—	84	162	—	58.5	57.0	55.5
4.75	159	—	—	83	159	—	57.5	55.5	54.5
4.80	156	—	—	82	154	—	56.0	54.5	53.0
4.85	153	—	—	81	152	—	55.0	53.5	52.0
4.90	149	—	—	80	149	—	53.5	52.0	50.5
4.95	146	—	—	78	147	—	52.5	51.0	50.0
5.00	143	—	—	76	144	—	51.0	49.5	48.5
5.05	140	—	—	76	—	—	50.0	49.0	47.5
5.10	137	—	—	75	—	—	49.5	48.0	46.5
5.15	134	—	—	74	—	—	48.6	47.0	45.5
5.20	131	—	—	72	—	—	47.0	45.5	44.5
5.25	128	—	—	71	—	—	46.25	44.75	43.5
5.30	126	—	—	69	—	—	45.0	43.5	42.5
5.35	124	—	—	69	—	—	44.0	43.0	42.0
5.40	121	—	—	67	—	—	43.5	42.5	41.0
5.45	118	—	—	66	—	—	42.5	41.5	40.0
5.50	116	—	—	65	—	—	41.75	40.75	39.25
5.55	114	—	—	64	—	—	41.25	40.25	38.75
5.60	112	—	—	62	—	—	40.5	39.5	38.5
5.65	109	—	—	61	—	—	39.0	—	—

Brinell hardness number		Rockwell hardness number			Diamond pyramid hardness number, H_V	Shore scleroscope hardness number, H_S	Tensile strength, kg/mm²		
Impression dia., mm	Hardness number	Scale C	Scale A	Scale B			Carbon steel	Chromium steel	Nickel and chrome-nickel steel
5.70	107	—	—	59	—	—	38.5	—	—
5.75	105	—	—	58	—	—	38.0	—	—
5.80	103	—	—	57	—	—	37.0	—	—
5.85	101	—	—	56	—	—	36.5	—	—
5.90	99	—	—	54	—	—	35.5	—	—
5.95	97	—	—	53	—	—	35.0	—	—
6.00	96	—	—	52	—	—	34.5	—	—
6.10	92	—	—	49.5	—	—	33.0	—	—
6.20	88	—	—	47	—	—	32.0	—	—
6.36	84	—	—	43.5	—	—	30.0	—	—
6.48	80	—	—	40.5	—	—	29.0	—	—
6.56	78	—	—	38.5	—	—	28.0	—	—

Note. Brinell hardness numbers were obtained with a 3,000 kg load and a 10-mm ball.

Rockwell hardness test. This method is used to determine the hardness numbers of metals (abbreviated to R_C, R_A and R_B) by forcing into them a conical diamond with rounded point, called the penetrator, under a load of 150 or 60 kg or a 1.59-mm steel ball to which a 100 kg load is applied. Test conditions are described in Table 3.

Table 3

Rockwell Hardness Testing Conditions

Metal	Approximate Brinell hardness number	Type of penetrator	Load, kg	Rockwell hardness number designation	Working range of scale	Scale
1. Annealed steel, brass, bronze, aluminium and magnesium hard alloys	60-230	Steel ball, dia. 1.59 mm	100	R_B	25-100	Red
2. Hardened steel and cast iron, white cast iron	230-700	Diamond cone	150	R_C	20-67	Black
3. Thin plates, case-carburised and nitrated articles, carboloys	Over 700	Ditto	60	R_A	Over 67	Black

On testing for hardness the following requirements should be met:

1. The piece being tested should be free from scale, decarburised layers, dents, grease or traces of machining.

2. Hollow thin-walled specimens should not be tested since the results would be wrong (because the piece will spring back or cave in).

3. For the same reason no pads should be inserted between the piece being tested and the anvil of the testing machine.

4. The piece to be tested should be thick enough to prevent bulging on the reverse side.

5. The centre of the impression should be spaced from the edge of the specimen not less than 2.5 mm for scales A and C, and not less than 4 mm for scale B.

6. Round-shaped specimens being tested for hardness by means of a diamond cone should be no less than 15 mm in diameter. When testing pieces of smaller diameters Correction Tables 4 and 5 should be consulted.

Table 4

Correction Values for Hardness Numbers Measured on Cylindrical Surfaces of Specimens by a TK Testing Machine (Rockwell Test)

Diameter of specimen, mm	Hardness of cylindrical surface (R_C)					
	58	59	60	61	62	63
	Values to be added to the hardness number obtained					
6	2.5	2.0	2.0	2.0	2.0	—
7	2.0	2.0	1.5	1.5	1.5	—
8	2.0	1.5	1.5	1.5	1.5	—
9	—	1.5	1.5	1.0	1.0	1.0
10	—	1.0	1.0	1.0	1.0	1.0
11	—	1.0	1.0	1.0	1.0	1.0
12	—	1.0	1.0	1.0	0.5	0.5
13	—	1.0	1.0	0.5	0.5	0.5
14 and 15	—	1.0	0.5	0.5	0.5	0.5

Table 5

Correction Values for Hardness Numbers as Measured on Spherical Surfaces by a TK Testing Machine (Rockwell Test)

Ball diameter, mm	Hardness of spherical surface, R_C								
	56	57	58	59	60	61	62	63	64
	Values to be added to the hardness number obtained								
Up to 4	5.5	5.5	5.0	5.0	4.5	4.5	—	—	—
From 4 to 6	4.5	4.5	4.0	4.0	3.5	3.5	3.5	—	—
„ 6 to 8.5	4.0	3.5	3.5	3.0	3.0	3.0	2.5	—	—
„ 8.5 to 11.5	—	3.0	2.5	2.5	2.0	2.0	2.0	1.5	—
„ 11.5 to 15.0	—	—	2.0	1.5	1.5	1.0	1.0	1.0	0.5

Table 6

Conversion of Rockwell Hardness Numbers Measured by the Use of Diamond Cone under Loads of 150 kg (Scale C) and 15, 30 and 45 kg (Microhardness Scale)

Rockwell hardness number, R_C	Microhardness number under loads of, kg			Rockwell hardness number, R_C	Microhardness number under loads of, kg		
	15N	30N	45N		15N	30N	45N
68	93.2	84.4	75.4	43	82.0	62.2	46.7
67	92.9	83.6	74.2	42	81.5	61.3	45.5
66	92.5	82.8	73.3	41	80.9	60.4	44.3
65	92.2	81.9	72.0	40	80.4	59.5	43.1
64	91.8	81.1	71.0	39	79.9	58.6	41.9
63	91.4	80.1	69.9	38	79.4	57.7	40.8
62	91.1	79.3	68.8	37	78.8	56.8	39.6
61	90.7	78.4	67.7	36	78.3	55.9	38.4
60	90.2	77.5	66.6	35	77.7	55.0	37.2
59	89.8	76.6	65.5	34	77.2	54.2	36.1
58	89.3	75.7	64.3	33	76.6	53.3	34.9
57	88.9	74.8	63.2	32	76.1	52.1	33.7
56	88.3	73.9	62.0	31	75.6	51.3	32.5
55	87.9	73.0	60.9	30	75.0	50.4	31.3
54	87.4	72.0	59.8	29	74.5	49.5	30.1
53	86.9	71.2	58.6	28	73.9	48.6	28.9
52	86.4	70.2	57.4	27	73.3	47.7	27.8
51	85.9	69.4	56.1	26	72.8	46.8	26.7
50	85.5	68.5	55.0	25	72.2	45.9	25.5
49	85.0	67.6	53.8	24	71.6	45.0	24.3
48	84.5	66.7	52.5	23	71.0	44.0	23.1
47	83.9	65.8	51.4	22	70.5	43.2	22.0
46	83.5	64.8	50.3	21	69.9	42.3	20.7
45	83.0	64.0	49.0	20	69.4	41.5	19.6
44	82.5	63.1	47.8				

To determine the hardness of thin layer of metals, a special testing machine "Super-Rockwell" is used.

The test is carried out by means of a diamond cone or a 1.59-mm ball under loads of 15, 30 and 45 kg (Tables 6 and 7).

Hardness test by a diamond pyramid penetrator, H_V in kg/mm^2. The hardness of metals is determined by indenting a tetrahedral diamond pyramid penetrator under loads of 5, 10, 20, 30, 50, 100 and 120 kg. Loads should be selected by referring to Tables 8 and 9.

The diamond pyramid can be used to test soft, as well as heat-treated metals. The diamond pyramid test is widely used to determine the hardness of thin specimens and articles with hard superficial layers.

Table 7

Conversion of Rockwell Hardness Numbers Determined by the Use of a Steel Ball under Loads of 100 kg (Scale B) and 15, 30 and 45 kg (Microhardness Scale)

Rockwell hardness number, R_B	Microhardness number under loads of, kg			Rockwell hardness number, R_B	Microhardness number under loads of, kg		
	15T	30T	45T		15T	30T	45T
100	93.0	83.0	73.0	75	85.5	67.5	49.0
99	92.5	82.5	72.0	74	85.0	66.5	48.5
98	92.5	82.5	71.0	73	85.0	66.0	47.5
97	92.0	81.0	70.0	72	84.5	65.5	46.5
96	92.0	80.5	69.0	71	84.0	65.0	45.5
95	91.5	80.0	68.0	70	84.0	64.0	44.5
94	91.0	79.0	67.0	69	83.5	63.5	43.5
93	91.0	78.5	66.0	68	83.5	63.0	42.5
92	90.5	78.0	65.0	67	83.0	62.0	42.0
91	90.0	77.0	64.0	66	83.0	61.5	41.0
90	90.0	76.5	63.0	65	82.5	61.0	40.0
89	89.5	76.0	62.0	64	82.0	60.5	39.0
88	89.5	75.0	61.0	63	82.0	60.5	38.0
87	89.0	74.5	60.0	62	81.5	59.0	37.0
86	89.0	74.0	59.5	61	81.0	58.5	36.0
85	88.5	73.5	58.5	59	81.0	58.0	35.0
84	88.0	73.0	57.5	58	80.5	57.0	33.0
83	88.0	72.0	56.5	57	80.0	56.0	32.5
82	87.5	71.5	55.5	56	80.0	55.5	31.5
81	87.0	71.0	54.5	55	79.5	55.0	30.5
80	87.0	70.5	53.5	54	79.0	54.5	29.5
79	86.5	70.0	52.5	53	79.0	53.5	28.5
78	86.5	69.0	52.0	52	78.5	53.0	28.0
77	86.0	68.5	51.0	49	77.5	51.0	25.0
76	86.0	68.0	50.0	48	77.5	50.5	24.0
				47	77.0	50.0	23.0
				45	76.5	49.0	21.0
				42	75.5	47.0	18.0
				40	75.0	46.0	16.0

Table 8

Recommended Loads for Diamond Pyramid Hardness Testing

Thickness of specimen, mm	Hardness number H_V			
	20-50	50-100	100-300	300-900
	Recommended loads, kg			
0.3-0.5	—	—	—	5-10
0.5-1.0	—	—	—	10-20
1.0-2.0	5-10	5-10	10-20	—
2.0-4.0	10-12	20-30	20-50	20-50
Over 4	20 and higher	30 and higher	50 and higher	—

Table 9

Recommended Loads for Diamond Pyramid Hardness Testing of Tubes and Various Thin-walled Articles

Outer diameter of tube or article, mm	Wall thickness of tube or article, mm							
	0.5	0.75	1.0	1.25	1.5	2.0	2.5	3.0
	Recommended loads, kg							
0-10	10	—	20	—	—	—	—	—
10-20	5	10	20	—	30	—	—	—
20-30	—	5	10	—	30	30	30	30
30-40	—	5	10	—	20	30	30	30
40-50	—	5	5	10	20	30	30	30
50-60	—	—	5	10	20	30	30	30
60-70	—	—	5	5	10	20	30	30
70-80	—	—	5	5	10	20	30	30

The surface to be tested should be dry, clean, free from pores, scale and decarburised layers and bear no rough traces of machining. The diagonal of the impression is measured with a microscope attached to the testing machine; the hardness number is determined by referring to a special table.

The TП testing machine can be used for Brinell hardness testing with 5- and 2.5-mm balls, which are part of the machine, under loads of 62.5 and 15.6 kg.

Shore scleroscope hardness test. A well-finished part (specimen) is set in the machine and an indentor is dropped onto the surface from a certain height. Upon rebounding the indentor deflects the pointer on a dial, thus indicating the hardness number of the part tested.

Shore hardness number is abbreviated to H_S.

Approximate hardness testing by ball impact indentation. The procedure employs a portable testing machine intended for the approximate hardness testing of bulky articles. This is accomplished by pressing a ball, with an impact of medium force, simultaneously into the article being tested and into the standard specimen; the hardness number is then determined by referring to a special table attached to the testing machine.

The hardness number in the table is found at the intersection of the columns giving the impression diameters of the article tested and the standard specimen. The precision of the method is within $\pm 7\%$.

Filing hardness test. Tools and articles (such as taps, reamers, drills, small-size tools) whose hardness cannot be determined with testing machines are tested by filing with smooth files and by comparing the abrasion with that produced on standard specimens. The latter consist of a set of quenched rings of varying hardness ranging from 45 to 63 R_C with gradations every 3-5 units. The hardness number is determined with adequate precision by alternately filing the article and the standard specimen and by comparing the forces applied.

2. Detection of Cracks in Metals

The most widely used methods of finding surface cracks are:

(a) magnetic-particle crack detection (applicable only to steel and cast iron);

(b) deep etching;

(c) kerosene or hot oil tests or blacking-in;

(d) fluoroscopic crack detection.

The method of magnetic-particle crack detection is performed as follows: the article under test is magnetised in the crack detector, after which it is dipped into a bath or flushed with a suspension of magnetic particles. The magnetic particles will settle on the cracks, if there are any. After the test, the article is demagnetised.

The first step in the preparation of the magnetic-particle powder is to thoroughly mix finely crushed ferric oxide or ochre with kerosene or oil to a paste of medium consistency. The paste is then packed into a crucible or tube, which should be tightly closed, luted and held in a furnace at 600-800°C until the kerosene is completely burned, after which the paste is allowed to cool down to room temperature. The resultant magnetic powder is thoroughly ground with a small amount of kerosene or oil to a thin paste, after which kerosene or oil is added to obtain 1 litre of suspension for every 25-40 grams of powder.

A non-corrosive liquid designated КИО is used as an aqueous suspension of magnetic particles to reveal very fine cracks; it has the following composition:

denaturated alcohol	400 millilitres
water	150 millilitres
sodium hydroxide NaOH	40 grams
oleic acid	120 millilitres
naphthenic acid	200 millilitres

The КИО liquid is added in the proportion of 40 millilitres per 1 litre of water, containing 2 grams of soda ash, after which magnetic powder is introduced into the mixture.

Fluoroscopic crack detection. This method is used to reveal cracks in non-magnetic metals, as well as in various other materials (e. g., plastics, etc.). The test is performed by the use of the ЛЮМ-1 testing machine manufactured by medical equipment plants. The piece to be tested is immersed in a special liquid after which it is flushed with water, wiped dry, sprinkled with magnesium oxide (the excess particles being blown off) and then examined in the ultra-violet light. If there are any cracks, the solution contained therein wets the magnesium oxide and the cracks are exposed upon examination in a dark room under the rays of a mercury vapour-quartz lamp.

The liquid used is a mixture of 15% (by volume) of transformer oil and 85% of kerosene.

The detection of cracks and other faults in steel by the deep etching method requires the use of the etchants listed in Table 10.

The following etchants are used for copper-base alloys:

a) 10-20% aqueous solution of ammonium persulphate;
b) 10% solution of hydrogen peroxide in saturated aqueous solution of ammonium;
c) solution of ferric chloride (10 grams) and hydrochloric acid (30 cu cm) in water (120 cu cm).

The latter etchant is also used for nickel-base alloys.

To etch duralumin, the following etchant is used: 16.5% hydrochloric acid, 16.5% nitric acid, 4.5% hydrofluoric acid, and 62.5% water. The etchants act quickly; following etching the specimen should immediately be washed and dried.

Table 10

Etchants Used for Deep Etching of Steel

Material etched	Etchant composition in % (by volume)				Etching schedule	
	Hydrochloric acid HCl	Nitric acid HNO_3	Sulphuric acid H_2SO_4	Water	Temperature, °C	Holding time
Carbon steel .	—	—	17	83	60	Up to 2 hrs
Ditto . . .	50	—	—	50	60-70	10-45 min
Ditto . . .	—	50	—	50	70-80	1-2 hrs
Alloy steel . .	17	—	33	50	Up to 100	20-60 min
Ditto . . .	66	—	10	24	95-98	20 min-2 hrs

Table 11

Characteristics of Grinding Wheels for Spark Testing of Steel

Wheel characteristics	For testing rods, castings and forgings	For testing finished articles
Wheel diameter, mm . . .	300-350	150-200
Wheel thickness, mm . . .	40-60	25-40
Grain size	36-40	60-80
Hardness	Grade Ст.1 steel	Grade Ст.1 steel

Deep etching is usually applied when testing parts for possible cracks. Since acids tend to dissolve metals, the parts may decrease in size as a result of etching.

Crack detection by blacking-in. The piece is immersed in a solution, then thoroughly washed with cold water, coated with a thin film of aqueous suspension of white clay, and finally dried in an air jet. The solution forced out of the cracks colours them brightly.

Composition of the solution:

kerosene . . . . 65% by volume
transformer oil . . . . 30% "
turpentine . . . . 5% "

Sudan III, sudan II, sudan I or fatty orange are added as colouring agents.

Kerosene or hot oil testing. The parts are immersed in kerosene or hot oil for 10-20 min, after which they are sand-blasted or wiped dry and rubbed with chalk. The kerosene and oil retained by the cracks make them appear as thin streaks.

Sonic inspection. Cracks can be detected by experienced operators by striking suspended parts. A cracked part gives off a dull sound when hit with a hammer.

3. APPROXIMATE DETERMINATION OF STEEL COMPOSITION

Steeloscope inspection. Spectroscopic analysis is being more and more widely used in heat-treatment shops, as a means of determining the approximate composition of steel. In the spectroscopic method an electric arc is struck between the piece being tested and an electrode. The light of the arc is directed by a lens, into the slit of a special apparatus—the steeloscope—where the spectrum is examined. Most of the components of steel emit characteristic spectral lines on burning. The pattern and intensity of these lines when referred to the special tables accompanying the apparatus, give information as to the approximate content of the various elements in the steel. The procedure takes only a few minutes and no damage is done to the piece tested. Carbon, sulphur and phosphorus cannot be determined by this method.

Spark test. The determination of the composition of steel by the spark test requires blacking out of the site of the test, adequate grinding

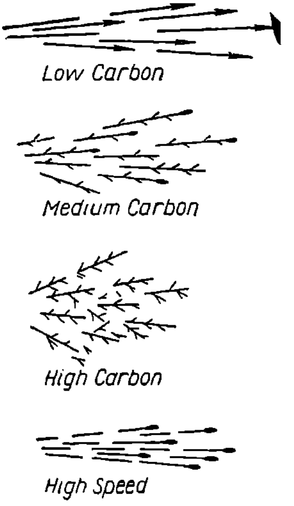


Fig. 2. Pattern of sparks produced by various grades of steels

wheels (Table II), as well as branded specimens of the steels used in the plant. By examining the colour and pattern of the sparks emitted from the part being tested and a standard specimen, one may determine approximately the steel grade.

Low-carbon steel throws off a long beam of light-yellow sparks with no explosions. As the carbon content increases the beam becomes shorter and wider and the number of explosions increases (Fig. 2).

As compared to carbon steel the colour of the sparks produced by chromium steel is darker, with a lesser number of explosions. Steel containing tungsten throws off dark-red sparks.

Chapter III

STEEL

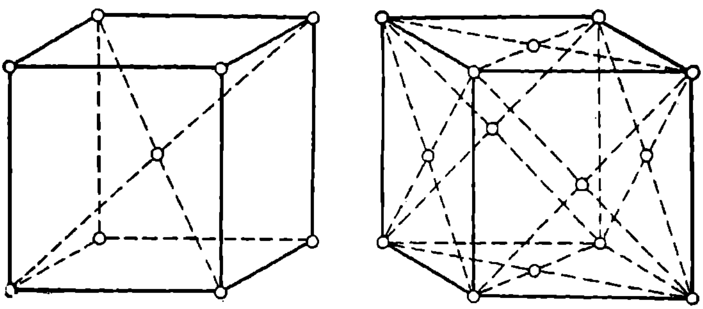
1. CONSTITUENTS OF STEEL

The internal arrangement of steel and other alloys is called their structure. The structure visible only under a microscope is called microstructure. To determine the microstructure of a steel specimen, the latter should be ground, polished, etched and examined with the aid of a microscope. Table 12 indicates the constituents of steel and presents some data on their formation, physical properties, etc.

2. STRUCTURE OF IRON AND STEEL. EQUILIBRIUM DIAGRAM OF IRON-GARBON ALLOYS

The crystal lattice of pure iron changes its structure, i. e., the arrangement of its atoms, with temperature. Various lattice structures are presented in Fig. 3. Data on lattice structure modifications on heating and cooling are given in Table 13.

Fig. 4 presents an equilibrium diagram of iron-carbon alloys. The temperatures at which solid-phase changes occur in iron and its alloys are called critical points (Table 14).



A B

Fig. 3. Structure of crystalline lattice:
a—alpha- and delta-iron; *b*—gamma-iron

Table 12

Structural Constituents of Iron-carbon Alloys

Structure	Definition	Conditions of formation	Stable at temperatures, °C	Physical properties	Brinell hardness number, H_B
Austenite	Solid solution of carbon and other elements in gamma-iron. Carbon content up to 2.0%	On heating above critical points	Above Ac_3, Ac_m and Ac_1	Soft, non-magnetic, malleable, but poorly ductile. Possesses high electric resistance	170-220
Ferrite	Solid solution of carbon and other elements in alpha-iron. Carbon content up to 0.04%	Rejected by austenite on slow cooling of hypo-eutectoid steel below Ar_3	Below Ac_3	Soft, very malleable, magnetic	60-100
Cementite	Chemical combination of iron and carbon. Iron carbide Fe_3C contains 6.67% carbon	Rejected by liquid and solid solutions on slow cooling		Hard, brittle. Magnetic up to 210°C. On heating above 210° C becomes non-magnetic	820
Pearlite	Eutectoid mixture of cementite and ferrite	Formed on decay of austenite	Below 723	Harder and stronger than ferrite but less ductile. Magnetic	160-230
Martensite	Solid solution of carbon and other elements in alpha-iron with distorted lattice	Formed on very rapid cooling of austenite from above its critical temperatures	Below 150	Brittle, hard. Hardness depends upon carbon content. Magnetic; heat and electric conductivities are low	650-700

Table 12 continued

Structure	Definition	Conditions of formation	Stable at temperatures, °C	Physical properties	Brinell hardness number, H_B
Troostite	Highly dispersed mixture of ferrite and carbides	Formed on heating of martensite in the 250-400° C range or on slow cooling of austenite	Approx. up to 400	Magnetic. Less stronger, more ductile and higher in electrical conductivity than martensite	330-400
Acicular troostite (bainite)	Ditto	Formed on isothermal transformation of austenite in the 250-400° C range	Up to 500	Hard, fairly ductile, Magnetic	Harder than troostite
Sorbite	Fine mixture of ferrite and cementite	Formed on heating of martensite in the 400° C-Ac_1 range or on very slow cooling of austenite	Up to Ac_1	Ductile and resilient. Less stronger and harder than troostite Magnetic	270-320
Ledeburite	An austenite-cementite eutectic mixture containing 4.3% carbon	Formed on solidification of liquid alloys containing more than 2.0% carbon	Below 1130	Brittle	

Notes. 1. Steel structures composed of martensite and troostite, as well as of troostite and sorbite are called troosto-martensite and troosto-sorbite structures respectively and have properties intermediate between the two named structures.
2. The word "dispersed" denotes fine-crushed.

Table 13

Stability Temperature Ranges of Various Crystalline Forms of Pure Iron

On heating		On cooling	
Stable lattice	Temperature range, °C	Stable lattice	Temperature range, °C
Body-centered cubic alpha-iron	Up to 910	Body-centered cubic delta-iron	1539-1390
Face-centered gamma-iron	910-1390	Face-centered cubic gamma-iron	1390-898
Body-centered cubic delta-iron	1390-1539	Body-centered cubic alpha-iron	Below 898

Notes. 1. Disagreement between transformation temperatures on heating and cooling is called the thermal hysteresis.

2. The difference in the structures of alpha- and detla-iron is attributed only to the distance between the atoms, the mutual arrangement of atoms of both structures being identical.

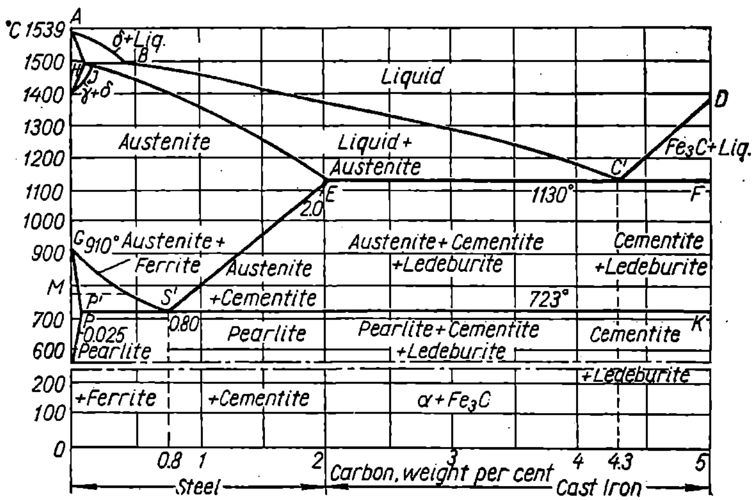


Fig. 4. Iron-carbon equilibrium diagram

Table 14

Principal Phase Transformations in Iron-carbon Alloys on Slow Heating and Cooling

Line of transformation	Temperature of transformation, °C	Nature of transformation	Designation of critical points	
			on heating	on cooling
PSK	723	Transformation of pearlite to austenite Transformation of austenite to pearlite	Ac_1	Ar_1
MO	768	Loss of magnetism for steels containing approximately up to 0.5% carbon Regaining of magnetism for the same steels	Ac_2	Ar_2
GOS	910-723	The end of the dissolution of ferrite in austenite in hypoeutectoid steels The beginning of the separation of ferrite from austenite in hypoeutectoid steels	Ac_3	Ar_3
SE	723-1130	The end of the dissolution of cementite in austenite in hypereutectoid steels The beginning of the rejection of cementite from austenite in hypereutectoid steels	Ac_m	Ar_m
IE		The beginning of melting of steel on heating The end of solidification of steel on cooling	—	—
ECF	1130	The beginning of melting of cast iron on heating The end of solidification of cast iron on cooling	—	—
ABCD	—	The end of melting of steel and cast iron on heating The beginning of solidification of steel and cast iron on cooling	—	—

3. Alloying Elements and Their Effect on the Properties of Steel

Alloying elements are added to steels with the aim of imparting specific mechanical and physicochemical properties to the latter (see Tables 15 and 16).

Table 15

Conventional Symbols for Elements Contained in Steels

Element	Designation of elements in tables of chemical composition	Designation of elements in Soviet Standards for marking steel grades
Aluminium	Al	Ю
Boron	B	Р
Carbon	C	У
Chromium	Cr	Х
Cobalt	Co	К
Copper	Cu	Д
Manganese	Mn	Г
Molybdenum	Mo	М
Nickel	Ni	Н
Niobium	Nb	Б
Phosphorus	P	П
Silicon	Si	С
Sulphur	S	—
Titanium	Ti	Т
Tungsten	W	В
Vanadium	V	Ф

Alloying elements comprise aluminium, boron, vanadium, tungsten, cobalt, molybdenum, nickel, titanium, chromium, etc. Silicon and manganese are considered alloying elements, only if they are contained in the steel in amounts higher than usually.

4. Chemical Composition and Hardness of Market Steels

Steels are divided into three classes according to their use:

1. *Structural steel* is used mainly for the manufacture of machine parts and various structures.
2. *Tool steel* is used for the manufacture of tools.
3. *Steels with specific physical and chemical properties* are used for the manufacture of special machinery and machine parts.

Structural and tool steels are divided into carbon and alloy grades according to their chemical composition.

Tables 17 to 36 present chemical composition, hardness numbers of various grades of steels (manufactured according to Soviet Standards and, partly, according to ministerial specifications), as well as critical temperatures of steels on heating.

Table 16

Effect of Alloying Elements on Properties of Steels

Element	Tendency to overheating	Hardenability	Annealing, normalising, and hardening temperatures	Hardness and strength	Ductility	High-temperature strength
Aluminium	Lowers considerably	Lowers	Increases noticeably	Increases slightly	Increases slightly when in small amounts	Influences slightly
Boron	—	Increases	Increases	Increases	Lowers	—
Chromium	Lowers slightly	Increases	Increases	Increases	No decrease up to 1.5%	Increases
Cobalt	Influences slightly	Lowers	Influences slightly	Increases slightly	Influences slightly	Increases slightly
Manganese	Increases slightly	Increases	Lowers	Increases	No decrease when added in amounts up to 1.5% in low-carbon steel, lowers for medium- and high-carbon steels	Influences slightly

Table 16 continued

Element	Tendency to overheating	Harden-ability	Annealing, normalising, and hardening temperatures	Hardness and strength	Ductility	High-temperature strength
Molybdenum	Influences slightly	Increases considerably	Increases	Increases	Increases when added in amounts up to 0.6%	Increases
Nickel	Influences slightly	Increases	Lowers	Increases	Increases slightly	Influences slightly
Niobium	—	—	Increases	Lowers	Increases	
Silicon	Influences slightly	Increases	Increases	Increases	Lowers	Increases slightly
Titanium	Lowers	—	Increases considerably	Increases slightly	Increases slightly	Influences slightly
Tungsten	Lowers	Increases	Increases	Increases	Increases slightly when added in amounts up to 1%	Increases considerably
Vanadium	Lowers noticeably	—	Increases	Increases	Increases	Influences slightly

Note. Boron content in steel averages 0.002-0.005%.

Table 17

Chemical Composition of Plain Carbon Steel

Grade	Chemical composition, %		
	Carbon	Manganese	Silicon
Open-hearth steel			
MCт.0	⩽0.23	—	—
MCт.1КП	0.06-0.12	⩽0.05	0.25-0.50
MCт.2КП	0.09-0.15	⩽0.07	0.25-0.50
MCт.3КП	0.14-0.22	⩽0.07	0.30-0.60
MCт.3	0.14-0.22	0.12-0.30	0.40-0.65
MCт.4КП	0.18-0.27	⩽0.07	0.40-0.70
MCт.4	0.18-0.27	0.12-0.30	0.40-0.70
MCт.5	0.28-0.37	0.15-0.35	0.50-0.80
MCт.6	0.38-0.49	0.15-0.35	0.50-0.80
MCт.7	0.50-0.62	0.15-0.35	0.50-0.80

Notes. 1. Phosphorus content should not exceed 0.07% for steel MCт.0, and 0.045% for other grades; corresponding amounts of sulphur are 0.06% and 0.055% respectively.
2. Table 32 lists chemical composition of open-hearth steels.

Table 18

Chemical Composition and Hardness Numbers of Free-cutting Steels

Grade	Chemical composition, %					Brinell hardness number
	Carbon	Silicon	Manganese	Sulphur	Phosphorus	
A12	0.08-0.16	0.15-0.35	0.6-0.9	0.08-0.20	0.08-0.15	167-217
A20	0.15-0.25	0.15-0.35	0.6-0.9	0.08-0.15	Below 0.06	167-217
A30	0.25-0.35	0.15-0.35	0.7-1.0	0.08-0.15	Below 0.06	174-223
A40Г	0.35-0.45	0.15-0.35	1.2-1.55	0.18-0.3	Below 0.05	179-229

Table 19

Chemical Composition and Mechanical Properties of Quality Carbon Steel

Grade	Chemical composition, %			Mechanical properties			
	Carbon	Silicon	Manganese	Tensile strength, kg/mm²	Elonga-tion, %	Impression diameter, mm, minimum	Hardness number, H_B, maximum
			Group I				
05КП	⩽0.06	⩽0.03	⩽0.40	—	—	—	—
08КП*	0.05-0.11	⩽0.03	0.25-0.50	30	35	5.2	131
08	0.05-0.12	0.17-0.37	0.35-0.65	33	33		
10КП*	0.07-0.14	0.07	0.25-0.50	32	33	5.1	137
10КП	0.07-0.14	0.17-0.37	0.35-0.65	34	31		
15КП*	0.12-0.19	⩽0.07	0.25-0.50	36	29	5.0	143
15*	0.12-0.19	0.17-0.37	0.35-0.65	38	27		
20КП*	0.17-0.24	⩽0.07	0.25-0.50	39	27	4.8	156
20*	0.17-0.24	0.17-0.37	0.35-0.65	42	25		
25*	0.22-0.30	0.17-0.37	0.50-0.80	46	23	4.6	170
30*	0.27-0.35	0.17-0.37	0.50-0.80	50	21	4.5	179
35*	0.32-0.40	0.17-0.37	0.50-0.80	54	20	4.4	187
40	0.37-0.45	0.17-0.37	0.50-0.80	58	19	4.4	187
45	0.42-0.50	0.17-0.37	0.50-0.80	61	16	4.3	197
50	0.47-0.55	0.17-0.37	0.50-0.80	64	14	4.2	207
55	0.52-0.60	0.17-0.37	0.50-0.80	66	13	4.1	217
60	0.57-0.65	0.17-0.37	0.50-0.80	69	12	4.0	229
65	0.62-0.70	0.17-0.37	0.50-0.80	71	10	4.0	229
70	0.67-0.75	0.17-0.37	0.50-0.80	73	9	4.0	229
75	0.72-0.80	0.17-0.37	0.50-0.80	110	7	3.9	241
80	0.77-0.85	0.17-0.37	0.50-0.80	110	6	3.9	241
85	0.82-0.90	0.17-0.37	0.50-0.80	115	6	3.8	255
			Group II				
15Г*	0.12-0.19	0.17-0.37	0.70-1.00	42	26	4.7	163
20Г*	0.17-0.24	0.17-0.37	0.70-1.00	46	24	4.3	197
25Г*	0.22-0.30	0.17-0.37	0.70-1.00	50	22	4.2	207
30Г	0.27-0.35	0.17-0.37	0.70-1.00	55	20	4.4	187
35Г	0.32-0.40	0.17-0.37	0.70-1.00	57	18	4.3	197

Table 19 continued

Grade	Chemical composition, %			Mechanical properties			
	Carbon	Silicon	Manganese	Tensile strength, kg/mm²	Elongation, %	Impression diameter, mm, minimum	Hardness number, H_B, maximum
40Г	0.37-0.45	0.17-0.37	0.70-1.00	60	17	4.2	207
45Г	0.42-0.50	0.17-0.37	0.70-1.00	63	15	4.1	217
50Г	0.48-0.56	0.17-0.37	0.70-1.00	66	13	4.1	217
60Г	0.57-0.65	0.17-0.37	0.70-1.00	71	11	4.0	229
65Г	0.62-0.70	0.17-0.37	0.90-1.20	75	9	4.0	229
70Г	0.67-0.75	0.17-0.37	0.90-1.20	80	8	4.0	229

Notes. 1. Sulphur and phosphorus content for all grades of steel averages ⩽ 0.04%, except for grades 05КП, 08 and 10 where phosphorus content amounts to ⩽ 0.035%.
2. Hardness numbers of steel grades marked with an asterisk refer to non-annealed steel, the balance representing hardness numbers of annealed steel.

Table 20

Chemical Composition and Hardness Numbers for Plough Share Rolled Steel

Grade	Chemical composition, %			Brinell hardness number, as supplied	
	Carbon	Manganese	Other elements	Minimum impression diameter, mm	Maximum hardness number
Л53	0.47-0.57	0.5-0.8	Silicon 0.15-0.4 Sulphur below 0.05	3.8	255

Table 21

Chemical Composition and Hardness Numbers of Alloy Structural Steel

Grade	Chemical composition, %				Brinell hardness number after annealing	
	Carbon	Manganese	Chromium	Other elements	Minimum impression diameter, mm	Maximum hardness number
35Г2	0.31-0.39	1.4-1.8	—	—	4.2	207
40Г2	0.36-0.44	1.4-1.8	—	—	4.1	217
45Г2	0.41-0.49	1.4-1.8	—	—	4.0	229
50Г2	0.46-0.55	1.4-1.8	—	—	4.0	229
15X	0.12-0.18	0.4-0.7	0.7-1.0	—	4.5	179
15XP	0.12-0.18	0.4-0.7	0.7-1.0	0.002 B	4.4	177
20X	0.17-0.23	0.5-0.8	0.7-1.0	—	4.5	179
30X	0.25-0.33	0.5-0.8	0.8-1.1	—	4.4	187
30XPA	0.27-0.33	0.5-0.8	1.0-1.3	0.002 B	—	—
35X	0.31-0.39	0.5-0.8	0.8-1.0	—	4.3	197
35XPA	0.33-0.40	0.5-0.8	0.8-1.0	0.002 B	4.1	217
38XA	0.34-0.42	0.5-0.8	0.8-1.1	—	4.2	207
40X	0.36-0.44	0.5-0.8	0.8-1.1	—	4.1	217
40XP	0.37-0.45	0.5-0.8	0.8-1.1	0.002 B	4.0	229
45X	0.41-0.49	0.5-0.8	0.8-1.1	—	4.0	229
45XЦ	0.41-0.49	0.5-0.8	0.8-1.1	0.5 Al 0.15-0.25 Zr	4.1	217
50X	0.46-0.54	0.5-0.8	0.8-1.1	—	4.0	229
15XГ	0.12-0.20	1.1-1.4	0.4-0.7	—	4.4	187
18XГ	0.15-0.21	0.9-1.2	0.9-1.2	—	4.4	187
18XГT	0.17-0.23	0.8-1.1	1.0-1.3	0.06-0.12 Ti	4.1	217
20XГ	0.15-0.25	0.9-1.2	0.9-1.2	—	4.4	187
20XГP	0.18-0.24	0.7-1.1	0.8-1.1	0.002-0.005B	4.3	197
30XГT	0.24-0.32	0.8-1.1	1.0-1.3	0.06-0.12 Ti	4.0	229
40XГ	0.37-0.45	0.9-1.2	0.9-1.2	—	4.0	229
40XГP	0.37-0.45	0.7-1.0	0.8-1.1	0.002-0.005B	3.9	241
35XГ2	0.32-0.40	1.6-1.9	0.4-0.7	—	4.0	229
40XГM	0.37-0.45	0.9-1.2	0.9-1.2	0.2-0.3 Mo	3.9	241
33XC	0.29-0.37	0.3-0.6	1.3-1.6	1.0-1.3 Si	3.9	241
38XC	0.34-0.42	0.3-0.6	1.3-1.6	1.0-1.3 Si	3.8	255
40XC	0.37-0.45	0.3-0.6	1.3-1.6	1.2-1.6 Si	3.8	255
27CГ	0.23-0.31	1.1-1.4	⩽0.25	1.1-1.4 Si	4.1	217

Grade	Chemical composition, %				Brinell hardness number after annealing	
	Carbon	Manganese	Chromium	Other elements	Minimum impression diameter, mm	Maximum hardness number
35СГ	0.31-0.39	1.1-1.4	⩽0.25	1.1-1.4 Si	4.0	229
36Г2С	0.32-0.40	0.4-0.7	⩽0.25	0.4-0.7 Si	4.0	229
15ХМ	0.11-0.18	0.4-0.7	0.8-1.1	0.4-0.55 Mo	4.5	179
20ХМ	0.15-0.25	0.4-0.7	⩽0.3	0.4-0.55 Mo	4.3	197
30ХМ	0.26-0.34	0.4-0.7	0.8-1.1	0.15-0.25 Mo	4.0	229
35ХМ	0.32-0.40	0.4-0.7	0.8-1.1	0.15-0.25 Mo	3.9	241
35Х2МА	0.32-0.40	0.4-0.7	1.6-1.9	0.15-0.25 Mo	3.9	241
38ХВА	0.35-0.42	0.25-0.5	0.9-1.3	0.5-0.8 W	4.0	229
15ХФ	0.12-0.18	0.4-0.7	0.8-1.1	0.1-0.2 V	4.4	187
20ХФ	0.17-0.23	0.5-0.8	0.8-1.1	0.1-0.2 V	4.3	197
40ХФ	0.37-0.44	0.5-0.8	0.8-1.1	0.1-0.2 V	3.9	241
15НМ	0.1-0.18	0.4-0.7	⩽0.3	1.5-2.0 Ni 0.2-0.3 Mo	4.3	197
20НМ	0.17-0.25	0.4-0.7	⩽0.3			
40НМ	0.37-0.45	0.5-0.8	—	1.5-2.0 Ni 0.2-0.3 Mo		
20ХН	0.17-0.23	0.4-0.7	0.45-0.75	1.0-1.4 Ni	4.3	197
40ХН	0.36-0.45	0.5-0.8	0.45-0.75	1.0-1.4 Ni	4.1	217
45ХН	0.41-0.49	0.5-0.8	0.45-0.75	1.0-1.4 Ni	4.2	207
50ХН	0.46-0.54	0.5-0.8	0.45-0.75	1.0-1.4 Ni	4.2	207
12ХН2	0.09-0.16	0.3-0.6	0.6-0.9	1.5-1.9 Ni	4.2	207
12ХН3А	0.09-0.16	0.3-0.6	0.6-0.9	2.8-3.2 Ni	4.1	217
12Х2Н4А	0.09-0.16	0.3-0.6	1.25-1.65	3.3-3.7 Ni	3.7	269
20ХН3А	0.17-0.24	0.3-0.6	0.6-0.9	2.8-3.2 Ni	3.9	241
20Х2Н4А	0.16-0.22	0.3-0.6	1.25-1.65	3.3-3.7 Ni	3.7	269
30ХН3А	0.27-0.34	0.3-0.6	0.6-0.9	2.8-3.2 Ni	3.9	241
37ХН3А	0.33-0.41	0.25-0.55	1.2-1.6	3.0-3.5 Ni	3.7	269
34ХН1М	0.3-0.4	0.5-0.8	1.3-1.7	1.3-1.7 Ni 0.2-0.3 Mo		
34ХН2М	0.3-0.4	0.5-0.8	0.8-1.2	1.75-2.25 Ni 0.25-0.4 Mo		
34ХН3М	0.3-0.4	0.5-0.8	0.7-1.1	2.75-3.25 Ni 0.25-0.4 Mo		

Table 21 continued

Grade	Chemical composition, %				Brinell hardness number after annealing	
	Carbon	Manganese	Chromium	Other elements	Minimum impression diameter, mm	Maximum hardness number
36XH1MФA	0.32-0.4	0.3-0.5	1.3-1.7	1.3-1.7 Ni 0.3-0.4 Mo 0.08-0.15 V		
45XHMФA	0.42-0.5	0.5-0.8	0.8-1.1	1.3-1.8 Ni 0.2-0.3 Mo 0.1-0.2 V		
30XHBA	0.27-0.34	0.3-0.6	0.6-0.8	1.27-1.65 Ni 0.5-0.8 W	3.9	241
38XHBA	0.34-0.42	0.3-0.6	1.3-1.7	1.25-1.65 Ni 0.5-0.8 W	3.7	269
40XHBA	0.37-0.44	0.5-0.8	0.6-0.9	1.25-1.65 Ni 0.8-1.2 W	3.7	269
40XHMA	0.37-0.44	0.5-0.8	0.6-0.9	1.25-1.65 Ni 0.15-0.25 W	3.7	269
30X2HBA	0.27-0.34	0.3-0.6	1.6-2.0	1.4-1.8 Ni 1.2-1.5 W	3.7	269
38XH3BA	0.34-0.42	0.25-0.55	0.8-1.2	2.75-3.25 Ni 0.5-0.8 W	3.7	269
18X2H4BA	0.14-0.2	0.25-0.55	1.35-1.65	4.0-4.5 Ni 0.8-1.2 W	3.7	269
25X2H4BA	0.21-0.28	0.25-0.55	1.35-1.65	4.0-4.5 Ni 0.8-1.2 W	3.7	269
30XHBФA	0.27-0.34	0.3-0.6	0.6-0.9	2.0-2.5 Ni 0.5-0.8 W 0.15-0.3 V		
30X2HBФA	0.27-0.34	0.3-0.6	1.6-2.0	1.4-1.8 Ni 1.2-1.5 W 0.18-0.28 V	3.7	269
38XH3BФA	0.34-0.42	0.25-0.55	1.0-1.4	3.0-3.5 Ni 0.5-0.8 W 0.1-0.2 V		

Table 21 continued

Grade	Chemical composition, %				Brinell hardness number after annealing	
	Carbon	Manganese	Chromium	Other elements	Minimum impression diameter, mm	Maximum hardness number
20ХН4ФА	0.17-0.2	0.25-0.55	0.7-1.1	3.75-4.25 Ni 0.15-0.3 V	3.7	269
38ХН3МФА	0.34-0.42	0.25-0.55	1.2-1.5	3.0-3.5 Ni 0.35-0.4 Mo 0.1-0.2 V	3.7	269
15ХГНТ	0.12-0.18	0.7-1.0	0.7-1.0	0.06-0.12 Ti	4.0	229
15Х2ГН2Т	0.12-0.18	0.7-1.0	1.4-1.8	0.06-0.12 Ti	3.7	269
15Х2ГН2ТРА	0.12-0.18	0.7-1.0	1.4-1.8	0.002-0.005B 0.06-0.12 Ti	3.7	269
18ХГН	0.16-0.22	0.8-1.1	0.4-0.7	0.4-0.7 Ni	3.8	255
25Х2ГНТА	0.22-0.29	0.8-1.1	1.3-1.7	0.9-1.3 Ni 0.06-0.12 Ti	3.7	269
30ХГНА	0.28-0.35	0.6-0.9	0.9-1.2	0.3-0.6 Ni	4.0	229
38ХГН	0.35-0.43	0.8-1.1	0.5-0.8	0.7-1.1 Ni	4.0	229
30Х2ГН2	0.26-0.34	0.8-1.1	1.4-1.7	1.4-1.8 Ni	3.8	255
16ХСН	0.13-0.20	0.3-0.6	0.8-1.1	0.6-0.9 Ni 0.6-0.9 Si		
18ХСНРА	0.16-0.21	0.6-0.9	0.8-1.1	0.8-1.1 Ni 0.6-0.9 Si 0.002-0.005B	4.3	197
20ХГСА	0.17-0.23	0.8-1.1	0.8-1.1	0.9-1.2 Si	4.2	207
25ХГСА	0.22-0.28	0.8-1.1	0.8-1.1	0.9-1.2 Si	4.1	217
30ХГСА	0.28-0.34	0.8-1.1	0.8-1.1	0.9-1.2 Si	4.0	229
30ХГСНА	0.27-0.34	1.0-1.3	0.9-1.2	0.9-1.2 Si 1.4-1.8 Ni	3.8	255
35ХГСА	0.32-0.39	0.8-1.1	1.1-1.4	1.1-1.4 Si	3.6	241
38ХЮ	0.35-0.43	0.2-0.5	1.5-1.8	0.5-0.8 Al	4.0	229
38ХМЮА	0.35-0.42	0.3-0.6	1.35-1.65	0.15-0.25 Mo	4.0	229
38ХВФЮ	0.35-0.43	0.2-0.4	1.5-1.8	0.2-0.4 W 0.4-0.7 Al 0.1-0.2 V	4.0	229
13Н2ХА	0.09-0.16	0.3-0.6	0.2-0.5	1.7-2.1 Ni	4.2	207

Table 22

Chemical Composition and Hardness Numbers of Non-annealed Spring Steels

Grade	Chemical composition, %				Brinell hardness number	
	Carbon	Silicon	Manganese	Other elements	Minimum impression diameter, mm	Maximum hardness number, H_B
65	0.6-0.7	0.17-0.37	0.5-0.8	—	3.8	255
70	0.65-0.75	0.17-0.37	0.5-0.8	—	3.7	269
75	0.72-0.80	0.17-0.37	0.5-0.8	—	3.6	285
85	0.82-0.90	0.17-0.37	0.5-0.8	—	3.5	302
55ГС	0.52-0.60	0.5-0.8	0.6-0.9	—	3.6	285
65Г	0.6-0.7	0.17-0.37	0.9-1.2	—	3.7	269
50C2	0.47-0.55	1.5-2.0	0.6-0.9	—	3.6	285
55C2	0.52-0.60	1.5-2.0	0.6-0.9	—	3.6	285
60C2	0.57-0.65	1.5-2.0	0.6-0.9	—	3.5	302
60C2A	0.56-0.64	1.6-2.0	0.6-0.9	—	3.5	302
63C2A	0.60-0.65	1.8-2.2	0.6-0.9	—	3.5	302
70C3A	0.66-0.74	2.4-2.8	0.6-0.9	—	3.5	302
70C2XA (ЭИ142)	0.65-0.75	1.4-1.7	0.4-0.6	Cr 0.2-0.4	—	—
50ХГ	0.46-0.54	0.17-0.37	0.7-1.0	Cr 0.9-1.2	3.5	302
50ХГА	0.46-0.54	0.17-0.37	0.8-1.0	Cr 0.95-1.2	3.5	302
50ХФА	0.46-0.54	0.17-0.37	0.5-0.8	Cr 0.8-1.1 V 0.1-0.2	3.5	302
50ХГФА	0.48-0.55	0.17-0.37	0.8-1.0	Cr 0.95-1.2 V 0.15-0.25	3.4	321
60C2ХФА	0.56-0.64	1.4-1.8	0.4-0.7	Cr 0.9-1.2 V 0.1-0.2	3.5	302
60C2XA	0.56-0.64	1.4-1.8	0.4-0.7	Cr 0.7-1.0	3.4	321
65C2BA	0.61-0.69	1.5-2.0	0.7-1.0	W 0.8-1.2	3.5	302
60C2H2A	0.56-0.64	1.4-1.8	0.4-0.7	Ni 1.4-1.7	3.5	302
55СГ	0.5-0.6	1.3-1.8	0.8-1.0	—	3.6	285
60СГ	0.55-0.65	1.3-1.8	0.8-1.0	—	3.6	285
60СГА	0.56-0.64	1.3-1.8	0.8-1.0	—	3.6	285

Notes. 1. The 70C2XA (ЭИ142) grade steel is marketed in the form of strips.

2. In addition, high-quality steel differs from quality steel as to lower sulphur and phosphorus content.

Table 23

Chemical Composition and Hardness Numbers of Ball-bearing Steels

Grade	Chemical composition, %				Brinell hardness number	
	Carbon	Manganese	Chromium	Silicon	Minimum impression diameter, mm	Maximum hardness number, H_B
ШХ6	1.05-1.15	0.2-0.4	0.4-0.7	0.15-0.35	4.2-4.6	170-207
ШХ9	1.0-1.1	0.2-0.4	0.9-1.2	0.15-0.35	4.2-4.6	170-207
ШХ15	0.95-1.1	0.2-0.4	1.3-1.65	0.15-0.35	4.2-4.6	170-207
ШХ15СГ	0.95-1.1	0.9-1.2	1.3-1.65	0.4-0.65	4.2-4.6	170-207
ШХ10	0.32-0.42	0.4-0.7	0.8-1.2	0.17-0.37		

Notes. 1. The grade ШХ10 steel contains maximum 0.03% both of sulphur and phosphorus. The remaining grades of steel contain less than 0.027% of sulphur and less than 0.02% of phosphorus.
2. Nickel content may rise up to 0.3%, that of copper up to 0.25%, while their sum should not exceed 0.5%.

Low-coercivity magnetic steels and alloys are used for the manufacture of parts of electrical machines. These steels comprise electric sheet steel, low-carbon electric steel, high permeability alloys and alloys with specific magnetic properties.

Table 24 lists data on electric sheet steels, while Table 25 presents data on low-carbon electric steels.

High permeability alloys, i. e., permalloys, include iron-nickel alloys of grades 45H, 50H, 50НП, 05НП, 38НС, 50НХС, 79НМ, 80НХС, 79НМА.

Table 26 presents data on alloys with specific magnetic properties.

Table 24

Electric Sheet Steel

Grade	Silicon content, %	Degree of alloying
Э11, Э12, Э13, Э1100, Э1200, Э1300	0.8-1.8	Low
Э21, Э22	1.8-2.8	Medium
Э31, Э32, Э3100, Э3200, Э310, Э320,		

Table 24 continued

Grade	Silicon content, %	Degree of alloying
Э330, Э330А	2.8-3.8	Fairly high
Э41, Э42, Э43, Э43А, Э44, Э45, Э46, Э47, Э48	3.8-4.8	High

Note. The steel grade designation is read as follows: Э – electric; the first figure designates the degree of alloying with silicon; the second figure – guaranteed electric and magnetic properties; the letter "A" after the last figure denotes extra low specific losses; the third figure "0" means that the steel has been cold-rolled and possesses adequate texture; the paired figures "00" denote that the steel is cold-rolled and has no definite texture.

Table 25

Low-carbon Electric Steel

Grade	Chemical composition, %, max						Former name of steel
	Carbon	Manganese	Silicon	Phosphorus	Sulphur	Copper	
Э, ЭА, ЭАА	0.04	0.2	0.2	0.025	0.03	0.15	Armco iron

Note. The difference between the grades is set by checking their magnetic properties after annealing. Coercivity of steels of grades Э, ЭА and ЭАА should not exceed 1.2, 1.0 and 0.8 oersteds, respectively.

Table 26

Alloys with Special Magnetic Properties

Name	Average content of main elements, %		
	Nickel	Cobalt	Iron
Permendur	—	50	50
Ditto	—	49	49
Perminvar	45	25	29.4
Ditto	70	7	22.4
Ditto	45	25	21.9
Isoperm	50	—	50
Ditto	36	—	55

Table 27

Chemical Composition and Hardness Number of Magnetic Steel as Supplied

Grade	Chemical composition, %						Brinell hardness number
	Carbon	Chromium	Tungsten	Cobalt	Molybdenum	Other elements	
EX	0.95-1.10	1.3-1.6	—	—	—	Manganese 0.2-0.4	217-241
EX3	0.9-1.1	2.8-3.6	—	—	—	Silicon 0.17-0.4	229-285
E7B6	0.68-0.78	0 3-0.5	5.2-6.2	—	—	Sulphur 0.02 *max*	255-321
EX5K5	0.90-1.05	5.5-6.5	—	5.5-6.5	—	Phosphorus 0.03 max	269-341
EX9K15M	0.90-1.05	8.0-10.0	—	13.5-16.5	1.2-1.7		285-341

Note. Steel which is off standard in chemical composition may be accepted provided all its properties are up to specifications.

Table 28

Chemical Composition of Cast Permanent Magnets

Grade of alloy		Chemical composition, %							Iron
New	Old	Nickel	Aluminium	Cobalt	Copper	Silicon	Carbon below	Manganese below	
АН1	АЛНИ1	22	11	—	—				
АН2	АЛНИ2	24.5	13	—	3.5	0.15			
АН3	АЛНИ3	23.5	15.5	—	4				
АНК	АЛНИСИ	33	13.5	—	—	1	0.03	0.35	
АНКо1	АЛНИКО12	18	10	12	6				The balance
АНКо2	АЛНИКО15	20	9	15	4	0.15			
АНКо3	АЛНИКО18	19	10	18	3				
АНКо4	АЛНИКО24 (МАГНИКО)	13.5	9	24	3				

Table 29

Chemical Composition of Г13 Steel

Grade	Chemical composition, %				
	Carbon	Manganese	Silicon, max	Sulphur, max	Phosphorus, max
Г13	1.0-1.3	10-14	0.5	0.03	0.03

Table 30

Chemical Composition of Corrosion-resisting, Non-scaling and Heat-resisting Steels and Alloys

Grade of steel or alloy	Chemical composition, %					
	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
			Martensitic Steels			
X5	⩽0.15	0.5	⩽0.5	4.5-6.0	—	—
X5M	⩽0.15	0.5	⩽0.5	4.5-6.0	—	Mo 0.45-0.6
X5BФ	⩽0.15	0.3-0.60	⩽0.5	4.5-6.0	—	W 0.4-0.7
X6CM	⩽0.15	1.5-2.0	⩽0.7	5.0-6.0	—	Mo 0.45-0.6
1X8BФ	0.08-0.15	⩽0.6	⩽0.5	7.0-8.5	—	W 0.6-1.0 V 0.3-0.5
4X9C2 (ЭСХ18)	0.35-0.45	2.0-3.0	⩽0.7	8.0-10.0	—	—
4X10C2M (ЭИ107)	0.35-0.45	1.9-2.6	⩽0.7	9.0-10.5	—	Mo 0.7-0.9
1X12H2BMФ (ЭИ961)	0.1-0.16	0.6	⩽0.6	10.5-12.0	1.5-1.8	W 1.6-2.0 Mo 0.35-0.5 V 0.18-0.3
2X13	0.16-0.24	⩽0.6	⩽0.6	12.0-14.0	—	—
3X13	0.25-0.34	⩽0.6	⩽0.6	12.0-14.0	—	—

Table 30 continued

Grade of steel or alloy	Chemical composition, %					
	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
4X13	0.35-0.44	≤0.6	≤0.6	12.0-14.0	—	—
3X13H7C2 (ЭИ72)	0.25-0.34	2.0-3.0	≤0.7	12.0-14.0	6.0-7.5	—
1X13H3	0.08-0.15	≤0.6	≤0.6	12.5-14.5	2.2-3.0	—
1X17H2	0.11-0.17	≤0.8	≤0.8	16.0-18.0	1.5-2.5	—
9X18 (ЭИ229)	0.9-1.0	≤0.8	≤0.7	17.0-19.0	—	—
Martensito-ferritic Steels						
X6CЮ (ЭИ428)	≤0.15	1.2-1.8	≤0.5	5.5-7.0	—	Al 0.7-1.1
1X11MФ	0.12-0.19	≤0.5	≤0.7	10.0-11.5	—	Mo 0.6-0.8 V 0.25-0.4
1X12BHMФ (ЭИ802)	0.12-0.18	≤0.4	0.5-0.9	11.0-13.0	0.4-0.8	W 0.7-1.1 Mo 0.5-0.7 V 0.15-0.3
2X12BMБФP (ЭИ993)	0.15-0.22	≤0.5	11.0-13.0	11.0-13.0	—	W 0.4-0.7 Mo 0.4-0.6 Nb 0.2-0.4 V 0.15-0.3 B 0.003
1X12B2MФ (ЭИ756)	0.1-0.17	≤0.5	0.5-0.8	11.0-13.0	—	W 1.7-2.2 Mo 0.6-0.9 V 0.15-0.3
1X13	0.09-0.15	≤0.6	≤0.6	12.0-14.0	—	—

Ferritic Steels

Grade of steel or alloy	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
1X12CЮ (ЭИ404)	0.07-0.12	1.2-2.0	≤0.7	12.0-14.0	—	Al 1.0-1.8
0X13 (ЭИ496)	≤0.08	≤0.6	≤0.6	11.0-13.0	—	—

Table 30 continued

Grade of steel or alloy	Chemical composition, %					
	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
X14 (ЭИ241)	⩽0.15	⩽0.7	⩽0.7	13.0-15.0	—	—
X17	⩽0.12	⩽0.8	⩽0.7	16.0-18.0	—	—
0X17T (ЭИ645)	⩽0.08	⩽0.8	⩽0.7	16.0-18.0	—	Ti 5·C-0.80
X18CЮ (ЭИ484)	⩽0.15	1.0-1.5	⩽0.5	17.0-20.0	—	Al 0.7-1.2
X25T (ЭИ439)	⩽0.15	⩽1.0	⩽0.8	24.0-27.0	—	Ti 5·C-0.80
X28 (ЭИ349)	⩽0.15	⩽1.0	⩽0.8	27.0-30.0	—	—
Austeno-martensitic Steels						
2X13H4Г9 (ЭИ100)	0.15-0.3	⩽0.8	8.0-10.0	12.0-14.0	3.7-4.7	—
X15H9Ю (ЭИ904)	⩽0.09	⩽0.8	⩽0.8	14.0-16.0	7.0-9.4	Al 0.7-1.3
X17H7Ю (ЭИ973)	⩽0.09	⩽0.8	⩽0.8	16.0-18.0	6.5-7.5	Al 0.8-1.3
2X17H2	0.22-0.28	⩽0.8	⩽0.8	16.0-18.0	1.5-2.5	—
Austeno-ferritic Steels						
0X20H14C2 (ЭИ732)	⩽0.08	2.0-3.0	⩽1.5	19.0-22.0	12.0-15.0	—
X20H14C2 (ЭИ211)	⩽0.2	2.0-3.0	⩽1.5	19.0-22.0	12.0-15.0	—
0X21H5T (ЭИ53)	⩽0.08	⩽0.8	⩽0.8	20.0-22.0	4.8-5.8	Ti 0.3-0.6
0X21H6M2T (ЭИ54)	⩽0.08	⩽0.8	⩽0.8	20.0-22.0	5.5-6.5	Ti 0.2-0.4 Mo 1.8-2.5
1X21H5T (ЭИ811)	0.09-0.14	⩽0.8	⩽0.8	20.0-22.0	4.8-5.8	Ti (C-0.02)5-0.80
X23H13 (ЭИ319)	⩽0.2	⩽1.0	⩽2.0	22.0-25.0	12.0-15.0	—
X28AH (ЭИ657)	⩽0.15	⩽1.0	⩽1.5	25.0-28.0	1.0-1.7	—
Austenitic Steels						
4X12H8Г8MФБ (ЭИ481)	0.34-0.4	0.3-0.8	7.5-9.5	11.5-13.5	7.0-9.0	Mo 1.1-1.4 Nb 0.25-0.45 V 1.25-1.55

Table 30 continued

Grade of steel or alloy	Chemical composition, %					
	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
0X10H20T2	≤0.08	≤0.8	≤2.0	10.0-12.0	18.0-20.0	Ti 1.5-2.5 Al ≤1.0
X12H20T3P (ЭИ696)	≤0.1	≤1.0	≤1.0	10.0-12.5	18.0-21.0	Ti 2.6-3.2 Al ≤0.8 B 0.003-0.02
X12H22T3MP (ЭП33)	≤0.1	≤0.6	≤0.6	10.0-12.5	21.0-25.0	Ti 2.6-3.2 Al ≤0.8 Mo 1.0-1.6 B 0.02
1X14H16Б (ЭИ694)	0.07-0.12	≤0.6	1.0-2.0	13.0-15.0	14.0-17.0	Nb 0.9-1.3
1X14H16БP (ЭИ694P)	0.07-0.12	≤0.6	1.0-2.0	13.0-15.0	14.0-17.0	Nb 0.9-1.3 B 0.005
1X14H18B2Б (ЭИ695)	0.07-0.12	≤0.6	1.0-2.0	13.0-15.0	18.0-20.0	W 2.0-2.75 Nb 0.9-1.3
1X14H18B2БP (ЭИ695P)	0.07-0.12	≤0.6	1.0-1.2	13.0-15.0	18.0-20.0	W 2.0-2.75 Nb 0.9-1.3 B ≤0.005 Ce ≤0.02
1X14H18B2БP1 (ЭИ726)	0.07-0.12	≤0.6	1.0-2.0	13.0-15.0	18.0-20.0	W 2.0-2.75 Nb 0.9-1.3 B ≤0.025 Ce ≤0.02
X14Г14H	≤0.12	≤0.8	13.0-15.0	13.0-15.0	1.0-1.5	—
X14Г14H3T (ЭИ711)	≤0.1	≤0.8	13.0-15.0	13.0-15.0	2.5-3.5	Ti (C-0.02)·5-0.60
4X14H14B2M (ЭИ69)	0.4-0.5	≤0.8	0.7	13.0-15.0	13.0-15.0	W 2.0-2.75 Mo 0.25-0.4

Table 30 continued

Grade of steel or alloy	Chemical composition, %					
	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
4Х15Н7Г7Ф2МС (ЭИ388)	0.38-0.47	0.9-1.4	6.0-8.0	14.0-16.0	6.0-8.0	Mo 0.65-0.95 V 1.5-1.9
0Х14Н28В3Т3ЮР (ЭИ786)	⩽0.08	⩽0.6	⩽0.6	13.0-15.0	26.0-29.0	Ti 2.4-3.2 Al 0.5-1.2 W 2.8-3.5 B ⩽0.02
1Х16Н13М2Б (ЭИ680)	0.06-0.12	⩽0.8	⩽1.0	15.0-17.0	12.5-14.5	Mo 2.0-2.5 Nb 0.9-1.3
Х16Н15М3Б (ЭИ847)	0.09	⩽0.8	⩽0.6	15.0-17.0	14.0-16.0	Mo 2.5-3.0 Nb 0.6-0.9
Х17Г9АН4 (ЭИ878)	⩽0.12	⩽0.8	8.0-10.5	16.0-18.0	3.5-4.5	Nitrogen 0.15-0.25
Х17Н13М2Т (ЭИ448)	⩽0.1	⩽0.8	1.0-2.0	16.0-18.0	12.0-14.0	Ti 0.3-0.6 Mo 1.8-2.5
Х17Н13М3Т (ЭИ432)	⩽0.1	⩽0.8	1.0-2.0	16.0-18.0	12.0-14.0	Ti 0.3-0.6 Mo 3.0-4.0
0Х17Н16М3Т (ЭИ580)	⩽0.08	⩽0.8	1.0-2.0	16.0-18.0	15.0-17.0	Ti 0.3-0.6 Mo 2.0-3.5
Х17АГ14 (ЭП213)	⩽0.15	⩽0.8	13.5-15.5	16.0-18.0	0.6	Nitrogen 0.3-0.4
00Х18Н10 (ЭИ842)	⩽0.04	⩽0.8	1.0-2.0	17.0-19.0	9.0-11.0	—
0Х18Н10 (0Х18Н9)	⩽0.08	⩽0.8	1.0-2.0	17.0-19.0	9.0-11.0	—
Х18Н9 (1Х18Н9)	⩽0.12	⩽0.8	1.0-2.0	17.0-19.0	8.0-10.0	—
2Х18Н9	0.13-0.21	⩽0.8	1.0-2.0	17.0-19.0	8.0-10.0	—
Х18Н10Е (ЭИ453)	⩽0.12	⩽0.8	1.0-2.0	17.0-19.0	9.0-11.0	Se or Te 0.18-0.35
0Х18Н10Т (ЭИ914)	⩽0.08	⩽0.8	1.0-2.0	17.0-19.0	9.0-11.0	Ti ⩽0.6
Х18Н10Т (1Х18Н9Т)	⩽0.12	⩽0.8	1.0-2.0	17.0-19.0	9.0-11.0	Ti (C-0.02)·5-0.7
Х18Н9Т (1Х18Н9Т)	⩽0.12	⩽0.8	1.0-2.0	17.0-19.0	8.0-9.5	Ti (C-0.02)·5-0.7
0Х18Н11 (ЭИ684)	⩽0.06	⩽0.8	1.0-2.0	17.0-19.0	10.0-12.0	

Table 30 continued

Grade of steel or alloy	Chemical composition, %					
	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
0X18H12T	$\leqslant$0.08	$\leqslant$0.8	1.0-2.0	17.0-19.0	11.0-13.0	Ti 5·C-0.8
X18H12T	$\leqslant$0.12	$\leqslant$0.8	1.0-2.0	17.0-19.0	11.0-13.0	Ti (C-0.02)·5-0.7
0X18H12Б (ЭИ402)	$\leqslant$0.08	$\leqslant$0.8	1.0-2.0	17.0-19.0	11.0-12.0	Nb 8·C-1.2
4X18H25C2	0.32-0.4	2.0-3.0	$\leqslant$1.5	17.0-19.0	23.0-26.0	—
3X19H9MBБT (ЭИ572)	0.28-0.35	$\leqslant$0.8	0.8-1.5	18.0-20.0	8.0-10.0	Ti 0.2-0.5 W 1.0-1.5 Mo 1.0-1.5 Nb 0.2-0.5
0X23H18	$\leqslant$0.1	$\leqslant$1.0	$\leqslant$2.0	22.0-25.0	17.0-20.0	
X23H18 (ЭИ417)	$\leqslant$0.2	$\leqslant$1.0	$\leqslant$2.0	22.0-25.0	17.0-20.0	
0X23H28M2T (ЭИ628)	$\leqslant$0.06	$\leqslant$0.8	$\leqslant$0.8	22.0-25.0	26.0-29.0	Ti 0.4-0.7 Mo 1.8-2.5
0X23H28M3Д3T (ЭИ943)	$\leqslant$0.06	$\leqslant$0.8	$\leqslant$0.8	22.0-25.0	26.0-29.0	Ti 0.4-0.7 Mo 2.5-3.0 Cu 2.5-3.5
X25H16Г7AP (ЭИ835)	$\leqslant$0.12	$\leqslant$1.0	5.0-7.0	23.0-26.0	15.0-18.0	Nitrogen 0.3-0.45 B 0.02
X25H20C2 (ЭИ283)	$\leqslant$0.2	2.0-3.0	$\leqslant$1.5	24.0-27.0	18.0-21.0	
1X25H25TP (ЭИ813)	0.07-0.12	$\leqslant$0.8	1.0-2.0	23.0-26.0	24.0-27.0	Ti 1.1-1.6 B $\leqslant$0.01
Iron-nickel Alloys						
XH35BMT (ЭИ692)	$\leqslant$0.12	$\leqslant$0.6	$\leqslant$1.0	14.0-16.0	32.0-36.0	W 2.3-3.0 Mo 2.0-3.0 B $\leqslant$0.02 Ce 0.025

Tadle 30 continued

Grade of steel or alloy	Chemical composition, %					
	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
ХН35ВТ (ЭИ612)	⩽0.12	⩽0.6	1.0-2.0	14.0-16.0	34.8-38.0	Ti 1.1-1.5 W 2.8-3.5
ХН35ВТЮ (ЭИ787)	⩽0.08	⩽0.6	⩽0.6	14.0-16.0	33.0-37.0	Ti 2.4-3.2 Al 0.7-1.4 W 2.8-3.5 B ⩽0.02
ХН35ВТР (ЭИ725)	⩽0.1	⩽0.6	⩽1.0	14.0-16.0	35.0-38.0	Ti 1.1-1.5 W 4.0-5.0 B ⩽0.005 Ce ⩽0.025
ХН38ВТ (ЭИ703)	0.06-0.12	⩽0.8	⩽0.7	20.0-23.0	35.0-39.0	Ti 0.7-1.2 Al ⩽0.5 W 2.8-3.5
Nickel-base Alloys						
ХН60Ю (ЭИ559А)	⩽0.1	⩽0.8	⩽0.3	15.0-18.0	55.0-58.0	Al 2.6-3.5 Ba ⩽0.1 Ce ⩽0.003
ХН70ВМЮТ (ЭИ765)	0.1-0.16	⩽0.6	⩽0.5	14.0-16.0	The bal ance	Ti 1.0-1.4 Al 1.7-2.2 W 4.0-6.0 Mo 3.0-5.0 B ⩽0.01 Fe ⩽3.0

Table 30 continued

Grade of steel or alloy	Chemical composition, %					
	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
ХН70ВМТЮ (ЭИ617)	⩽0.12	⩽0.6	⩽0.5	13.0-16.0	The balance	Ti 1.8-2.3 Al 1.7-2.3 W 5.0-7.0 Mo 2.0-4.0 V 0.1-0.5 B ⩽0.02 Ce ⩽0.02 Fe ⩽5.0
ХН80ТБЮ (ЭИ607)	⩽0.08	⩽0.8	⩽1.0	15.0-18.0	Ditto	Ti 1.8-2.3 Al 0.5-1.0 Nb 1.0-1.5 Fe ⩽3.0
ХН70МВТЮБ (ЭИ598)	⩽0.12	⩽0.6	⩽0.5	16.0-19.0	Ditto	Ti 1.9-2.8 Al 1.0-1.7 W 2.0-3.5 Mo 4.0-6.0 Nb 0.5-1.3 B ⩽0.01 Ce ⩽0.02 Fe ⩽5.0
ХН67ВМТЮ (ЭИ445Р)	⩽0.08	⩽0.6	⩽0.5	17.0-20.0	Ditto	Ti 2.2-2.8 W 4.0-5.0 Mo 4.0-5.0 B ⩽0.01 Ce ⩽0.01 Al 1.0-1.5 Fe ⩽4.0

Table 30 continued

Grade of steel or alloy	Chemical composition, %					
	Carbon	Silicon	Manganese	Chromium	Nickel	Other elements
ХН75МБТЮ (ЭИ602)	⩽0.1	⩽0.8	⩽0.4	19.0-22.0	The balance	Ti 0.35-0.75 Al 0.35-0.75 Mo 1.8-2.3 Nb 0.9-1.3 Fe ⩽8.0
ХН78Т (ЭИ435)	⩽0.12	⩽0.8	⩽0.7	19.0-22.0	Ditto	Ti 0.15-0.35 Al ⩽0.15 Fe ⩽6.0
ХН77ТЮ (ЭИ437А)	⩽0.06	⩽0.6	⩽0.4	19.0-22.0	Ditto	Ti 2.3-2.7 Al 0.55-0.95 Fe ⩽4.0 Ce ⩽0.01
ХН77ТЮР (ЭИ137Б)	⩽0.06	⩽0.6	⩽0.4	19.0-22.0	Ditto	Ti 2.3-2.7 Al 0.55-0.95 Fe ⩽4.0 B ⩽0.01 Ce ⩽0.01
ХН60В (ЭИ868)	⩽0.1	⩽0.8	⩽0.5	23.5-26.5	Ditto	Ti 0.3-0.7 Al ⩽0.5 W 13.0-16.0 Fe ⩽4.0
ХН70Ю (ЭИ652)	⩽0.1	⩽0.8	⩽0.3	26.0-29.0	Ditto	Al 2.6-3.5 Fe ⩽1.0 Ba ⩽0.1 Ce ⩽0.03
ХН70 (ЭИ442)	⩽0.07	⩽0.8	⩽0.5	28.0-31.0	Ditto	Al ⩽0.15 Fe ⩽5.0

Table 31

Hardness Numbers of Stainless Steels Supplied in Annealed State

Grade	Brinell hardness number	
	Impression diameter, mm	Hardness number
0X13	4.5-5.5	116-179
1X13	4.4-5.4	121-187
2X13	4.3-5.3	126-197
3X13	4.2-5.2	131-207
4X13	4.0-5.0	143-229
X17	4.3-5.3	126-197
9X18	3.8 min	225 max
1X17H2	3.6 min	286 max

Table 32

Chemical Composition of Alloys Used for the Manufacture of Electric Heating Resistors

Grade	Chemical composition, %							
	Carbon	Manganese	Silicon	Chromium	Nickel	Aluminium	Titanium	Iron
	maximum							
X13Ю4	0.15	0.4	1.0	16.0-19.0	⩽0.6	4.0-6.0	—	The balance
0X23Ю5	0.06	0.5	0.7	21.5-24.5	Ditto	4.5-5.5	—	Ditto
0X23Ю5A	0.05	0.3	0.6	21.5-23.5	Ditto	4.5-5.2	—	Ditto
0X27Ю5A	0.05	0.3	0.6	26.0-28.0	Ditto	5.0-6.8	—	Ditto
X15H60	0.15	0.7	0.4-1.3	15.0-18.0	55.0-61.0	⩽0.2	—	Ditto
X20H80	0.15	0.7	0.4-1.3	20.0-23.0	75.0-78.0	⩽0.2	—	⩽1.0
X20H80T3	0.08	0.5	1.0 max	19.0-23.0	The balance	0.4-1.2	2.0-2.9	⩽2.5

Table 33

Chemical Composition and Hardness Numbers of Carbon Tool Steels

Grade	Chemical composition, %			Brinell hardness number	
	Carbon	Manganese	Other elements	Impression diameter, mm, minimum	Hardness number, maximum
У7	0.65-0.74	0.20-0.40	Silicon	4.4	187
У8	0.75-0.84	0.20-0.40	0.15-0.35	4.4	187
У8Г	0.80-0.90	0.35-0.60		4.4	187
У9	0.85-0.94	0.15-0.35	Sulphur	4.35	192
У10	0.95-1.04	0.15-0.35	0.03 max	4.3	197
У11	1.05-1.14	0.15-0.35		4.2	207
У12	1.15-1.24	0.15-0.35	Phosphorus	4.2	207
У13	1.25-1.35	0.15-0.35	0.035 max	4.1	217

Note. High-quality steel differs from quality steel, the amount of carbon being equal for both, by lower sulphur and phosphorus contents, 0.02% and 0.03 as a maximum, respectively, and by a slightly different content of manganese and silicon. High-quality steel is designated У7А, У8А, УВГА, etc.

Table 34

Chemical Composition and Hardness Numbers of Alloy Tool Steels

Grade	Chemical composition, %				Brinell hardness number	
	Carbon	Chromium	Tungsten	Other elements	Impression dia, mm	Hardness number
7X3	0.60-0.75	3.2-3.8	—	—	4.0-4.4	229-187
8X3	0.76-0.85	3.2-3.8	—	—	3.8-4.2	255-207

Grade	Chemical composition, %				Brinell hardness number	
	Carbon	Chromium	Tungsten	Other elements	Impression dia, mm	Hardness number
65Х	0.60-0.70	0.50-0.75	—	—	4.4 min	187 max
9Х	0.80-0.95	1.4-1.7	—	—	4.1-4.5	217-179
Х	0.95-1.10	1.3-1.6	—	—	4.0-4.4	229-187
Х09	0.95-1.10	0.75-1.05	—	—	4.0-4.5	229-179
Х05	1.25-1.40	0.4-0.6	—	—	3.9-4.3	241-197
Х12	2.00-2.30	11.5-13.0	—	—	3.7-4.1	269-217
Ф	0.95-1.05	—	—	Vanadium 0.2-0.4	4.1-4.5	217-179
В1	1.05-1.25	0.1-0.3	0.8-1.2	Vanadium 0.15-0.30	4.0-4.4	229-187
ХГ	1.3-1.5	1.3-1.6	—	Manganese 0.45-0.70	3.9-4.3	241-197
4ХС	0.35-0.45	1.3-1.6	—	Silicon 1.2-1.6	4.2-4.6	207-170
6ХС	0.6-0.7	0.95-1.25	—	Silicon 0.6-1.0	4.0-4.4	229-187
ХГС	0.95-1.1	1.4-1.8	—	Silicon 0.5-1.0 Manganese 0.8-1.2	3.8-4.2	255-207
9ХС	0.85-0.95	0.95-1.25	—	Silicon 1.2-1.6	3.9-4.3	241-197
8ХФ	0.75-0.85	0.5-0.8	—	Vanadium 0.15-0.30	4.2-4.6	207-170
85ХФ	0.80-0.90	0.45-0.70	—	Vanadium 0.15-0.30	4.2-4.6	207-170
4ХВ2С	0.35-0.44	1.0-1.3	2.0-2.5	Silicon 0.6-0.9	4.1-4.5	217-179
5ХВ2С	0.45-0.54	1.0-1.3	2.0-2.5	Silicon 0.5-0.8	3.8-4.2	255-207
6ХВ2С	0.55-0.65	1.0-1.3	2.2-2.7	Silicon 0.5-0.8	3.6-4.0	285-229
5ХВГ	0.55-0.70	0.5-0.8	0.5-0.8	Manganese 0.9-1.2	4.1-4.5	217-179
9ХВГ	0.85-0.95	0.5-0.8	0.5-0.8	Manganese 0.9-1.2	3.9-4.3	241-197
ХВГ	0.90-1.05	0.9-1.2	1.2-1.6	Manganese 0.8-1.1	3.8-4.2	255-207

Grade	Chemical composition, %				Brinell hardness number	
	Carbon	Chromium	Tungsten	Other elements	Impression dia, mm	Hardness number
3X2B8	0.30-0.40	2.2-2.7	7.5-9.0	—	3.8-4.2	255-207
4X8B2	0.35-0.45	7.0-9.0	2.0-3.0	—	3.8-4.2	255-207
XB5	1.25-1.50	0.4-0.7	4.5-5.5	Vanadium 0.15-0.30	3.6-4.0	285-229
X12M	1.45-1.70	11.0-12.5	—	Molybdenum 0.4-0.6 Vanadium 0.15-0.30	3.8-4.2	255-207
5XHM	0.5-0.6	0.5-0.8	—	Molybdenum 0.15-0.30 Nickel 1.4-1.8	3.9-4.3	241-197
5XΓM	0.5-0.6	0.6-0.9	—	Molybdenum 0.15-0.30 Manganese 1.2-1.6	3.9-4.3	241-197
5XHT	0.5-0.6	0.6-0.9	—	Nickel 1.4-1.8 Titanium 0.1-0.2	3.95-4.35	235-192
5XHC	0.5-0.6	1.3-1.6	—	Nickel 0.8-1.3 Silicon 0.6-0.9	3.8-4.2	255-207
5XHCB	0.5-0.6	1.3-1.6	0.4-0.6	Nickel 0.8-1.3 Silicon 0.6-0.9	3.8-4.2	255-207
5XHB	0.5-0.6	0.5-0.8	0.6-1.0	Nickel 1.4-1.8	3.9-4.3	241-197
45XHT	0.43-0.5	1.2-1.4	—	Nickel 1.5-2.0 Titanium 0.03-0.12	3.9 min	241 max
45XHB	0.43-0.5	0.5-0.8	0.6-1.0	Nickel 1.5-2.0	3.9 min	241 max
X12Φ1	1.45-1.70	11.0-12.5	—	Vanadium 0.7-0.9	3.8-4.2	255-207

Table 35

Chemical Composition and Hardness Numbers of High-speed Steels

Grade	Chemical composition, %						Hardness number in annealed condition	
	Carbon	Chromium	Tungsten	Vanadium	Molybdenum	Cobalt	Impression diameter, mm	Hardness number, H_B
P9	0.85-0.95	3.8-4.4	8.5-10.0	2.0-2.6	$\leqslant$0.3	—	3.8-4.2	255-207
P9Φ5	1.4-1.5	3.8-4.4	9.0-10.5	4.3-5.1	$\leqslant$0.4	—	3.55	$\leqslant$293
P10K5Φ5	1.45-1.55	4.0-4.6	10.0-11.5	4.3-5.1	$\leqslant$0.3	5.0-6.0	3.55	$\leqslant$293
P9K10	0.9-1.0	3.8-4.4	9.0-10.5	2.0-2.6	$\leqslant$0.3	9.5-10.5	3.55	$\leqslant$293
P14Φ4	1.2-1.3	4.0-4.6	13.0-14.5	3.8-4.1	$\leqslant$0.4	—	—	
P18	0.7-0.8	3.8-4.4	17.5-19.0	1.0-1.4	$\leqslant$0.3	—	3.8-4.2	255-207
P18Φ2	0.85-0.95	3.8-4.4	17.5-19.0	1.8-2.4	$\leqslant$0.5	—	3.55	$\leqslant$293
P18K5Φ2	0.85-0.95	3.8-4.4	17.5-19.0	1.8-2.4	$\leqslant$0.5	5.0-6.0	3.55	$\leqslant$295
P18K5	0.65-0.77	3.6-4.5	17.0-18.5	1.0-1.4	0.3-0.6	4.5-5.5	3.7-4.1	269-217
P18K10	0.65-0.77	3.6-4.5	17.0-18.5	1.0-1.4	0.3-0.6	9.5-10.5	3.7-4.1	269-217

Table 36

Critical Points of Steels upon Heating

Grade	Critical point, °C	
	Ac_1	Ac_3
Carbon Structural Steels		
08	732	874
10	732	874
15	735	863
20	735	854
25	735	840
30	732	813
35	730	810
40	730	800
45	725	780
50	725	770
55	727	774
60	727	766
65	727	752
70	730	743
15Г	735	863
20Г	720	854
30Г	720	820
40Г	720	790
50Г	720	770
60Г	726	765
65Г	724	750
10Г2	720	830
30Г2	715	805

Grade	Critical point, °C	
	Ac_1	Ac_3
35Г2	713	794
40Г2	710	780
45Г2	713	766
50Г2	710	750
Л53		$\geqslant 750$
Alloy Structural Steels		
15Х	735	870
20Х	740	840
30Х	740	815
35Х	740	815
38ХА	740	815
40Х	740	800
45Х	721	771
50Х	721	771
55С2	775	840
60С2	750	820
15ХФ	770	850
20ХФ	760	840
40ХФА	750	800
50ХФА	750	790
15М	730	930
30М	740	815
15ХМА	740	860
20ХМ	735	840

Grade	Critical point, °C	
	Ac_1	Ac_3
30ХМ	735	820
35ХМ	735	810
35Х2МА	715	776
33ХС	750	850
37ХС	763	850
40ХС	750	840
20ХГ	765	838
40ХГ	740	820
50ХГ	750	775
35ХГ2	720	800
18ХГТ	730	850
40ХГТ	745	830
18ХГМ	740	830
38ХГМ	—	780
27СГ	750	880
35СГ	750	830
27СГТ	710	900
20ХГС	750	860
25ХГС	750	850
30ХГС	750	840
35ХГС	750	830
25Н	720	820
30Н	710	800
13Н5А	700	800
21Н5А	700	780

Table 36 continued

Grade	Critical point, °C	
	Ac_1	Ac_3
30Н3А	700	780
15НМ	725	800
40НМ	715	776
20ХН	715	810
40ХН	715	780
50ХН	715	760
12ХН2	720	840
12ХН3	715	820
20ХН3А	710	790
30ХН3	710	780
37ХН3А	710	760
12Х2Н4	715	820
35ХЮА	780	900
38ХМЮА	780	900
35ХМФА	740	840
13ХНВА	710	820
18ХНВА	710	800
33ХН3МА	720	790
18ХНМА	710	800
35ХНМ	730	810
40ХНМА	710	790
45ХНМФА	720	820
Free-cutting Steel		
А12	735	866
А20	735	843

Grade	Critical point, °C	
	Ac_1	Ac_3
High-speed Steels		
Р9	810-840	—
Р18	820-840	—
Ball-bearing Steel		
ШХ6	730-740	880 Ac_m
ШХ9	730-755	890 Ac_m
ШХ15	730-765	900 Ac_m
ШХ10	740-760	800 Ac_3
Stainless Steels		
1Х13	730	850
2Х13	820	950
3Х13	800	—
4Х13	820	1200
Х17	880	—
9Х18	830-865	—
4Х9С2	900	970
4Х10С2М	850	950
Carbon Tool Steels		
У7	730	760
У8-У13	730	—

Grade	Critical point, °C	
	Ac_1	Ac_3
Alloy Tool Steels		
Х05	740	—
Х	750	—
9Х	750	—
7Х	750	—
7Х3	770	—
ХГ	750	—
9ХС	785	—
В1	750	—
В2	765	—
9ХВГ	750	—
ХВГ	755	—
ХВ5	760	—
3Х2В8	830	—
4Х8В2	820	—
4ХВ2С	780	840
5ХВ2С	775	820
5ХНМ	730	780
5ХГМ	740	770
4ХС	770	860
Х12	810	—
Х12М	810	—
Х09	750	—
Ф	735	—

Steel grades	Uses
	Carbon Structural Steels
10, 15, 20, 25, 30, Ст. 1, Ст. 2, Ст. 3, Ст. 4, Ст. 5, 15Г, 20Г	Parts of machines, non-heat-treated, working under light loads, such as pins, screws, nuts, studs, flanges, couplings, rollers, caps, etc. Parts of machines requiring high surface hardness and subjected to carburising: gears, spindles, arbors, pivots, shafts, sliding blocks, etc. Measuring tools: carburised horseshoe gauges and templets. Steels Ст. 30 and Ст. 5 are used to manufacture carburised simple-shaped parts
35, 40, 45, 50, Ст. 6, 30Г, 40Г, 50Г, 30Г2, 40Г2, 45Г2, 50Г2	Parts of machines working under medium loads. These steels are used after normalising, as well as after a special heat-treatment process aimed at improving their machinability (quenching and high-temperature tempering): screw fastenings, tie bars, levers, spindles, gears, shafts, supports, disks, connecting rods, couplings, rods, etc., pliers, hand vice, screw-drivers, spanners, jaws for lathe chucks, track tools. Steels with increased manganese content possess higher hardenability and, following heat treatment, are harder and tougher than carbon steels with similar carbon content. This must be taken into account when choosing steels
55, 60, 65, 70, Ст. 7, 60Г, 65Г, 70Г	Collets, coil and plate springs, spring washers, expanding rings, vehicle springs, construction and harness-making hand tools. Manganese steels are best as far as springiness is concerned
	Alloy Structural Steels
15Х, 20Х, 20Х3, 15ХФ, 20ХФ, 15ХГ, 20ХГ, 18ХГТ, 18ХГМ, 13Н2А	Carburised extra-strength parts of machines working at high speeds and under heavy loads: gears, shafts, arbors, worms, spindles, plungers, pushers, cams, piston pins, pivots, crosspieces of agricultural machinery, etc. Slim and intricate-shaped carburised measuring tools

Continued

Steel grades	Uses
15XH, 20XH, 12XM, 15XM, 20XM, 12XH2, 12XH3, 12X2H4. 12X2H3MA, 13H5A, 13XHBA, 13XHMA, 18XHBA, 18XHMA, 20XH3A, 20X2H4A, 18X2H4MA	Large heavily loaded parts working at high speeds and subject to impacts. Following carburising and quenching they acquire a wear-resistant case and a tough and resilient core: gears, shafts, worm-shafts, jaw clutches, piston pins, connecting rods, parts of vibroshears, spindles of automatic lathes, etc. The latter five grades can also be used after heat-treatment
38XA, 40X, 45X, 50X, 40XГ, 40XH, 45XH, 40XMФA, 50XMФA, 35XГC, 35XMФA, 30XM, 35XM, 35X2MA, 25X2MФA, 30M, 35XГ2, 37XH3A, 40XHMA	Heavy loaded heat-treated parts working under increased bending loads and low speeds, as well as cyanided parts and those subject to quenching and low-temperature tempering, working at high speeds and under heavy non-impact loads: gears, shafts, arbors, spindles, couplings, water-pump rotors, critical fastenings. The more the steel is alloyed, the more it is suitable for the manufacture of large critical machine parts
	The heaviest loaded critical parts: gears, spindles, shafts, clutch pawls for engaging presses, etc. Fancy-shaped parts which are to be minimum in size
45XHMФA	Large heavily loaded parts: spindles, torsion shafts, etc.
34XM, 34XH1M, 34XH2M, 34XH3M, 34X2H3M, 34XH3MФ, 35XMA, 33XH3MA	Turbine disks and shafts, and turbine rotors
30X, 35X	Axles, arbors, rockers, gears, fastenings, autocrane gears, etc.
33XC, 37XC, 40XC	Extra-strength and tough parts with high torsional resistance: torsion shafts, cranks, axles, chain links, etc.
27CГ, 35CГ	Axles, shafts, connecting rods, cranks, buckets of excavating machines and other parts requiring high toughness and wear resistance

Steel grades	Uses
25ХГС, 30ХГС	Arbors, gears, main rods, rods, critical fastenings, critical welded and stamped parts, excavator buckets
35ХЮА, 38ХМЮА	Highly corrosion-resistant nitrated parts working in abrasive media: spindles, shafts, rams, plungers, measuring tools
25Н, 30Н	Extra-hard critical parts having high resistance to impacts: crankshafts, axles, connecting rods, gears, rotors, etc.
	Ball-bearing Steels
ШХ6	Balls up to 13.5 mm, rollers up to 10 mm
ШХ9	Balls from 13.5 to 22.5 mm, rollers from 10 to 15 mm
ШХ15	Balls from 22.5 to 50 mm, rollers from 15 to 35 mm Rings with wall thickness from 20 to 30 mm
ШХ15СГ	Balls above 50 mm, rollers above 35 mm, rings with wall thickness above 20-30 mm
ШХ10	Flat wire used for flexible rollers
	Wear-resistant Steels
Г13	Machine parts working under heavy impact loads: track shoes, and other excavator parts, crusher jaws and jaw plates, bucket lips, buckets, tracks of excavating machines, railroad switches and frogs
	Magnet Steels
ЕХ	Rotors of internal-combustion engines
ЕХ3, Е7В6	Magnets in telephones, electric meters, etc.
ЕХ5К5, ЕХ9К15М	Powerful magnets for navigational devices, etc.
	Electric Sheet Steels
Э1, Э2	Armature and pole shoes of d-c electrical machines

Steel grades	Uses
Э3, Э4	Stators and rotors of a-c electrical machines, magnetic circuits of transformers, electromagnets for a-c apparatus (measuring instruments)
	Low-carbon Electric Steels
Э, ЭА, ЭАА	Magnetic circuits of relays, screens of audio-frequency apparatus, etc.
	High-permeability Alloys
45Н, 50Н	Cores of power transformers, choke coils, relays and elements of magnetic circuits operating at high inductances, mainly with no or negligible magnetising
50НП, 65НП	Cores of magnetic amplifiers, choke coils, commutating devices, elements of computers, etc.
38НХС, 42НС, 50НХС	Cores of impulse transformers and audio- and/or high-frequency communications systems, operating with no or negligible magnetising
79НМ, 80НХС, 79НМА	Cores of miniature transformers, choke coils, relays as well as magnetic screens
	Corrosion-resisting Steels
0Х13, 1Х13, 2Х13, 4Х13, Х14, 2Х13Н4Г9, Х14Г14Н, Х14Г14Н3Т, 1Х13Н3	Intended for operation in weak corrosive media below 30°C (aqueous solutions of salts, dilute nitric and various organic acids, food media). Steels are adequately resistant to corrosion by fresh water, steam, air
9Х18, 1Х17Н2, 2Х17Н2, Х17, 0Х17Т, Х25Т, Х25Н91, Х17Н7Ю, 0Х21Н5Г, Х28 1Х21Н5Т, 00Х18Н10, 0Х18Н10, Х18Н9, 2Х18Н9, Х18Н10Е, 0Х18Н10Т, Х18Н10Т, 0Х18Н11, 0Х18Н12Т, Х18Н12Т, 0Х18Н12Б, Х28АН, Х18Н9Т, Х17Г9АН4, Х17АГ14, 0Х10Н20Т2, Х16Н15М3Б	Intended for operation in average corrosive media—nitric and organic (except acetic, formic, lactic, oxalic) acids, most of the solutions of organic and non-organic salts at various temperatures and in various concentrations

Continued

Steel grades	Uses
0X21H6M2T, X17H13M2T, 0X17H16M3T	For operation in highly corrosive media, organic acids in particular: formic, acetic, lactic, oxalic (below 5%), etc., as well as phosphoric (up to 32% P_2O_5), containing fluoric compounds; boric acid with admixture of sulphuric acid (up to 1%); hydrosilicofluoric acids (up to 10% concentration)—for temperatures below 40°C
0X23H28M2T	Recipients for dissolving: sulphuric acid in low concentrations (up to 20%) below 60°C; phosphoric acid, containing fluoric compounds, and for other highly corrosive media
0X23H28M3Д3T	Recipients for sulphuric acids in all concentrations, below 80°C; phosphoric acid (32-50% P_2O_5), containing fluoric compounds; hydrosilicofluoric acid in increased concentrations (up to 25%) below 70°C
	Carbon Tool Steel
У7 and У7A	Cold chisels, cape chisels, simple hand dies, snaps, screwdrivers, lathe centres, plate cutters, augers, lettering dies, centre punches, dinking dies, compound pliers, cutting pliers, hammers, forging punches, chisels shaping dies, pneumatic tools, coppersmith's and tinner's tools, woodworking planing cutters, chip axes, twist drills, joiner's tongs and mason's tools
У8, У8A, У8Г	The same as for grade У7 steel plus metal cutters, collets, simple dies for cold punching, plane bits
У9, У9A	Blades for saws, cold punching dies, centres, woodworking tools—twist drills, changeable cutters, planing cutters, gouges, axes, chisels, planing bits, stone chisels
У10, У10A, У11, У11A, У12, У12A	Small simple-shape metal cutters working under light loads: round-nose tools,

Continued

Steel grades	Uses
	metal slitting and end-milling cutters, drills, reamers, screw taps, threading dies, files, saw blades, scrapers, cold punching dies, hand wood saws, cross-cut and band saws. Measuring tools. The choice of one of the above-mentioned steel grades is dependent upon the intended use of a tool*)
У13, У13А	Scrapers, razors, engraving tools, drawing tools for the working of hard stones
	Alloy Tool Steel
7X3, 8X3	Hot upsetting dies, dies and punches for hot bending, working below 500°C and under slight impacts
9X	Rolls for cold rolling, cogging rolls, lettering dies, drifts, cold upsetting dies and punches
X09	Cold punching dies, measuring tools
X, ШX15	Round-nose tools, milling cutters, drills, reamers, threading dies, screw taps, measuring tools, cold punching dies, wood saws. Grade ШX15 steel is superior to grade X steel
X05	Scrapers, engraving tools, sharp surgical instruments, razors, drawing tools
X12, X12M, X12Ф1	Broaches, thread-rolling dies and knurls, drawing tools, knives for presses and cold metal slitting shears, intricate-shaped dies for cold pressing Grade X12 steel is intended for tools which require no great impact strength and which are not subject to heavy impacts
XГ	Long and fancy-shaped tools for which, at hardening, slight deformation is allowable such as cutting tools working under light loads: milling cutters, screw taps, threading dies, reamers,

* Tools subject to slight impacts in the course of operations should be manufactured from steels lower in carbon. Tools which require extra hardness and which suffer no impacts should be manufactured from high-carbon steels.

Continued

Steel grades	Uses
	broaches, etc.; measuring tools, cold pressing dies, press moulds for plastics, woodworking cutters, jig bushings
B1	Drills, screw taps, reamers, saw blades, roller knives
XB5	Cutting tools for working of extra-hard metals at low cutting speeds
5XBГ	Intricate-shaped dies for cold and hot pressing, which tolerate slight warping only
9XBГ	Cutting and measuring tools of complicated shapes. Dies of complicated configuration for cold pressing which tolerate slight warping only. Long knives for cold cutting of metals
XBГ	Cutting and measuring tools of long and complicated configuration which tolerate slight warping only
Ф	Screw taps, threading dies, embossing dies for thin pieces, dies for the manufacture of bolts, nuts and rivets
8XФ	Knives for cold cutting of metals, dies for cold trimming, centre punches
85XФ	Woodworking tools: saws, cutters, knives, etc.; paper-mill knife-tools
4XC	Dies for hot pressing, knives for cold and hot cutting of metals, pneumatic tools
6XC	Knives for cold and hot cutting of metals, small dies for cold pressing, pneumatic tools
9XC	Cutting tools, mainly subject to grinding in the manufacturing process: drills, centre points, milling cutters, reamers, counterbores, screw taps, broaches. Dies for cold pressing
XГC	Measuring tools
4XB2C	Press moulds for low-temperature pressure casting, hot pressing dies, knives for hot cutting of metals, pneumatic tools
5XB2C	Dies for cold and hot pressing, knives for cold and hot cutting, press moulds for casting low-melting alloys, threading rolls

Continued

Steel grades	Uses
6XB2C	Cold and hot pressing dies, threading rolls, woodworking tools
3X2B8	Press moulds for pressure casting of aluminium and copper alloys, hot pressing dies and knives for hot cutting of metals working under heavy-duty and high-temperature conditions
4X8B2	Press moulds for casting non-ferrous alloys, dies for hot pressing working under heavy-duty and high-temperature conditions
5XHM, 5XГM, 5XHT, 5XHC, 5XHB, 5XHCB	Forging dies
P9, P18	High-efficient cutting tools which retain their cutting ability at a temperature of up to 600° C. Grade P9 is more difficult to grind than the P18 grade Efficiency, wear resistance, and red hardness of steels listed below with their particular features and uses are higher than those of the P9 and P18 grades
P9Ф5	Chiefly used for the manufacture of finishing tools. A difficult-to-grind material
P9K10	Heavy-duty cutting tools. Drills for working of heat-resistant alloys and hard-to-work materials This steel has a tendency to decarburise
P14Ф4	Cutting tools for the working of extra-hard materials. A difficult-to-grind material
P18Ф2	Cutting tools for the working of materials of different hardness numbers, and of stainless and heat-resistant alloys Takes grinding satisfactorily
P18K5Ф2	Cutting tools for the working of hard-to-work materials Satisfactory grindability
P18K5, P18K10	High-speed cutting tools. Retain hardness at temperatures up to about 670° C

Heat-resisting and Non-scaling Steels *

Grade	Use	Heat-resisting	Non-scaling
		up to, °C	
X5	Pipes	—	650
X15M, X5BФ	Parts of oil-refinery equipment	600, v.l.d.	650
X6CM	Pipes, parts of pumps, valves	660, l.d.	700
1X8BФ	Pipes for furnaces, apparatus and mains of oil-refining plants	500, l.d.	650
4X9C2, 4X10C2M (ЭИ107)	Exhaust valves of internal combustion engines, pipes of recuperators, heat exchangers, fire bars	650, l.d.	850
1X12H2BMФ (ЭИ961)	Compressor disks, blades and various heavy duty elements	600, s.d.	750
1XB, 2X13	Parts of machines and hardware requiring high plasticity: turbine blades, valves, bolts, etc.	500, l.d.	750
0X13	Ditto	—	—
3X13, 4X13	Machine parts requiring high hardness: cutting, measuring and surgical instruments, springs, hardware	—	—
3X13H7C2 (ЭИ72)	Valves for automobile engines	—	950
1X13H3	Heavy duty parts working in fresh and/or sea water	—	—
1X17H2 (ЭИ26-8)	High-strength steel for blades of axial compressors	—	—
9X18 (ЭИ229)	Bearings for oil-refinery equipment and various extra-hard wear-resistant parts	—	—
X6C10 (ЭИ428)	Parts of boiler installations	—	700
1X11MФ	Blades of steam boilers	550, l.d.	750
1X12BHMФ (ЭИ802)	Rotors, disks, blades, bolts	570, l.d.	750

* The terms "heat-resisting" and "non-scaling" when referring to steels are rather loosely used and it is necessary to finalise their meaning.

Heat-resisting steels are those that retain much of their strength at elevated temperatures.

Non-scaling steels are those that are highly resistant to corrosion at elevated temperatures.— *Tr.*

Continued

Grade	Use	Heat-resisting	Non-scaling
		up to, °C	
2Х12ВМБФР (ЭИ993)	Rotors, disks, blades, bolts	600, l.d.	750
1Х12В2МФ (ЭИ756)	Rotors and disks of steam turbines, blades	600, l.d.	—
1Х12СЮ (ЭИ404)	Valves of engines and various other parts	—	950
Х14 (ЭИ241)	Parts turned in automatic lathes—screws, nuts, threaded parts	—	—
Х17	Equipment of nitric acid plants, hardware. Not recommended for welded structures	—	900
0Х17Т (ЭИ645)	The same as for the Х17 steel and also recommended for welded structures	—	900
Х25Т (ЭИ439)	Structures (including welded structures), working in more corrosive media than the Х17 steel. Thermocouple shields, pipes for pyrolisis installations, etc.	—	1050
Х18СЮ (ЭИ484)	Pipes for pyrolisis installations, various equipment, etc.	—	1050
Х28 (ЭИ349) Х28АН (ЭИ657)	Same uses as for steel Х25Т, as well as for media containing acetic acid. Pipes for pyrolisis installations, heat exchangers	—	1150
2Х13Н4Г9 (ЭИ100), Х18Н9, 2Х18Н9, Х18Н10Е (ЭИ453), Х14ГМН, Х17НГ14, Х17Г9АН4	Parts manufactured from sheets and strips welded by point welding. When welded by other methods, intercrystalline corrosion is possible. Furnace fittings, etc.	—	800
Х15Н9Ю (ЭИ904), Х17Н7Ю (ЭИ973)	Extra-strength steel working in the air	—	—

Continued

Grade	Use	Heat-resisting	Non-scaling
		up to, °C	
2X17H2	The same as above, but in corrosive media		
0X2ЭHM14C2 (ЭИ732)	Pipes	—	1050
X20H14C2 (ЭИ211)	Furnace conveyors, carburising boxes	—	1050
0X21H5T (ЭИ53), 1X21H5T (ЭИ811), X18HЮT, X18H9T, X18H12T, X14T14H3T	Manufacture of welded apparatus for various branches of industry. Furnace fittings, parts of exhaust manifolds	—	800
9X18H10T (ЭИ914), 0X18H11 (ЭИ684), 00X18H10 (ЭИ842), 0X18H12T, X18H12T, 0X18H12Б	Welded apparatus operating in higher corrosive media than those manufactured from steel X18H10T. Parts of furnace equipment	—	800
0X21H6M2T (ЭИ54), X17H13M2T (ЭИ448), X17H13M3T (ЭИ432), 0X17H16M3T (ЭИ580)	Parts operating in boiling phosphoric, formic, lactic, acetic acids and other highly corrosive media	—	—
0X23H28M2T (ЭИ628)	Welded structures operating in hot phosphoric and sulphuric acids, below 60° C	—	—
0X23H28M3Д3T (ЭИ943)	Welded structures operating in hot sulphuric acids (below 80° C), resistant also to hydrofluoric acids	—	—
4X18H25C2	Furnace conveyors and other heavy-duty parts	—	1100

Continued

Grade	Use	Heat-resisting	Non-scaling
		up to, °C	
0Х23Н18, Х23Н18(ЭИ417)	Pipes and parts for methane conversion and pyrolisis installations, for gas mains, combustion chambers	1000, d.	1050
Х25Н16Г7АР (ЭИ835)	Parts of gas mains, manufactured from sheet steels	950, s.d.	1100
Х25Н20С2 (ЭИ283)	Boiler brackets and supports, pipes for pyrolisis installations	—	1200
1Х25Н25ТР (ЭИ813)	Parts of different systems	950, s.d.	1100
ХН38ВТЮ (ЭИ787)	Turbine and compressor disks and blades	750, s.d.	900
ХН60Ю (ЭИ559А), ХН70Ю (ЭИ652)	Parts of gas mains, and equipment	850-1100, s.d.	1200
ХН78Т (ЭИ435)	Ditto	—	1100
ХН70 (ЭИ442)	Equipment	—	1150
4Х12Н8Г8МФБ (ЭИ481)	Turbine disks	650, s.d.	750
Х12Н22Т3МР (ЭИ33)	Turbine disks	750, s.d.	850
0Х14Н28В3Т3ЮР (ЭИ786)	Ditto	750, s.d.	900
Х12Н20Т3Р (ЭИ695)	Turbine parts	700, s.d.	850
1Х14Н16Б (ЭИ694),	Superheater pipes and extra-high pressure pipelines	650, l.d.	850
1Х14Н16БР (ЭИ694Р),		650, l.d.	850
1Х14Н18В2Б (ЭИ695),		700, l.d.	850
1Х14Н18В2БР (ЭИ695Р)		700, l.d.	850
1Х14Н18В2БР1 (ЭИ726)	Turbine rotors, disks and blades	700, l.d.	850
4Х14Н14В2М (ЭИ69)	Engine valves, pipeline fittings	650, l.d.	850
4Х15Н7Г7Ф2МС (ЭИ388)	Blades of gas turbines, fastenings	650, s.d.	800
1Х16Н13М2Б (ЭИ680)	Forgings for disks and rotors, blades	600, v.l.d.	850

Continued

Grade	Use	Heat-resisting	Non-scaling
		up to, °C	
Х16Н15М3Б (ЭИ847)	Superheater pipes and high-pressure pipelines	350, v.l.d.	850
3Х19Н9МВБ (ЭИ572)	Rotors and disks, bolts	600, v.l.d.	800
ХН35ВТ (ЭИ612)	Gas-turbine blades, disks, rotors, fastenings	700, l.d.	—
ХН35ВМТ (ЭИ692)	Turbine blades, fastenings	700, l.d.	900
ХН35ВТР (ЭИ725)	Gas-turbine parts manufactured from thick sheets	750, v.l.d.	900
ХН38ВТ (ЭИ703)	Parts manufactured from sheet steel and working at medium pressures	600-950, s.d.	1050
ХН70ВМЮТ (ЭИ765)	Blades, fastenings	750, v.l.d. 800, l.d.	1000
ХН70ВМТЮ (ЭИ617)	Turbine blades	850, s.d.	1000
ХН80ТБЮ (ЭИ607)	Turbine blades, fastenings	700, v.l.d.	1050
ХН70МВТЮБ (ЭИ598)	Turbine blades	850, s.d.	1000
ХН67МВТЮ (ЭИ445Р)	Turbine blades	800, l.d. 850, s.d.	1000
ХН75МБТЮ (ЭИ602)	Turbine parts manufactured from sheet steel	800-950, s.d.	1050
ХН77ТЮ (ЭИ437А)	Turbine disks and blades	750, s.d.	1050
ХН77ТЮР (ЭИ437)	Ditto	750, s.d.	1050
ХН60В (ЭИ868)	Turbine parts manufactured from sheet steel	800-1000, s.d.	1200

Notes. 1. High-temperature resistance is defined as the temperature of the beginning of intensive scaling.

2. Short duration of service of an element (s.d.) denotes a life span from 100 to 1,000 hours, while long duration (l.d.) implies an interval from 1,000 to 10,000 hours; very long duration (v.l.d.) signifies a considerably longer period, extending usually from 50,000 to 100,000 hours.

Chapter IV

HEAT-TREATMENT OF STEEL

1. HEATING OF STEEL

A heat-treatment procedure consists in heating metals and alloys to a certain temperature, holding and cooling them at various rates with the aim of altering their structure and properties.

Each of the heat-treatment processes comprises the following operations:

1. Heating to a prescribed temperature.
2. Holding for heat saturation and completion of structural changes.
3. Cooling at a requisite rate.

The rate of heating depends on chemical composition, shape and size of the work.

A. When using flame or electric furnaces the following work may be charged into a furnace preheated to a given temperature: (1) articles from low-carbon steels, regardless of their structure, shape and size; (2) small- and medium-size articles from other grades of steels which have been annealed or normalised.

Articles with sharp angles, large-size articles, as well as any articles subject to repeated hardening should be heated up gradually, after being charged to a cooled furnace.

B. When using salt or lead baths, the following articles may be immersed in a bath preheated to a given temperature: (1) articles from low-carbon steels, regardless of their structure, shape or size; (2) articles from other grades of steel having simple configuration, and with no abrupt changes in section (rolls, rollers, tools with welded bits, etc.).

The heating of all other articles should comprise a preheating procedure to about 500-800°C. Preheating can be carried out in separate furnaces as well as in bath-type furnaces hy repeated (depending on size) immersion of the article in molten salts (see Table 37) or lead for 2-3 seconds. Two preheatings, up to 600 and 850°C, are necessary for articles from high-speed steels having a highly complicated configuration.

Approximate duration of heating in various furnaces may be found by referring to Table 38.

The duration of heating is influenced by many factors, e.g., the number of articles charged into the furnace, the useful volume of the furnace, the arrangement of articles in the furnace (in bulk or in such a way that each piece is flushed by the hot gases), charging temperature, temperature uniformity, looseness of furnace door, etc. Practically, the duration of heating is to be determined on the spot with due consideration of the all above-mentioned factors.

Heating temperature, holding time, and cooling rate are dependent upon the steel grade and the heat-treatment process employed.

Table 37

Salt Mixtures Most Frequently Used for Heating in Salt Baths on Hardening

Mixture components	Chemical formula	Weight, %	Melting point, °C	Recommended temperature ranges, °C
Common salt Soda ash	$NaCl$ Na_2CO_3	50 50	560	590-900
Common salt Calcium chloride	$NaCl$ $CaCl_2$	50 50	595	630-850
Common salt Barium chloride	$NaCl$ $BaCl_2$	22.5 77.5	635	665-870
Common salt Potassium chloride	$NaCl$ KCl	44 56	660	720-900
Common salt	$NaCl$	100	800	830-1100
Barium chloride	$BaCl_2$	100	962	1100-1350

Table 38

Approximate Heating Time for Articles in Various Types of Furnaces

	Furnace temperature, °C	Heating time for 1 mm of diameter or thickness of article, sec		
		Round section	Square section	Rectangular section
Electric furnace	800	40-50	50-60	60-75
Oil furnace	800	35-40	45-50	55-60
Salt bath	800	12-15	15-18	18-22
Lead bath	800	6-8	8-10	10-12
Salt bath	1300	6-8	8-10	10-12

2. OXIDATION AND DECARBURISATION ON HEATING

The furnace gases affect the heated steel by oxidising and decarburising it. The combination of the oxygen of the furnace gases with iron results in the formation of scale, while its combination with steel carbon causes decarburisation.

The best method to protect the work from oxidation or decarburisation is the use of muffle furnace provided with controlled or protective atmosphere.

Controlled atmosphere composed of CO_2, CO, H_2, and N_2 is mostly used in the practice of heat-treatment shops.

Controlled atmospheres may be produced by incomplete combustion of coke-oven, generator, natural and various other gases, purified from CO_2 and thoroughly dried to remove water vapours.

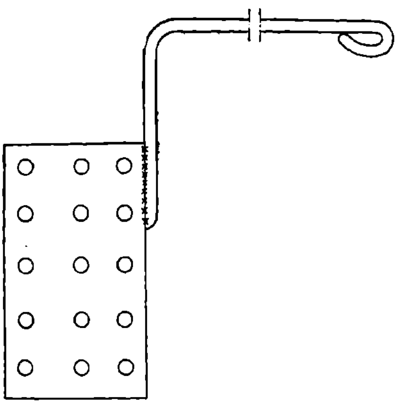


Fig. 5. Perforated cylinder used for deoxidising salt baths

If no installations are available for the production of controlled atmosphere, the articles to be heat-treated are packed into containers filled with insulating solid material consisting of: (a) used carburiser; (b) cast-iron chips, fresh or with the addition of 50% of the used ones; (c) burned asbestos, etc.

Pure charcoal is not an effective means of protection of high-carbon steels against decarburisation.

Tools from high-speed and high-chromium steels are protected against decarburisation by preliminary immersion in a saturated solution of borax.

Upon heating, the borax melts and spreads itself in a thin layer over the surface of the article, thus safeguarding the latter from reaction with the oxidising medium.

To protect heated parts against oxidation, some charcoal is placed in the furnace near the charging door.

Smaller parts are protected against scaling by immersion in the solution prepared as follows: 1 part of calcium chloride is dissolved in 25 parts of water; after boiling the solution is allowed to cool, then 2 parts of ground fluorite are added to it.

To avoid decarburisation, salt baths should be deoxidised 2-3 times per shift by adding, to the molten salt, crushed 75% ferrosilicon (200-300 g per one СПЗ-75 type bath), boric acid, and 40 to 50 g of potassium ferrocyanide or potassium ferricyanide per bath. The deoxidation of a barium chloride bath is effected at 1300-1320°C. With the deoxidising agent charged, the bath is allowed to stand for 15-25 minutes, after which the slag is skimmed and the temperature brought down to the required level.

Deoxidation of salt baths with charcoal is widely gaining recognition. A perforated cylinder with a welded handle (Fig. 5) is filled with charcoal and immersed in the molten salt. As the cylinder with charcoal is immersed, big tongues of flame appear and then fade away gradually (within 15-20 minutes) and disappear. This indicates the end of the deoxidising process. It is recommended to deoxidise the baths in the above manner 2-3 times per shift.

Salt baths are checked for deoxidation with the aid of ordinary safety razor blades. A blade heated for 3-5 min. in a properly deoxidised bath and quenched in water should rather break than bend.

The deoxidation of alkaline baths is effected by charging potassium ferrocyanide on the bath surface in the amounts equal to 0.2-0.3% of the alkali weight. The bath should be mixed for 15-20 minutes, after which the slag is skimmed.

A layer of charcoal 15-20 mm thick is charged on the surface of lead baths to protect the latter against oxidation.

Files are safeguarded against decarburisation by luting (Table 39).

Table 39

Lutes Used to Protect Files Against Decarburisation on Hardening

Material	Composition, %	
	No 1	No. 2
Crushed horn	30	45
Potassium ferrocyanide	3	4.5
Common salt	38	45
Saltpetre	12	—
Flour	17	1.5
Joiner's glue	—	4

A Leningrad plant uses abrasive powder No. 100 as a protective lute. The files are flushed with joiner's glue, coated with the abrasive powder to a layer 1.0-1.5 mm thick, and dried. A simple reliable protective means is a prehardening pickling of files for 10-15 minutes in an acid solution composed of (% by volume): sulphuric acid (concentrated) — 7%, nitric acid (concentrated)—7%, water—86%. After pickling, the files are dried near the furnace.

3. ANNEALING

Annealing is used to decrease hardness, to relieve internal stresses, to correct structure, to eliminate strain hardening, to improve machinability. Data given in Table 40 may be useful to determine the type of annealing necessary.

Recrystallisation Annealing of Cold-Worked Steels

Grade of steel	Heating temperature, °C	Cooling medium
У7-У13, У8, Ф, В1, 08-70, 15Г-70Г, 10Г2-50Г2, 70С2ХА, ЕХ3	680	Air
ШХ6-ШХ15, ШХ15СГ, 40Х, 38ХА, 20Х3, 40ХФА, 38ХМЮА, 30ХГСА, Х, 9Х, Х05, 7Х3, 8Х3, 9ХС, ХГС, 4ХС, ХГ, 4ХВ2С, 5ХВ2С, 6ХВ2С, ХВГ, ХВ5	700	Air
Р9, Р18	760-780	Water
Х12, Х12М, Х12Ф1, 9Х18	730-750	Water
Х9С2, Х10С2М, Х17	850	Water
1Х13, 2Х13, 3Х13, 4Х13	720	Air
0Х18Н10, 1Х18Н9, 1Х18Н9Т, 2Х13Н4Г9, Х18Н11Б, 2Х18Н9, Х15Н60, Х20Н80, Х20Н80М3, 4Х14Н14В2М, 4Х18Н25С2	850	Water
12ХН3А, 12Х2Н4А, 20ХН3А, 30ХН3А, 37ХН3А, 40ХНМА	660	Air
18ХНВА, 25ХНВА, 20ХН4ФА	640	Air
Х13Ю4, 1Х17Ю5, 0Х17Ю5, 1Х25Ю5, 0Х25Ю5, Х25, Х27, Х28, Х25Т	700	Water

Note: Holding at recrystallisation temperature on open heating can last up to one hour.

Table 40

A Rough Guide for the Choice of Annealing Treatments

Type of annealing	Steels subject to the process	Heating temperature, °C	Cooling rate	Purpose
Full annealing	Hypoeutectoid, eutectoid, small- and medium-size steel castings	$Ac_3 + 20\text{-}30$, $Ac_1 + 20\text{-}30$	Down to 500-600° C at a rate of: 1) 50-100° C per hour for carbon steels; 2) 20-60° C per hour for alloy steels	1. Softening 2. Stress relieving 3. Structure improvement
Process annealing	Hypoeutectoid	Between Ac_1 and Ac_3	Ditto	1. Softening 2. Stress relieving
Spheroidising (globular pearlite annealing)	Hypereutectoid	$Ac_1 + 10\text{-}20$	Down to 500-600° C at a rate of 20-30° C per hour	1. Softening 2. Improvement of machinability (cutting) 3. Improvement of cold broaching 4. Preparation of structure for subsequent hardening
Isothermal annealing	Chiefly for alloy steels	1. $Ac_3 + 20\text{-}30$; 2. $Ac_1 - 20\text{-}30$	Rapid cooling down to Ar_1 — 20-30° C, holding at the said temperature followed by air cooling	The same as for full annealing

Table 40 continued

Type of annealing	Steels subject to the process	Heating temperature, °C	Cooling rate	Purpose
Interdiffusion annealing (homogenisation)	Large steel castings and ingots	$Ac_3 + 150\text{-}250$	With the furnace	To eliminate coarse cast structure and segregation
High tempering (low-temperature annealing)	Hypereutectoid and high-alloy structural steels	$Ac_1 - 15\text{-}30$	With the furnace or in the air	1. Softening 2. Stress relieving 3. Improvement of machinability
Recrystallisation annealing	All grades of steels following cold working	Ref. to Table, § 3		Regeneration of structure after cold working

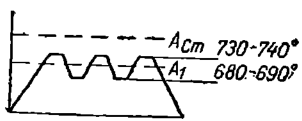


Fig. 6. Diagram of step (pendulum) annealing

Notes. 1. Spheroidising is also carried out as a step or cyclic annealing process according to the diagram presented in Fig. 6.

2. Rapid cooling from the temperature of initial heating down to the temperature of isothermal holding is effected by transferring the parts to a furnace heated to a predetermined temperature or by cooling in the furnace with its door open.

3. High tempering is the only type of softening operation for chrome-nickel-tungsten and chrome-nickel-molybdenum structural steels.

4. NORMALISING

Normalising is used to correct the structure of overheated steel, to relieve internal stresses and to improve machinability of structural carbon and low-alloy steels.

For normalising, the articles are heated to 30-50°C above the Ac_3 point and then cooled in still air.

When it is necessary to increase the depth of hardening of carbon tool steels, they are also normalised.

Hardness numbers of carbon steels in annealed and normalised conditions are presented in Table 41.

Table 41

Brinell Hardness Numbers of Steels in Annealed and Normalised Conditions

Condition	Structural steels		
	Low-carbon	Medium-carbon	High-carbon
Annealed	125	160	185
Normalised	140	190	230

5. HARDENING

Hardening is used to impart maximum hardness to steel. Prior to hardening of hypoeutectoid steel, the latter is heated to 20-30°C above Ac_3, while eutectoid and hypereutectoid steels are heated to 20-30°C above Ac_1 and then, after holding, rapidly cooled. The work is cooled in water, oil or air depending on its chemical composition, size, and shape.

Cooling of work on hardening. The rate of cooling on hardening should be sufficient to ensure the transformation of austenite to martensite. In practice, the required rate of cooling is attained by cooling carbon steels in water; alloy steels, depending on their composition, are cooled in water, oil, kerosene or between plates, while certain grades of high-alloy steel are air-cooled (Table 42).

Table 42

Cooling Rates of Steels in Various Quenching Media (according to S. S. Steinberg)

Cooling media	Cooling rate per second at	
	650-550° C	300-200° C
Water at 18° C	600	270
Water at 26° C	500	270
Water at 50° C	100	270
Water at 74° C	30	200
Solution of 10% of sodium hydrate in water at 18° C	1200	300
Solution of 10% of common salt in water at 18° C	1100	300
Solution of 10% of soda in water at 18° C	800	270
Solution of 10% of sulphuric acid in water at 18° C	750	300
Soap water	30	200
Mineral oil	100-150	20-50
Kerosene	160-180	40-60
Copper plates	60	30
Iron plates	35	15

Table 43

Oils Used for Isothermal and Step Hardening and Tempering

Oil	Flash point, °C	Oil	Flash point, °C
Spindle oil 2	165	Cylinder oil 2	215
Spindle oil 3	170	Viscosine 3	240
Motor oil 4	180	Cylinder oil 6	290
Machine oil Л	180	Distillate 6	300
Machine oil C	190	Vapour T	320
Machine oil CУ	200		

Oil retains its hardening ability from 20 to 150°C.

Copper and iron plates are better when hollow and water-cooled. When using massive plates, their surface should be coated with a thin film of oil to add to their cooling ability.

When hardening work from high-carbon steels and of very complicated configuration, 50% aqueous solution of caustic soda (sp.gr. 1.36) at 20-60°C is used as a hardening medium. The quenching in the above solution is to be effected under the hood.

When employing isothermal or step hardening, hot oil or low-melting salts are to be used (Tables 43, 44).

Fig. 7 shows the manner in which the work should be immersed in the cooling medium to prevent warping.

Table 44

Compositions of Salts Most Frequently Used for Hardening and Tempering

Constituents	Formula	Weight, %	Melting point, °C	Temperature recommended for use, °C
Potassium nitrate	KNO_3	56	153	175-500
Sodium nitrate	$NaNo_2$	44		
Potassium nitrate	KNO_3	50	220	245-500
Sodium nitrate	$NaNO_3$	50		
Sodium nitrate	$NaNO_3$	100	317	325-500
Potassium nitrate	KNO_3	100	337	350-500

When considering hardening, the following methods are to be distinguished:

1. **Hardening in one cooling medium.** The heated work is cooled down to below 150-100°C in one medium. This is the chief procedure for hardening oil-cooled alloy steels and carburised carbon steels cooled in water; this method is also used for hardening simple-shaped work from

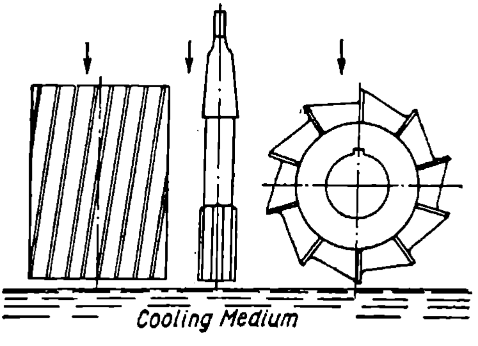


Fig. 7. Direction of immersion of tools in a cooling medium

medium- and high-carbon steels. Carbon-steel articles up to 6-7 mm in diameter are oil-hardened.

2. **Hardening in two cooling media.** The heated work is cooled in water down to 200-250°C, then it is quickly transferred to an oil bath for further cooling. Approximate duration of cooling in water prior to transfer is about 1-1.5 sec for every 5-6 mm of diameter or thickness.

This is the main hardening procedure for carbon tool steels.

Table 45

Effect of Salt Temperature on Cooling Time of Heated Steel Cylinders

Diameter of cylinder, mm	Salt temperature, °C		
	205	260	315
	Time necessary to bring the cylinder to the salt temperature, min		
25	5.0	4.0	3.5
50	8.0	7.0	6.0
70	13.5	12.5	11.5

3. **Jet hardening.** Cooling is by a water jet or shower, this method being used for work with through or blind holes.

4. **Isothermal hardening.** The heated work is cooled in hot oil, molten salt or metal (lead, tin) at 20-30°C above the beginning of the martensitic transformation for the grade of steel considered (Table 45). Once the transformation of austenite is over, the work is air-cooled. As a result of isothermal transformation, acicular troostite is formed. Tempering, following isothermal hardening, is optional.

This method is used to harden work of complex shape with a view to avoid cracks and warpage.

5. **Step hardening.** 1) The heated work is cooled in a hot medium to 20-30°C above the martensitic transformation point to even the temperature throughout the cross-section, following which it is air-cooled. After the work is removed from the heated medium, it can be straightened before the austenite transformation is over. This method is used for the hardening of complex-shape articles from carbon tool steel up to 8-10 mm in diameter.

2) The heated work is cooled, first in a hot medium at 150-180°C, to balance its temperature, then in the air. This method prohibits the straightening operation but the number of rejected pieces due to cracks and warpage, as compared to the usual hardening procedure, is considerably reduced.

6. **Tempering combined with hardening.** The working edge of the heated work is water-cooled, then removed and tempered to the colour

required. This method is mainly used for percussive tools made of carbon steel.

7. **Hardening through air-cooling.** The work, heated above the required temperature, is air-quenched down to normal hardening temperature, after which it is hardened. This method is widely employed for carburised work when the latter is hardened directly from the case-hardening temperature (chiefly used for dies manufactured from grade 5XHT steel, etc.).

8. **Bright hardening.** The work, heated to hardening temperature is cooled in molten alkalis, after which it is flushed, first in hot water, then with a heavy jet of cold water and, finally, immersed in aqueous solution of 1.5% sodium nitrite and 0.3% soda ash to prevent corrosion. The bright-hardening technique, while displaying all the merits of the isothermal and step hardening procedures, is superior to them on the following points: the work remains bright, warping is minimised and higher mechanical properties are obtained.

Salt baths used for heating prior to bright hardening should contain no barium chloride as its presence spoils the alkali bath. The best composition is 100% KCl or a mixture of 50% NaCl and 50% KCl. Table 46 gives chemical compositions of alkali baths and their operation temperature charts.

Table 46

Chemical Composition of Alkalis Used for Bright Hardening

Bath composition	%	Melting point, °C	Temperature range of use, °C
Potassium hydrate . . . . . Sodium hydrate . . . . . . Water	75 25 6	130	150-250
Potassium hydrate . . . . . Sodium hydrate	63 37	159	180-350
Sodium hydrate	100	322	350-700

Baths working above 250°C are deoxidised, when necessary, by additions of potassium ferrocyanide (0.2-0.3% of alkali weight). Parts treated in non-deoxidised baths blacken. Baths working below 250°C do not require deoxidising. In case the bath thickens, small amounts of 30-50% aqueous solution of potassium hydrate are added, at below 200°C, in minute portions, with the aid of a long-handled ladle, in order to fluidise the bath and to enhance its hardening ability.

Hardening power of low-temperature alkali baths depends on the amount of water added to it. Maximum hardness is displayed by articles processed in baths with 10% of water. A greater amount of water causes soft spots. No eruptions are observed when water is added. The amount of water in the bath is determined by measuring the hardness of samples hardened under similar conditions. Fig. 8 presents hardness curves of samples from grade 45 steel 25 mm in diameter and 50 mm in length.

The alkali bath should be agitated by an impeller at 800 to 1,400 r.p.m. or by a rotating worm at 600 to 800 r.p.m. The bath should be cleaned periodically from foam and sediments.

When bright-hardened parts rust as a result of inadequate flushing, the defect may be corrected without change of the part's size, by heating it in a special solution at 70-80°C for 30-40 min (to remove rust) with subsequent thorough washing by a strong water jet and immersion in a solution of sodium nitrite. The solution is prepared as follows: 100 grams of chromic anhydride and 110 grams of orthophosphoric acid (sp.gr. 1.6) are dissolved in 200 cm^3 of water, after which water is added to obtain 1 litre of solution.

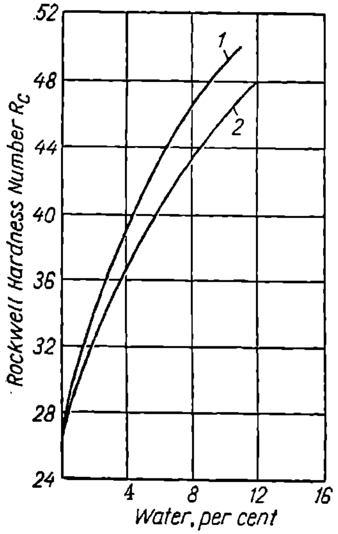


Fig. 8. Relation of hardness number of a sample from steel Cт. 45 to the amount of water introduced into a low-temperature alkali bath:
1—bath temperature equal to 200°C;
2—bath temperature equal to 250°C

9. Sub-zero hardening (sub-zero treatment). The structure of hardened carbon and alloy steels always includes some amount of austenite. In articles tempered above 200-250°C, this austenite turns to tempered martensite upon heating. In articles tempered below 200°C, the austenite is "frozen dead" and remains unaltered in the steel.

Austenite is remarkably stable in some high-alloy steels, and on tempering, its transformation to martensite is incomplete. Maximum austenite decay can be achieved through additional cooling to below zero after hardening. Table 47 lists the sub-zero treatment temperatures for some grades of steels. Sub-zero treatment should be carried out immediately after the article has cooled down to room temperature, since maturing at room temperature makes austenite very stable. Time interval from hardening to sub-zero treatment should not exceed 1-3 hrs while it should be still shorter for carbon tool steels. Sub-zero treatment should be carried out prior to tempering. It has been found that sub-zero treatment does not improve the cutting ability of high-speed steels. Rapid cooling should be avoided in order to prevent cracks. Liquid nitrogen, liquid oxygen, solid carbon dioxide, freon, etc., may be used as cooling media.

Table 47

Sub-zero Treatment Temperatures for Some Grades of Steels to Enhance Austenite Transformation

Grade of steel	Treatment temperature, °C	Grade of steel	Treatment temperature, °C
У8	0	ШХ15	—30
У10	0	Х12Ф1	—70
У12	—20	18ХНВА (carburised)	—85 *
ХГ	—50	12Х2Н4А (carburised)	—85 *
ХВГ	—80		

* For the carburised layer.

10. Surface hardening. It is effected by heating the work quickly in an electrolyte, oxygen-gas flame, by contact method or high-frequency current.

The electrolyte used is a 5-10% aqueous solution of soda ash or potash. Direct current at 180 V, as a minimum, is used.

There are three methods of heating in an electrolyte:

(a) butt heating used to heat the tip of an article;

(b) surface-heating method used to heat the work surfaces;

(c) heating in which the work is gradually passed through an electrolyte. The lower part of the work is insulated by a bushing and is not heated.

11. Surface hardening by oxy-gas flame (flame hardening). This procedure consists of local heating of the part to be hardened by means of an oxy-gas flame, and of subsequent cooling. The depth of hardening ranges from 1 to 6 mm, and cooling is ensured by a sprayer.

There exist the following methods of surface hardening by oxy-gas flame:

1. *Stationary.* The work and the burner are stationary, the former being cooled after the withdrawal of the burner.

2. *Rotary.* The work rotates at 100-200 r.p.m. The burner is stationary. The work is cooled following the extinguishing of the burner.

3. *Flat-translatory.* The work moves in a straight line, while the burner is stationary, or vice versa. Cooling is continuous, being applied at a distance of 10 to 20 mm from the burner.

1. Parts with negligible hardened areas, such as teeth of chain gear, cams, lathe centres, short end-cutting tools, etc.

2. Cylinder-shaped parts up to 20 mm in diameter, e. g., necks, journals of arbors and axles, low-module gears, etc.

3. Flat parts of considerable length: frame guides, shears, etc.

4. *Rotary-translatory.* The part rotates slowly. The burner is stationary. Cooling is continuous, being applied at a distance of 10 to 20 mm from the burner.	4. Cylinder-shaped parts with diameters exceeding 200 mm: wheel bands, mounting rings, crane wheels, large-diameter rollers, etc. A tempered streak borders on the hardened area.
5. *Helical-translatory.* The work rotates slowly. The burner moves in a straight line. Cooling is continuous, being applied at a distance of 10 to 20 mm from the burner.	5. Cylinder- and helix-shaped parts: worms, screws, etc. An annealed streak is formed at the point where the helices meet.
6. *Combined.* The ring-shaped burner moves in a straight line along the axis of the part which rotates rapidly inside the burner. Cooling is continuous, being applied at a distance of 10 to 20 mm from the burner.	6. Slim cylinder-shaped parts: shafts, spindles, rods, etc.

Gas burners used for prehardening heating should follow the profile of the work to be hardened (Fig. 9). This ensures uniform heating and

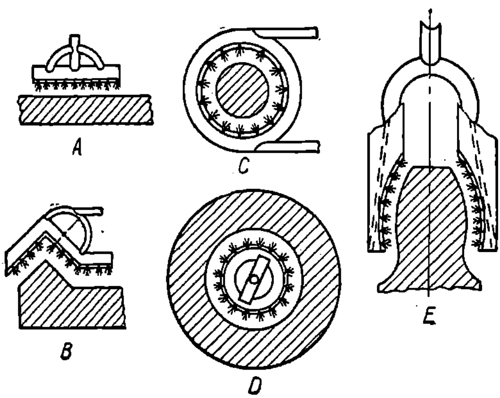


Fig. 9. Configuration of hardening inductors:
a — flat rectilinear configuration; *b* — angle configuration; *c* — annular configuration for surface hardening of cylinder-shaped parts; *d* — annular configuration for hardening of internal surfaces; *e* — modular configuration

completion of the hardening process in one run. Cooling is ensured by water dispersed by a sprayer. Water consumption is 0.4-0.5 litres/min per 1 cm^2 of the surface being cooled. The less the distance from the burner to the hardened work and the less the speed, the greater the hardened depth.

Stationary or rotary hardening procedures for alloy steels are to be followed by oil-cooling. Large parts are hardened in special hardening machines which ensure the requisite direction and speed of the work and the burner. Hardening in special machines permits automation, use of control instruments, etc.

12. Hardening by high-frequency current. When a high-frequency current flows through a solenoid-shaped inductor, a magnetic field is created in the coil. As a result of a great number of magnetising cycles per second, current is generated in the work located in the magnetic field; the current heats the work up very quickly, the depth of heat penetration being a function of the current frequency.

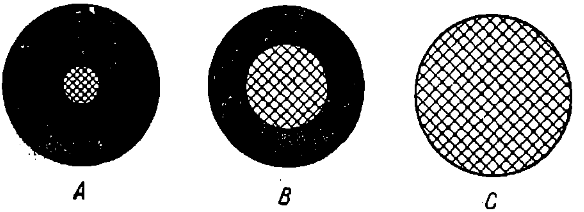


Fig. 10. Diagram illustrating distribution of currents in a conductor at various frequencies:
a — at 50 cps; *b* — at 2,500 cps; *c* — at 250,000 cps

Heat-treatment induction heating makes use of audio- (from 1,000 to 10,000 cps) and radio-frequencies (from 100,000 to 1,000,000 cps). The depth of heat penetration diminishes, as current frequency increases. Fig. 10 presents a diagram showing the effect of current frequency on heat penetration.

In practice, radio-frequency current, supplied by radio-tube oscillators, is employed to heat articles up to 2-3 mm in depth, while a deeper heating, including heat soaking, requires audio-frequency current, supplied by motor generators.

The best material for inductors is red copper. Brass should be used only when red copper is not available. Usually, the inductors are made of square or rectangular red-copper tubes which carry water for cooling.

Table 48 gives data on tube profiles. Inductors for fancy-shaped work are made sectional, cast or forged. The thickness of the sides of a water-cooled inductor ranges from 0.5 to 2 mm, while that of an uncooled one reaches 7-10 mm.

To prevent the inductor from coming into contact with the work, it is wound with asbestos cord impregnated with soluble glass.

Profiles of Copper Tubes Used for Inductors

Initial diameter, mm		Cross section, mm	Initial diameter, mm		Cross section, mm
External	Internal		External	Internal	
4	3	2.5×5.5	13	11 or 10	8×12.5
5	4	3.5×4	13	11 or 10	10×10.5
6	4.5	4.5×5	14	12 or 11	8×14
7	5	4×7	14	12 or 11	10×12
8	6.5	5×7.5	14	12 or 11	11×11
9	7	4×10	15	13 or 12	8.5×15
9	7	5×9	15	13 or 12	10.5×13
9	7	7×7	16	14 or 13	10×15
10	8.5 or 7	5×10.5	16	14 or 13	12.5×12.5
10	8.5 or 7	7.5×8	17	13	10×16.5
11	9 or 8	5×12	18	16 or 14	12×16.5
11	9 or 8	6×11	19	16	10×20
11	9 or 8	8.5×8.5	19	16	15×15
12	10 or 9	7×12	20	17 or 16	11.5×20
12	10 or 9	8×11	20	17 or 16	15×16.5
12	10 or 9	9×9	—	—	

The inductors should be brazed with hard solder.

The following methods of induction hardening are in general use:

1. Simultaneous hardening of the whole area to be treated.	1. Used for hardening disk-shaped pieces.
2. Step hardening of separate sections of the work. Each section is heated separately. When treating pieces with large surface areas, the heating is carried out by a continuous-successive method.	2. Used for hardening gear teeth, axle journals, etc.
3. Continuous-successive method of hardening (Fig. 11).	3. Used for hardening parts of great length. Cylinder-shaped parts are to be rotated in order to obtain a uniform hardened layer; speed of rotation is from 50 to 200 r.p.m.

To prevent uneven heating, particular care should be taken to centre the work properly in the inductor. The clearance between the work and the inductor should remain within 2-6 mm. Inadequate spacing may cause contact between the work and the inductor, or the puncture of the air gap between them, and overheat the external layer, particularly when vacuum-tube oscillators are used. Larger clearance is required for brazing or for deeper hardening. The spacing of turns in a multiturn inductor should be minimum to ensure uniform heating. Practically this gap should average 2 mm.

Induction heating considerably raises critical points of steel and widens hardening temperature ranges.

Fig. 12 presents temperature diagrams for induction heating of some grades of steel in initial annealed state.

To avoid overheating and even melting of the sharp edges of the work, it is recommended to fill the grooves with brass or copper inserts

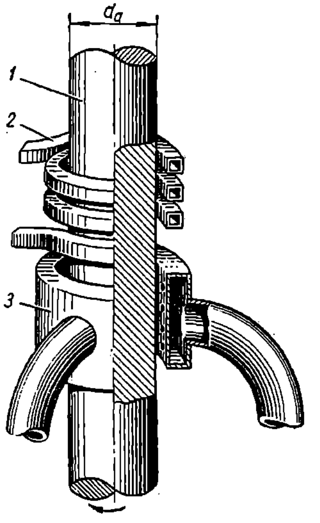


Fig. 11. Relative positions of inductor and sprayer when hardening a shaft:

1 — shaft; 2 — inductor; 3 — sprayer

or to use an adequately shaped inductor in which the sharp edge of the work would remain at considerably greater distance from the sides of the inductor than the rest of the work.

Parts from carbon steels, heated by means of high-frequency current, are cooled in water, those from medium-alloy structural steels—in aqueous solutions, while those from high-alloy steels—in oil. The latter is practicable only in case of simultaneous hardening of the whole work.

When the continuous-successive method of hardening is employed, cooling is effected by a sprayer in which the orifices, 1-2 mm in diameter, are spaced at an angle of 20-30° to the axis of the work and oriented away from the inductor. This prevents early cooling of the heated work.

When the simultaneous method of hardening is used and the work is cooled by water or aqueous solutions, spraying is ensured by the inductor itself (Fig. 13), the internal section of which is provided with a number of orifices. After the work has been heated, current is switched off and the inductor tube is supplied with water or aqueous solution under pressure, which quenches the work.

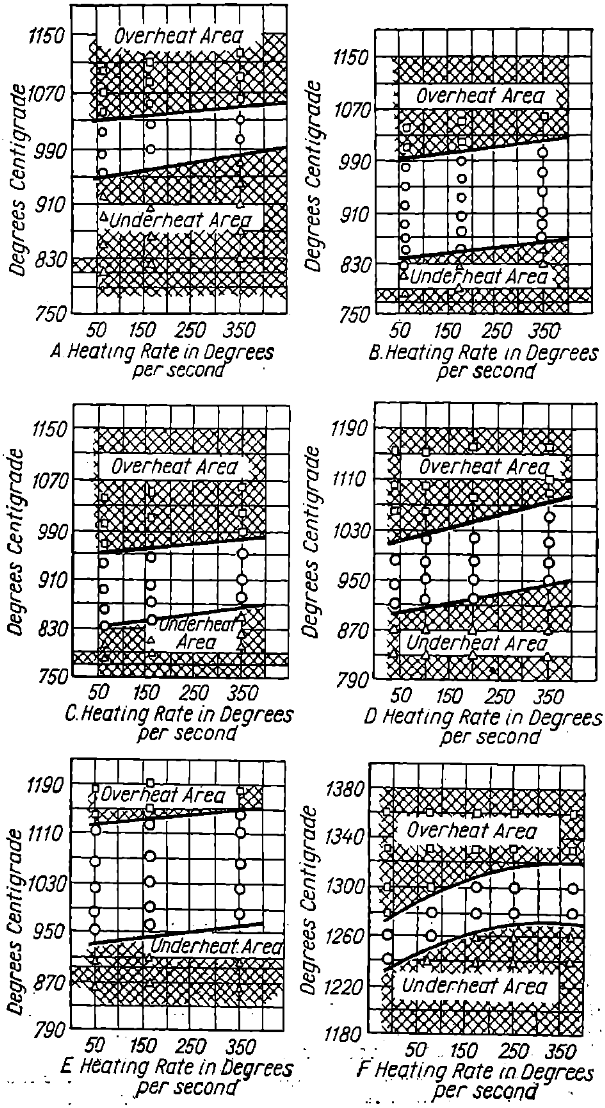


Fig. 12. Temperature diagrams for heating of steel by induced heat: *a* – for steel Ст. 50; *b* – for steel У8; *c* – for steel У12; *d* – for steel 9ХС; *e* – for steel 30ХГСА; *f* – for steel Р9

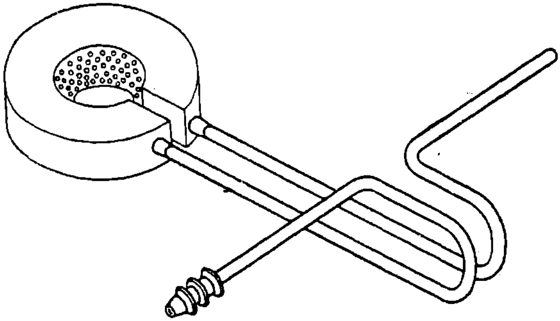


Fig. 13. Inductor for simultaneous hardening of articles

6. TEMPERING

Tempering is employed to lessen or eliminate entirely internal stresses, to soften the hardened steel and to increase its ductility.

Tempering consists in heating the hardened steel to below Ac_1, in maintaining the work at the said temperature and in subsequent cooling. For tempering, the work is heated in oil, saltpetre or alkali baths, as well as in furnaces with air atmosphere. The total holding time for work in such a furnace should not be less than 30-40 minutes and should average 2-3 min per each millimetre of the least section.

When the work is charged in bulk in large numbers, the holding time should be increased 1.5-2 times. After tempering, the work is usually air-cooled.

To avoid temper brittleness in some grades of steels, the latter are cooled in oil in the 450-650°C range; these steels include chromium, chrome-nickel, chrome-silicon, chrome-manganese, chrome-silicon-manganese, chrome-nickel-vanadium, chrome-aluminium steels.

Colour tempering or tempering with surface hues as temperature indicators is carried out in the 220-330°C range (Tables 49 and 50), with subsequent dipping in oil or water.

Colour tempering of selected areas of the work is done chiefly in lead baths which ensure rapid heating necessary to prevent tempering of the rest of the work.

The above-mentioned tempering process may be effected much quicker in an inductor. The rate of heating and the necessary tempering colour are dependent upon the distance between the work and the inductor. To facilitate and stabilise the operation, the inductor is encased in an asbestos sheath (Fig. 14) which serves as a mounting for the work to be tempered. The thickness of the sheath permits adjusting the duration and degree of tempering.

Table 49

Tempering Colours

Tempering colours	Temperature, °C	Approximate thickness of oxidised layer, microns
Pale yellow	220	0.45
Straw	240	
Yellowish brown	255	0.50
Purple brown	265	
Violet	280	0.65
Blue	300	
Light blue	315	0.72
Grey	330-350	

Table 50

Approximate Holding Time at Tempering Temperatures

Tool diameter or thickness, mm	Furnace type	Holding time at the tempering temperature, hrs
Up to 20	Oil or saltpetre baths,	1.0
21-40	electric shaft furnace,	1.5
41-60	type ПН-31, ПН-32 or	2.0
Above 60	ПН-34 furnaces	2.5

At present, tempering, in some plants, is carried out in induced heat installations at the expense of incomplete cooling following hardening; this is the so-called "self-tempering". The work heated for hardening in an induced heat installation is cooled for a definite length of time, determined by calculation or, in most cases, experimentally. At a given moment cooling is automatically cut out and the work heats itself up to the tempering temperature at the expense of accumulated heat. This method is applicable in plants with mass or large-scale production, provided they are equipped with up-to-date automatic machines.

To avoid warping and cracking, the work, after grinding, is subjected to low-temperature tempering, also called ageing, at 120-160°C.

The heat-treatment process consisting in hardening the work with subsequent high-temperature tempering at 500°C and above is called *improving**.

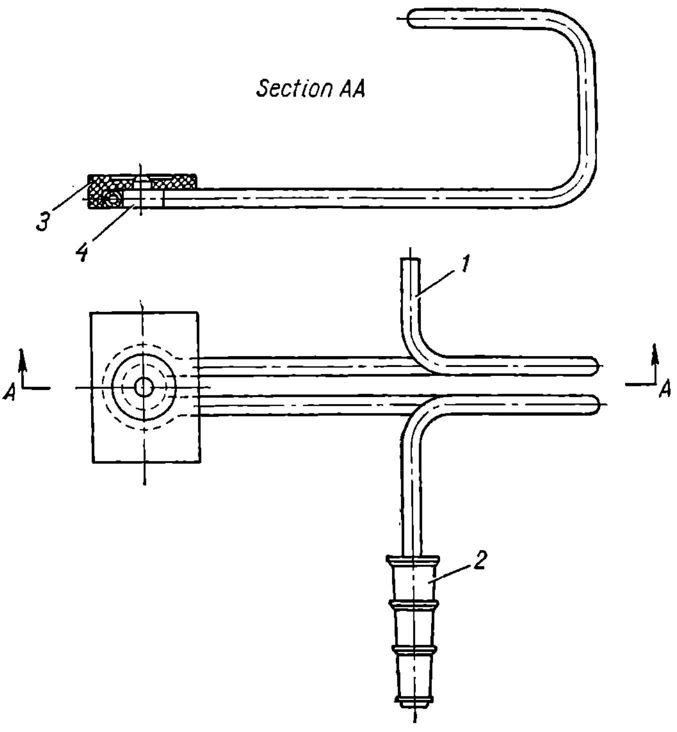


Fig. 14. Inductor for tempering of parts:
1 – inductor; 2 – nipple; 3 – asbestos sheath; 4 – asbestos plug for fastening and centering the sheath

The improving is used to reduce the coarseness of structure as well as to attain the best combination of strength and toughness in structural steels, and chiefly in the alloy steels.

Table 51 lists defects which may be met with in heat-treatment processes.

---

* The word *improving* (a literal translation from the Russian) is used to denote a special heat-treatment procedure aimed at bettering the properties of steel. – *Tr.*

Table 51

Defects in Heat-treatment of Steel

Defect	Detection	Chief cause	Chief measures to prevent and correct the defect
1. Annealing and Normalising Defects of Structural Steels			
Low ductility, the fracture being relatively fine-grained	Tensile test	Underheat. Annealing temperature below that required or insufficient holding	Repeat annealing or normalising at normal temperatures
Coarse-grained fracture. Low ductility and, particularly, impact strength	Fracture inspection. Tensile and impact tests	Overheat. Considerable overheating or excessive holding time	Repeat annealing or normalising at normal temperature. In case of considerable overheating use double annealing, the first one at a temperature by 50-150°C above the normal
Very coarse and bright fracture	Fracture inspection. Microstructural analysis	Overheat. Heating of steel in an oxidising atmosphere at high temperatures, in the proximity of the melting point	No remedy
High hardness	Hardness test	Excessive cooling rate	Repeat annealing at the required cooling rate

2. Defects in Annealing of Tool and High-speed Steels

High hardness	Hardness test	1. Underheat 2. Excessive cooling rate in normal annealing or insufficient holding in isothermal annealing	Repeat annealing at a requisite temperature and follow strictly the prescribed cooling schedule, or temper at high temperature
Carbide lattice	Microsection inspection under a microscope	Heating above Ac_m	Normalising or hardening with subsequent tempering at 670-700° C, holding time not less than 2 hrs

3. Defects in the Hardening of Steel

Cracking	Visual inspection and crack detector test; kerosene test and blacking-in	Stresses caused by changes in volume arising from transformation of austenite to martensite at temperatures below 250° C	Irreparable defect. Preventive measures: 1. Whenever possible use step-hardening, as well as intermittent hardening in two quenching media 2. Avoid manufacturing parts with acute angles and sharp changes in section; when this is unavoidable, use only alloy steel 3. No water should be present in the oil quenching tank

Table 51 continued

Defect	Detection	Chief cause	Chief measures to prevent and correct the defect
Cracking	Visual inspection and crack detector test: kerosene test and blacking-in	Stresses caused by changes in volume arising from transformation of austenite to martensite at temperatures below 250° C	4. Heat slowly the hardened work when hardening procedure is repeated 5. Grooves, holes near edges, sharp transitions in section should be insulated with asbestos
Insufficient hardness	Hardness test	Low hardening temperature, insufficient holding or low cooling rate	The work should be normalised or annealed and hardened again according to normal schedule
Increased brittleness. Coarse-grained fracture	Visual inspection of fracture. Impact test	Excessive hardening temperature or too prolonged holding	To be corrected by the same method as is used for insufficient hardness defect
Soft spots	Hardness tests at various points	Ineffective cooling, local decarburisation, scaling, non-uniform grain size, contamination of steel by abnormally high amounts of slag, mutual contact of parts on cooling	Defect is corrigible except for local decarburisation. The work should be normalised and hardened by the use of a more efficient cooling agent, or hardened at an increased temperature, by 20-50° C above normal

Oxidation and decarburisation	Oxidation is detected by inspection, while decarburisation by hardness tests and microstructure analysis	Combination of furnace atmosphere oxygen with the iron of the work (oxidation) or with its carbon (decarburisation)	If the depth of penetration is greater than the grinding allowance, the defect is irreparable. To prevent the defect, the part should be heated in a controlled atmosphere, and, if the latter is not available, in cases containing cast-iron turnings (50% fresh, 50% used), charcoal with 5% soda, etc. To avoid decarburisation, crushed ferrosilicon (1.0-1.5% of the weight of the salt), borax, boric acid, potassium ferrocyanide (25-30 grams), are added to the salt baths two-three times per shift or the bath is deoxidised with charcoal
Deformation (change in dimensions)	Checking for size	Structural transformation in the 650-500° C range and below 300° C, causing distortion	The defect is mostly irreparable. To prevent it, hardening temperature and cooling rates should be lowered and fine-grained and alloy steel used

Table 51 continued

Defect	Detection	Chief cause	Chief measures to prevent and correct the defect
Warping (change in shape)	Checking for beat (in centres) or by thickness gauge on a face plate	Incorrect immersion of work in quenching media, internal stresses prior to heating, etc.	Reparable defect which can be corrected through: 1) cold or hot straightening; 2) grinding if the warping does not exceed the allowance. Preventive measures comprise slow cooling in the martensite range, proper dipping in quenching media, uniform heating, and checking for warpage prior to hardening
Point or groove-like pitting of the surface	Visual inspection	Uneven scaling. High content of sulphuric salts and chemical action of chloride salts in salt baths. Contact with molten lead spilled on the furnace hearth	Prevention: 1) scrupulous chemical control of salts used for heating; 2) deoxidation of salt baths; 3) covering of lead bath surface with charcoal; 4) elimination of oxidising atmosphere in the furnace; 5) strict control of hearth contamination

Coarse-grained flaky fracture characteristic of high-speed steel articles over 12 mm in diameter	Visual inspection	Annealing at high temperature. Repeated hardening omitting intermediate annealing	Correction: 1) heat to 1140-1160° C, hold for 3-8 min, cool to 800-720° C, hold for 15-30 min, cool in air; 2) repeat the above operation; 3) conduct normal annealing; 4) apply hardening and tempering (this procedure is in need of further investigation)

*4. Bright Hardening Defects**

Darkening or oxide tinting of the work	1. Heat thoroughly a bright work in an alkali bath and dip in water	Alkali bath is insufficiently deoxidised	Deoxidise alkali bath additionally with potassium ferrocyanide
	2. Heat work in a salt bath 150-200° C below the hardening temperature and cool in alkali	Salt bath is deoxidised insufficiently	Deoxidise additionally the salt bath
	3. Check by chemical analysis to make sure the salt composition meets the appropriate technological requirements	Salt bath is too fluid	Bring the bath to proper consistency by adding the required salt

* Column "Detection" lists methods of detecting causes of the blackening of the work in molten alkali in the bright hardening processes.

Table 51 continued

Defect	Detection	Chief cause	Chief measures to prevent and correct the defect
Sooty deposits on the work	4. Check by chemical analysis for absence of saltpetre in the alkali bath	Presence of saltpetre in the alkali bath	Make up a new alkali bath and prevent saltpetre from getting into it
Required hardness is not attained	Visual inspection of surface	Addition to the alkali bath of an excessive amount of potassium ferrocyanide used as a deoxidiser	Heat the alkali at the operating or somewhat higher temperature for a few hours
	Hardness testing with machines	1. Poor mixing of the alkali	Adequate mixing of the bath in operation
		2. Lack of water in low-temperature alkali baths	Check the bath for water by thermal analysis and adjust its amount to that required

5. Defects in Steel Tempering

Under-tempering. Increased hardness and low ductility. A drop in hardness for high-speed steel	Hardness test	Low temperature or insufficient holding time	Repeat tempering according to normal schedule

Over-tempering. Low hardness and low tensile strength and elastic limit	Hardness and tensile tests	Tempering at temperature above that required	Annealing or normalising followed by hardening and tempering according to normal schedule
Temper brittleness. Low resilience after tempering at 450-600° C and slow cooling	Izod impact test	Carbides, oxides, nitrides and phosphides separate out at the grain boundaries	Prevention: 1) cool in water or oil after tempering at 450-600° C; 2) use steel containing molybdenum, titanium and niobium Correction: repeated tempering followed by oil cooling, the temperature being by 20-30° C above that of the initial tempering

Chapter V

CASE-HARDENING

The combined chemical and heating treatments called case-hardening consist in the heating of the work up to a given temperature in a specially chosen chemically active medium, e. g., in coal with additions of salts, in a medium producing atomic nitrogen, in chemically active molten salts, etc. As a result of the interaction with the surrounding medium, the chemical composition of the outer layer of the work is altered.

The work subjected to case-hardening acquires surface hardness, high resistance to corrosion, heat resistance, wear resistance or the ability to harden, depending upon the nature of the treatment. Pertinent details on the different case-hardening processes can be summarised as in the following paragraphs.

1. CARBURISING

Carburising consists in the saturation of the surface layers of the steel with carbon. The carburised work, following hardening, acquires an extra-high surface hardness while retaining a tough core.

Carburising is used for work from carbon and alloy steels with up to 0.25% carbon. Steels with up to 0.3-0.4%C may be used for large simple-shaped parts as well as for parts requiring high core strength.

In shop practice carburising is being used for tool steels (chiefly alloy chromium steels) hardened in oil. Cold stamping dies of regular shape, extruding dies, etc., are subjected to carburising which raises considerably the wear-resistance of the above tools.

Carburised tools are not to be ground, as in this case the most valuable wear-resistant layer will be removed. The carburising procedure follows the usual pattern yielding a 1-mm case. Hardening should be carried out carefully, with all precautions taken against warping and decarburisation. Hardening temperature averages 800-820°C, while tempering is accomplished at lower temperatures.

Steels are carburised in solid, gas or liquid media, called carburisers.

Carburising by solid carburising compounds (pack carburising). Table 52 lists the chemical composition of carburisers used in shop practice. Charcoal, chiefly oak or birch by its nature, is crushed to pieces 3 to 10 mm in size and impregnated with a solution of carbonate salts, after which it is dried at 100-150°C. Sometimes plain mixing of charcoal with powdered carbonate salts proves to be satisfactory.

Table 52

Composition of Carburisers for Pack Carburising (% by weight)

No.	Charcoal	Barium carbonate	Soda ash	Calcuim carbonate	Coke	Turf coke	Fuel oil
1	74-78	12-15	1.0-1.5	3.5	—	—	4.5-5.0
2	65	10	1	1	20	—	3
3	87	—	10	3	—	—	—
4	85-90	—	10-15	—	—	—	—
5	90	10	—	—	—	—	—
6	—	—	10-15	—	—	85-90	—
7	60	40	—	—	—	—	—
8	45	12	—	—	43	—	—
9*	98	2	—	—	—	—	—

* This carburiser is used for boron-bearing steel.

The moisture content of the carburiser should not exceed 5-7%. A carburising mixture consists of 20-30% and 70-80% of fresh and used carburiser, respectively. Parts subject to carburising should be dry and free from scale, rust, dirt, grease, etc. The parts are packed into boxes or containers made of heat-resisting steel, and, when the necessary steel is not available, boxes manufactured from plain structural

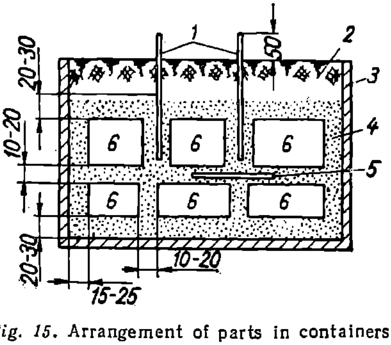


Fig. 15. Arrangement of parts in containers:
1 — outside "witnesses"; 2 — luting; 3 — container; 4 — carburiser; 5 — internal "witness"; 6 — parts

steel are used; the wall thickness of the box or container should be equal to 4-6 mm. The shape of the box should follow, as much as possible, that of the carburised work. The packing of the work should conform to the dimensions indicated in Fig. 15. The width of the box should not exceed 250 mm in order to facilitate its handling and to hasten heating.

The boxes are luted with a mixture consisting of two parts of refractory clay and one part of river sand, diluted to paste-like consistency.

The boxes are charged into a furnace heated to the required temperature. The boxes should be heated through at 780-800°C, after which the temperature is raised to 900-950°C, this being taken as the beginning of the carburising process.

Table 53

Relation of Holding Time to Layer Thickness in Carburising by Solid Carburisers at 900-950° C

The least cross-section of the box, mm	Thickness of carburised layer, mm							
	0.25	0.5	0.7	0.9	1.1	1.2	1.3	1.4
	Total holding time in furnace, hours							
100	3.0	4.0	5.0	6.0	7.0	7.5	8.0	8.5
150	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5
200	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5
250	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5

Too rapid a heating to 900-950°C of cold boxes causes a difference in carbon saturation of parts situated near the walls and in the centre of the box.

Witness samples for determining the depth of the case are 6 to 10 mm in diameter. These samples are manufactured from the same steel as the carburised parts, or from grade Ст. 15-20 steel.

After the supposed ending of the carburising process, the outer witness sample is extracted from the container, hardened and the fracture is etched for 1 minute in a compound composed of 100 cm³ of methylated alcohol, 1 cm³ of hydrochloric acid and 2 g of copper chloride. Copper separates out at the non-carburised core. The thickness of the case can also be found by tempering of the fractured hardened witness until tempering colours are observed; in this instance the case and the core are coloured in different tints.

After the case-hardening process, the containers are cooled on the shop floor.

Paste carburising. Table 54 presents the composition of pastes used for carburising. The prepared powder of one of the pastes indicated is diluted in a 15% aqueous solution of molasses or glue, to a consistency which permits colouring.

The surface to be carburised or the whole work is coated by a layer 3-4 mm thick, the coating being accomplished by immersion or by the use of a brush. This done, the parts are dried and packed into boxes provided with sand seal (ref. to Fig. 22). The paste carburising process is carried out at 920-930°C, the approximate speed of case-hardening being 1 mm per hour.

When the carburising is completed, the parts are air-cooled or quenched immediately after they are taken out of the container.

Gas carburising. In gas carburising, the parts are heated up in a gas atmosphere containing carbon.

The following gases are used for carburising: 1) natural gases, 2) artificial gases (producer gas, pyrolysis gas, etc.).

An artificial gas produced by dissociation (pyrolysis) of oil products has gained widest application.

Table 54

Chemical Composition of Pastes Used for Carburising

Paste component	Paste number						
	Stalite		3	4	5	6	7
	1	2					
	Composition in % by weight						
Ivory black or coke	30-60	30-60	30-60	35	45	40	50
Barium carbonate . .	—	—	—	15	20	15	—
Sodium or potassium carbonate	20-40	20-40	30-60	20	20	20	40
Cyanide compound "ГИПХ"	5-10	5-10	—	—	—	—	—
Sodium or potassium oxalate	—	5-10	5-10	—	—	—	10
Nickel formiate or cobalt oxalate . .	—	5-10	—	—	—	—	—
Ferrochrome (for carbon steel)	—	—	15	15	—	—	—
Sand	—	—	—	—	—	5	—
Potassium ferrocyanide	5-10	5-10	—	15	15	20	—

Note. The composition of the cyanide compound «ГИПХ» is given in the footnote to Table 64.

Carburising is effected chiefly in shaft furnaces of the "Ц" series. When the carburising is carried out in shaft furnaces, the pyrolysis of oil products occurs directly in the furnace retort, as the carburiser is fed by drops. Kerosene, benzene, pyrobenzene, spindle oil, and synthol filtered from solids are used as carburisers.

Table 55

Amounts of Black, Coke and Gas Obtained in the Pyrolysis of Some Carburisers

Carburiser	Amount of gas (litres) from 1 cm^3 of carburiser	Amount of black and coke (grams) per 1 cm^3 of carburiser
Benzene	0.42	0.60
Pyrobenzene	0.58	0.54
Kerosene	0.73	0.39
Synthol	0.80	0.28

A new carburiser for gas carburising, the so-called synthol, which produces less black and coke and increases the speed of the process, has currently found wide application in shop practice. Table 55 presents data on the amounts of black, coke and gas generated in the pyrolysis of some carburisers. Maximum effectiveness has been obtained with the use of synthol in continuous furnaces. Synthol is currently used in a great number of plants.

Table 56

Recommended Kerosene Feeding Rate for Carburising in Shaft Furnaces of Various Sizes

	Furnace type					
	Ц25	Ц35	Ц60	Ц75	Ц90	Ц105
	Drops per minute					
During the heating with temperature reaching 800° C	20-40	40-50	70-80	90-100	120-140	160-180
During the heating with temperature reaching 900° C	60-70	70-80	110-130	160-180	200-220	240-260

Table 56 presents the kerosene feeding rates recommended for shaft furnaces of various sizes during the carburising process. These data are compiled from published literature, and practical results obtained in a number of plants. The author considers it expedient to cut off the carburiser feed one hour before the termination of the gas carburising process in order to give the carbon enough time to diffuse into the inner areas of the work and to avoid oversaturation of the outer layers. This is of utmost importance when a thicker case is required.

As the carbon absorption rate on the work surface decreases with holding time, some investigators believe that kerosene should be fed at maximum rate at the beginning of the carburising process and that its supply should then be gradually diminished (Table 57).

Table 57

Kerosene Feed Rates Recommended for Carburising in Shaft Furnaces (Data by Chirikov V. T.)

Furnace type	Kerosene fed during the initial period		Kerosene fed (drops per min) during the remaining period
	Drops per min	Feed duration, hrs	
Ц25, Ц35	70-80	2-3	20
Ц60, Ц75	100-120	2-3	30-40
Ц90, Ц105	200-300	2-3	50-70

Note. Furnaces may be fed either with artificial or natural gases, instead of the iquid fuel.

The following sequence of technological operations for gas carburising process in shaft furnaces is recommended:

1. Charge the work into the furnace heated to 850-950°C.
2. Witness samples for process control should be charged at the same time as the work.
3. Press the cover tightly on the retort.
4. Feed the kerosene according to Table 56.
5. Set fire to the waste gases; in a normal process the flame should smoke slightly.
6. The termination of the process is determined with the aid of witness samples; to this end, the process is interrupted, the samples extracted and hardened (Table 58).

At present the gas carburising process has been automated by controlling the carburising medium for its dew point.

Table 58

Approximate Holding Time for Gas Carburising at 900-950° C in "Ц"-Type Furnaces

Time, hrs	2-3	4-5	6-7	8-9	9-10
Layer depth, mm	0.3-0.5	0.6-0.7	0.8-1.0	1.1-1.2	1.2-1.4

Note. Time is counted off from the moment the temperature of 900° C has been attained.

The composition of the waste gases should be within the following limits: carbon dioxide—0.5%, oxygen—0.5%, unsaturated hydrocarbons—10%. Surplus pressure varies from 8 to 25 mm water gauge.

Liquid carburising. This process is practised in a number of plants, in baths, where the carburising component is carborundum (silicon carbide). The usual composition of the bath is: soda ash (Na_2CO_3)—80%, common salt (NaCl)—10-12%, carborundum (SiC)—8-10%. This compound is currently supplemented with ammonium chloride (NH_4Cl), which speeds up the carburising process, and produces active nitrogen, which in conjunction with carbon saturates the surface of the work.

A liquid carburising process such as it is practiced at the Kharkov Sewing Machine Plant is described below.

The composition of the bath is: soda ash 70-74%, common salt 9-12%, ammonium chloride 8-9%, carborundum 9-10%. The carborundum used is black, coarse-grained, the size of grains being 24-50 mesh (mesh is the number of openings per linear inch).

Soda and salt are melted first, then ammonium chloride is added. As soon as the bath heats up to 850-870°C, carborundum is charged.

Ammonium chloride and carborundum, to avoid vaporisation and rapid burning out, are charged into the bath in paper wire-corded packets, sunk to the bath bottom with a poker, perforated bell or some other object and held there till melting, after which the bath is brought to the carburising temperature through continuous mixing. The process is sometimes accompanied by such intensive foaming that the bath temperature is to be temporarily lowered.

To protect the bath against oxidation, a layer of slag 10-15 mm thick is left over, while the remainder is skimmed. The amount of salt should not exceed $^2/_3$ of the bath height, the remaining volume being intended to counteract foaming.

The work subject to carburising should be dry and clean. The temperature of the process averages 850-900°C. Holding time is a function of the case thickness (Table 59). Hardening is carried out either in oil or water depending upon the grade of the steel.

Table 59

Approximate Time of Carburising in a Liquid Carburiser as a Function of Case Thickness

Case thickness, mm	Duration of the process, hrs	Case thickness, mm	Duration of the process, hrs
0.4	1	1.2	4
0.6	1.5	1.4	5
0.8	2	1.6	6.5
1.0	3	1.8	8

Note. The bath should be refreshed every 5-8 hrs of operation by adding carborundum (2-5% of the total salt weight).

A complete replenishment of salt is carried out every 3-4 weeks of continuous bath operation, as the bath thickens and loses carburising ability.

The bath is controlled by observing the following practical symptoms: 1) considerable flaming and foaming (runs against the normal functioning of the bath); 2) the work should possess a uniform silvery colour (dark spots are signs of bath exhaustion).

Carborundum consumption averages 10-12 kg per 1 ton of work.

High-temperature carburising. High-temperature carburising, at 1050°C and above, is currently finding increasing application. Pack carburising at the above temperatures is effected in furnaces with silit (silicon carbide) resistors. After carburising, normalising and hardening or double hardening are carried out.

High-temperature gas carburising is a current practice at the Likhachev Plant, where induction heating in a special installation is being applied.

Protection of work surface not required to be carburised.

1. Positive allowance which is machined off after carburising.
2. Luting (Table 60).
3. Copper-plating (Table 61).

To protect holes against carburising, a mixture of quartz sand and scale (from the hardening tanks) is used, or the apertures are plugged with metallic plugs.

Heat-treatment schedules for carburised work are presented in Table 62.

Table 60

Lutes Used for Protection against Carburising

Lute composition		Method of manufacture
Component	%	
Copper monochloride . . Minium	70 30	The powders are mixed thoroughly and diluted in alcohol rosin varnish (250 g of varnish per litre of ethyl alcohol). The lute is spread over the surface of the part in a uniform layer with the aid of a brush. Layer thickness is equal to 0.5-1 mm
Silica . . . . Alumina . . . . Iron oxide . . . . Titanium oxide . . . . . Magnesium oxide	60 35 3 0.25 1.75	The paste consists of both the liquid (20-25% by volume) and solid (75-80% by volume) phases. The liquid phase comprises 80% soluble glass and 20% water. Prior to use, both phases are mixed and then spread over the part with a brush. After drying (after 30-40 min) the part is given a second coat

Continued

Lute composition		Method of manufacture
Component	%	
Sand . . . . Refractory clay Borax . . . . Sodium saltpetre . . . . Lead oxide.	40 44 10 3 3	The compound is diluted in soluble glass and applied uniformly over the work. The clay should be well ground
Talcum . . . . Refractory clay . . . . Water	50 25 25	The clay is well ground. The compound is diluted in soluble glass to paste-like consistency
Fireclay . . . . Asbestos powder . . .	90-95 5-10	The compound is diluted in water to paste-like consistency

Table 61

Relation of Copper Coating Thickness to Depth of Carburising

Required carburising depth, mm	Below 0.8	0.8-1.2	Above 1.2
Thickness of copper coating, mm	0.02	0.03-0.04	0.05-0.07

Table 62

Heat-treatment Schedules for Carburised Articles

Heat-treatment schedule	Application	Notes
Hardening from 860-900° C Hardening from 760-800° C Tempering at 160-180° C	1. For natural coarse-grained steel inclined to overheating 2. Whenever extra-high quality is required for carburised parts	
Hardening from 800-850° C Tempering at 160-180° C	1. For natural fine-grained steel 2. For non-critical parts from natural coarse-grained carbon steel	

Continued

Heat-treatment schedule	Application	Notes
1. a) Tempering at 640-650° C b) Hardening from 850-860° C c) Tempering at 160-180° C d) Sub-zero treatment e) Tempering at 160-180° C	For high-alloy steel (grades 18XHBA, 12X2H4, 12XH3, etc.)	High-temperature tempering and sub-zero treatment decrease residual austenite
2. a) Rapid partial cooling in a molten salt or oil from carburising temperature to 250-550° C b) Transfer to a furnace heated to 550° C, and a 4-8 hr holding c) Air cooling d) Tempering at 630-680° C for 8-10 hrs with cooling in air or furnace e) Hardening		The heat-treatment method was proposed by V. T. Chirikov to ensure optimum structure both of the case and the core
f) Low-temperature tempering. Hardening from carburising temperature with air-blast cooling to 740-840° C. Tempering at 160-180° C. Sub-zero treatment. Tempering at 160-180° C	For parts from high-alloy steel of the 18XHBA grade which was given the gas carburising treatment	

2. NITRIDING

Nitriding (nitrogen-hardening) consists in the saturation of surface layer of steel or cast iron with nitrogen. There exist two varieties of nitriding:

1. Strength-nitriding aimed at increasing hardness, wear resistance and fatigue endurance (Table 63).

2. Anticorrosive nitriding aimed at increasing the resistance to corrosion in water (fresh) and in humid atmosphere (Fig. 16).

Strength-nitriding. Nitriding is chiefly applied to special grades of steel (35ХЮА and 38ХМЮА), containing aluminium, with a view to raise their hardness. In addition to these, alloy tool and stainless steels are also nitrided. Maximum hardness, after nitriding, is displayed by articles made from grade 35ХЮА and 38ХМЮА steels (1000-1150 H_V).

Plain alloy structural steels—chrome-nickel, chrome-nickel-molybdenum, etc.—are nitrided to increase fatigue endurance. Surface hardness of these steels, after nitriding, is 600-700 H_V.

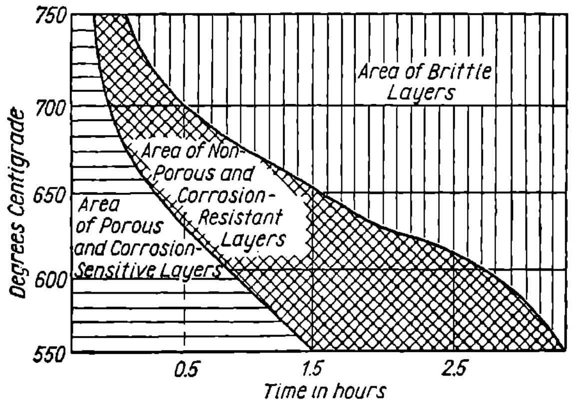


Fig. 16. Diagram for computing optimum schedules of anticorrosion nitriding

Cast irons, subject to nitriding, should contain some aluminium and chromium. Hardness of cast irons following nitriding is 1000 H_V.

Prior to nitriding, steel parts are hardened and tempered at 550-650°C, while those from cast iron are hardened and tempered at 600-650°C.

Protection against nitriding. Areas not to be nitrided are to be insulated by one of the following methods: (1) tinning; (2) nickel plating; (3) luting with compounds composed of three parts of powdered tin, one part of powdered lead and one part of powdered chromium oxide. A well ground mixture is diluted in a solution of zinc chloride. After luting, the part should be dried.

Strength-nitriding checking. 1) Hardness is checked by instruments with diamond tips, at low loads (Table 8). 2) Brittleness is characterised by the distortion of the diamond indentation (shearing of the indentation edges). 3) The layer depth is determined by etching a ground

Table 63

Strength-nitriding Schedules

Nitriding schedule	Version	1st step			2nd step			3rd step			Thickness of nitrided layer, mm
		Tempera-ture, °C	Dissociation degree, %	Time, hrs	Tempera-ture, °C	Dissociation degree, %	Time, hrs	Tempera-ture, °C	Dissociation degree, %	Time, hrs	
One-step	1	480-520	20-25	Up to 90	—	—	—	—	—	—	0.5-0.7
	2	540-560	30-50	36-65							0.5-0.6
Two-step	1	500-510	Below 25	18-20	550-570	35-55	20-24	—	—	—	0.5-0.7
	2	540-560	30	10	570	30	8				0.35-0.45
Three-step	1	500-520	20-35	12-15	550-570	40-60	12-15	500-520	40-60	12-15	0.5-0.8

butt of a sample with a 4% solution of aqueous nitric acid, as well as by the nature of the fracture and the microsection.

Anticorrosion nitriding. Articles from carbon and alloy steels and cast iron may be subjected to anticorrosion nitriding. Prior to nitriding, the parts should be thoroughly degreased.

Nitriding of work from high-carbon steels requiring high hardness should be followed by hardening at adequate, for the given steel, temperature.

The degree of dissociation should be maintained within the range of 35-70%.

Anticorrosion nitriding checking is effected through dipping or wetting the part with 10% aqueous solution of blue vitriol (copper sulfate) for 1-2 min. Copper is deposited at pores, fractures, and other defective points.

Uniform heating throughout the muffle furnace is essential for successful nitriding. The volume of the retort should be filled with parts to maximum capacity.

3. CYANIDING

Cyaniding consists in the simultaneous saturation of the surface of the steel both with carbon and nitrogen. Cyaniding is carried out in liquid, gas or solid media.

Two types of cyaniding are distinguished: (a) high-temperature cyaniding aiming to increase hardness, wear resistance, and fatigue endurance of parts from structural steels; (b) low-temperature cyaniding intended to increase hardness and red hardness of tools from high-speed steel.

1. **High-temperature liquid cyaniding.** To prepare the bath for operation, first neutral salts (soda ash, etc.) are melted, then cyanides are

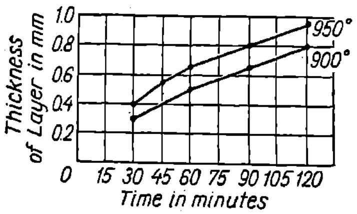


Fig. 17. Effect of duration of cyaniding at 900° and 950°C on the depth of cyanided layer

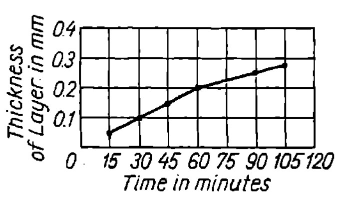


Fig. 18. Effect of duration of cyaniding of steel 20X at 850°C on the depth of cyanided layer

added. In baths containing compounds 6 and 7 (Table 64) excessive foaming occurs when cyanide compound is charged; the excess foam is removed, a thin layer being left to protect the bath from exhaustion. The melt surface of a deep cyaniding bath (compounds 4 and 5) is covered with a layer of graphite, 3-4 mm thick, for the same reasons.

The working temperature averages 830-860°C for common cyaniding and 900-950°C for deep cyaniding (Figs. 17 and 18).

The refreshing of baths with sodium cyanide is effected by adding high-percentage sodium cyanide at a rate of 0.5-1% of the weight of the salts in the bath per hour; for baths containing the "ГИПХ" cyanide compound, the additions should average 2-4% of the weight of the salts in the bath every 2 hours of operation.

The author practises high-temperature cyaniding, in conjunction with bright hardening, in a bath containing 38-40% sodium chloride, 38-40% potassium chloride and 20-24% potassium ferrocyanide. The latter should be well dried and added by small portions, while mixing the bath. On charging, foam and slag are formed, and they should be removed.

Table 64

Composition of Baths for High-temperature Cyaniding

Compound No.	Composition of baths, %					
	Sodium cyanide	"ГИПХ" cyanide compound	Soda ash	Common salt	Calcium chloride	Barium chloride
1	25	—	15-20	55-60	—	—
2	40	—	30	30	—	—
3	45	—	35-40	15-20	—	—
4	50	—	—	15	—	35
5	6	—	—	14	—	80
6	—	9	—	26	65	—
7	—	9	—	37	54	—

Note. The "ГИПХ" cyanide compound consists of: 43-49% $Ca(CN)_2$; 2-3% $CaCN_2$; 30-35% NaCl; 14-16% CaO; 4-5% C.

After requisite holding in the bath, the work is cooled in a 50% aqueous solution of caustic soda. Hardened parts are clean and bright. The depth of cyaniding equals 0.15 mm, the holding time for the abovementioned compound averaging 15 min.

2. **High-temperature gas cyaniding.** Gas cyaniding is carried out in a mixture of ammonium and carbonaceous gases used for gas carburising. The cyaniding mixture comprises: ammonium 20-30%, carburising gas 70-80%.

Benzene, pyrobenzene, kerosene and synthol are used as materials for producing carburising gas. They are fed dropwise direct into the retorts of shaft furnaces.

The working temperature of gas cyaniding should average 840-860°C. For parts of simple shapes, the temperature may be raised to 900°C.

Approximate depth of cyaniding after 1 hour of operation at 850°C is 0.12-0.16 mm (Fig. 19).

The hardening of the work, following liquid and gas cyaniding, should be effected as soon as the work is withdrawn from the furnace at the termination of cyaniding. On high-temperature cyaniding, the work is air-blast cooled. After hardening, the parts are tempered at 160-200°C. Small non-critical parts from low-carbon steels are not tempered at all.

Parts to be machined after cyaniding are air-cooled, then tempered at 630-650°C; after machining they are hardened and then tempered again.

Areas not to be cyanided are copper-plated, the thickness of the coat being 0.018-0.025 mm; the copper-plated layer should be compact.

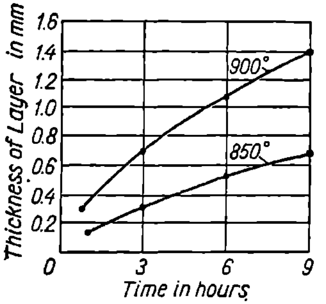


Fig. 19. Variation in the depth of cyanided layer in relation to the duration of gas cyaniding at various temperatures

The cyanided parts are checked in the shop by testing hardness with the aid of a file, diamond pyramid or cone, depending on cyaniding depth.

3. **Low-temperature liquid cyaniding.** Tools are cyanided after final machining, sharpening, cleaning, and degreasing. The temperature of the process averages 540-560°C (Tables 65 and 66).

Table 65

Composition of Baths for Low-temperature Cyaniding

Sodium cyanide	Potassium ferrocyanide	Soda ash	Sodium or potassium hydrate	Melting point, °C
50-55	—	23-30	15-20	515
85-90	—	10-15	—	—
—	80-90	—	10-20	490-500

Table 66

Relation of Holding Time to Cyaniding Depth in Low-temperature Cyaniding of High-speed Steels

Holding time, min	Layer thickness in mm, the bath containing the below-mentioned amounts of cyanide		
	90%	50%	30%
5	0.008	0.006	0.006
15	0.020	0.018	0.015
30	0.035	0.030	0.030
45	0.037	0.035	0.035
60	0.045	0.043	0.040
120	0.055	0.055	0.052
360	0.080	0.075	0.070

Tools smaller than those indicated in Table 67 are not cyanided because of high brittleness. Optimum cyaniding depth for cutting tools is 0.02-0.035 mm. Prior to cyaniding, the tools should be preheated in a separate furnace or near the crucibles. Long, slim tools should be suspended throughout the heating and cooling.

One of the Kiev plants performs low-temperature cyaniding in a bath with a slightly poisonous compound of the following composition: 70% sodium hydrate and 30% potassium ferrocyanide. Potassium ferrocyanide is added to the bath in the same way as for high-temperature bath. The bath is analysed for CN and CNO once every two days. Normal cyaniding requires at least 5% CNO. Potassium ferrocyanide is added as the bath exhausts itself. The above-mentioned plant cyanides dies for pressure casting; for more information refer to page 185.

4. **Low-temperature gas cyaniding.** The composition of the gas cyaniding medium and the proportions of the gases are the same as for high-temperature cyaniding.

After being held at 540-560°C the tools are air-cooled or cooled in a furnace down to 200°C. In the latter case the tools acquire a silvery tint (Table 68).

One of the plants in Leningrad conducts low-temperature cyaniding of tools from high-speed steel in a "Ц25" furnace, the kerosene feed amounting to 60-80 drops per minute and that of ammonium to 2 litres per minute. Aluminium-silicon alloy turnings are used as catalyst. Taking over the practice of the above-mentioned plant the author introduced gas cyaniding of stamping dies from grade 3X2B8 steel in a shop-made electric furnace with a retort 200 mm in diameter and 600 mm high. The feeding rates are: kerosene—10-15 drops per minute, ammonium—1.2-1.4 litres per minute. Positive mixing of the medium is essential. Fig. 20 presents a schematic view of a cyaniding furnace.

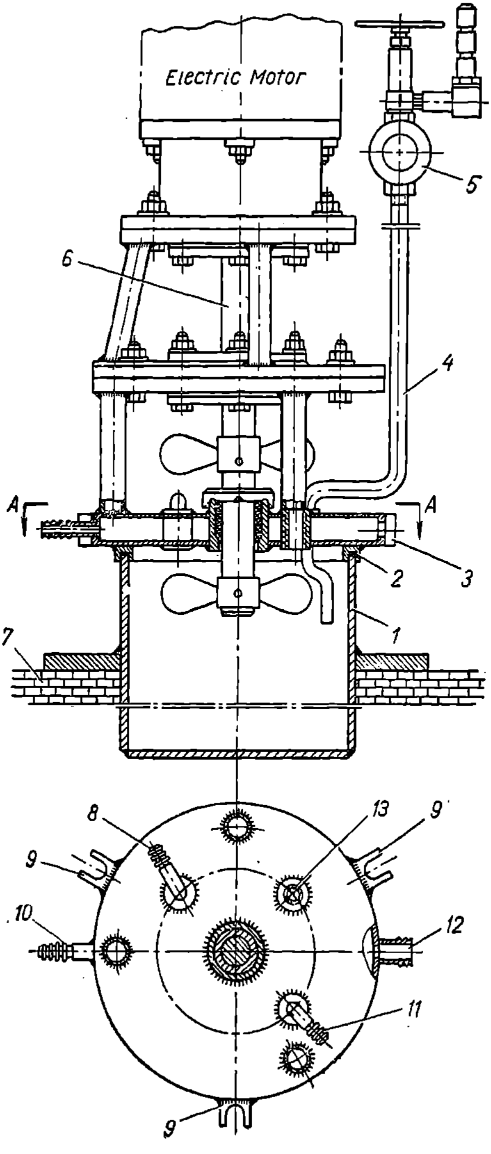


Fig. 20. Gas cyaniding installation:
1 — muffle; 2 — rubber gasket; 3 — water-cooled muffle lid; 4 — tube for feeding kerosene into the furnace; 5 — kerosene dropper; 6 — impeller shaft; 7— furnace lining; 8—ammonia feed sleeve; 9— shackle for fastening lid to crucible; 10 — water inlet sleeve; 11 — gas outlet sleeve; 12 — water outlet sleeve; 13 — kerosene feed orifice

Table 67

Recommended Holding Time for High-speed Steel Tools Cyanided in Liquid Media with Minimum Content of 50% Sodium Cyanide

Tools	Diameter or thickness, mm	Holding time at 560° C, min
Drills, reamers, and counterbores	3-5	6
	6-10	8
	10-15	10
	15-20	12
	20-30	15
	Above 30	16-23
Taps	5-8	5
	8-12	8
	12-20	10
	20-30	12
	Above 30	14-18
Broaches	5-10	8
	10-15	12
	15-20	14
	20-30	16
	Above 30	20-25
Threading cutters with non-honed teeth	25-35	12
	35-50	15
	Above 50	18
Threading cutters with honed teeth	25-35	10
	35-50	12
	Above 50	15
Tangential threading dies	—	8-10
Hob cutters with non-honed teeth	50-60	30
	Above 60	40-50
Hob and slot cutters with honed teeth	50-60	16
	Above 60	20-26
Cylindrical profile cutters and end cutters with honed teeth	Up to 30	10-12
	30-40	16
	40-60	20
	Above 60	25-30
Disk milling cutters	1-2	6
	2-5	8
	5-10	12
	10-15	15
	Above 15	18-23
Forming and tangential cutters	—	12-30
Cutters for tooth-cutting machine	—	10-12
Turning and shaping tools	—	12-40
Gear cutters	—	15

Note. Holding above the recommended limits results in a brittle cyanided layer.

5. **Low-temperature solid cyaniding**. The cyaniding mixture consists of the following well-mixed components: 60-80% charcoal (size of grains approximates 3-6 mm) and 20-40% powdered potassium ferrocyanide. The tools are packed into iron containers in the same manner as for carburising (Fig. 15).

The temperature of the process is 550-560°C. Cooling is effected without unloading the containers, in the air, down to 100-200°C.

Some of the defects which are met with in case-hardening of steel are listed in Table 69.

4. CALORISING

Calorising or aliting is employed to increase the resistance to scaling of steel articles working at high temperatures, and consists in the saturation of steel surface layer with aluminium. Calorising can be carried out in solid, liquid or gas media, but at the present time solid calorising treatment is most widely used. In this method, clean, degreased articles are packed into steel containers filled with thoroughly mixed powder-like mixture, consisting of 99.5% ferro-aluminium alloy and 0.5% ammonium chloride.

Articles are packed in the same manner as for the pack-carburising procedure. Areas not to be calorised are covered with asbestos or luted with fireclay. Emphasis should be placed upon thorough luting of the containers to avoid oxidation of the calorising mixture. A calorising compound consists of used and fresh mixtures (80% and 20%, respectively). The temperature of the process is within 850-1000°C. Calorising rate is approximately 0.05-0.08 mm per hour depending upon the temperature of the process.

The calorised layer is highly brittle which cannot be tolerated for a number of critical parts. These calorised parts are annealed at 900-1000°C for 3-6 hours to bring down the aluminium content of the surface layer at the expense of its diffusion into the inner areas.

In thin parts, this may lead to a through calorising of the article and cause brittleness throughout the whole section. Such defects should be prevented by adequate choice of temperature and duration of annealing.

5. SULPHIDING (SULPHATING)

Sulphiding is used to raise wear resistance of machine parts and certain tools manufactured from high-speed steel by saturating their surface layers with sulphur.

Sulphiding is brought about through treatment in liquid or solid media. In the liquid sulphiding process degreased dry articles are placed in baths containing: 1) sodium chloride—17%; 2) calcium chloride—38%; 3) barium chloride—25%; 4) iron sulphide—13.2%; 5) sodium sulphate—3.4%, and 6) potassium ferrocyanide—3.4%.

The former three salts are melted first, then, gradually, the remaining components of the bath are fused. After the complete fusing of the salts and subsequent cleaning of the bath, the latter's surface is covered with graphite. Sulphiding is effected within the 560-750°C temper-

Table 68

Recommended Holding Time for Tools from High-speed Steels in Gas and Solid Cyaniding

Tool	Diameter or thickness, mm	Holding time in hours at 550-560° C	
		In gas medium	In solid medium
Drills, counterbores, reamers	Up to 15	1.0-1.5	2.0-2.5
	15-25	1.5-2.0	2.5-3.0
	25-50	2.0-3.0	3.0-4.0
Taps	Up to 15	0.5-1.0	—
	15-25	1.0-1.5	—
	25-50	1.5-2.0	—
Threading cutters:			
a) honed teeth	25-50	1.0-1.5	1.5-2.0
	Above 50	1.5-2.0	2.0-3.0
b) non-honed teeth	25-50	1.5-2.0	2.0-2.5
	Above 50	2.0-2.5	2.5-3.0
Threading chasers and dies:			
a) screw pitch up to 2 mm	—	1.0-1.5	1.5-2.0
b) screw pitch above 2 mm	—	1.5-2.0	2.0-3.0
Worm and slitting cutters			
a) honed teeth	50-75	1.0-1.5	2.0-2.5
	Above 75	1.5-2.0	2.5-3.0
b) non-honed teeth	50-75	1.5-2.0	2.5-3.0
	Above 75	2.0-2.5	3.0-4.0
Cylindrical, profile and end cutters	Up to 50	1.0-1.5	2.0-2.5
	50-75	1.5-2.0	2.5-3.0
	Above 75	2.0-2.5	3.0-4.0
Disk cutters	Up to 10	1.0-1.5	2.0-3.0
	Above 10	1.5-2.0	3.0-4.0
Round-nose cutters	Up to 5	1.0-1.5	2.0-2.5
	5-15	1.5-2.0	2.5-3.0
Tangential cutters	10×10	1.5	3.0
	25×25	2.0	3.5

Notes. 1. Holding time is counted off from the moment the tool is heated through.

2. Holding time in excess of that recommended results in a brittle cyanided layer.

Table 69

Defects in Case-hardening Processes

Defect	Detection	Cause	Prevention and correction
1. Defects in Carburising of Steel			
Pitting	Visual inspection	Over 3-6% of sulphate in the carburiser	Prevention: Keep sulphate content below 3-6%
Vitreous bulges on the surface of articles	Visual inspection	Presence of sand in the carburiser	Prevention: Keep sand out when storing or unpacking carburiser. Pass the carburiser through a sieve
Uneven carburising depth	Fracture inspection	Poor mixing of carburiser. Uneven heat soaking of containers	Prevention: Thorough mixing of the carburiser; use of a solution of carbonates and molasses as a binder in the manufacture of the carburiser. Uniform heat soaking of the containers
Excessive carburising depth. Increased carbon content in the carburised layer	Fracture inspection Microscope inspection of microsection	Elevated temperature and holding time on carburising. Strong carburiser used	Correction for excess carbon: Hardening in oil or normalising at 900-910° C for carbon steels and 850-860° C for alloy steels with subsequent hardening at 760° C
Low carbon content in the carburised layer	Hardness test. Microsection inspection	Carburising at low temperature. Weak solid carburiser or insufficient gas or kerosene feed in gas carburising	Correction: Repeated carburising at normal temperature and with normal carburiser Prevention: Use adequately strong carburiser

Insufficient carburising depth	Fracture and microsection inspection	Carburising at low temperature. Weak solid carburiser or insufficient gas or kerosene feed in gas carburising	Correction: Repeated carburising at normal temperature and with normal carburiser. Prevention: Use stronger carburiser
Surface decarburisation of carburised layer	Hardness test. Microsection inspection	Too slow cooling of containers in the furnace after carburising (particularly when coarse-lumped carburiser is used)	Correction: Repeated short-term carburising at normal temperature. Prevention: Cooling of the boxes in the air
Non-uniform carburising	Hardness test	Dirty, greasy work surface, shrinkage of carburiser, abnormality of steel	Prevention: Strict conformance to technology chart. Use natural coarse-grained steel
Scaling-off of hardened carburised layer	Visual inspection	Use of a strong carburiser	Correction: Heating in containers, filled with charcoal plus 3-5% soda ash, up to 920-940° C and holding at this temperature for 2-4 hours
Increased amounts of residual austenite. Low hardness. Defect is characteristic of high-alloy steels	Hardness test	High carbon content in carburised layer; too rapid quenching	Correction: 1. Sub-zero treatment. 2. Improving with subsequent hardening from 750° C. 3. Hardening with air-blast cooling to 650-600° C
Considerable sooty deposits on gas carburising	Visual inspection	Excessive gas or kerosene feed to the furnace	Correction: Accurate proportioning of carburising material fed to the furnace

Table 69 continued

Defect	Detection	Cause	Prevention and correction
		2. Defects in Nitriding of Steel	
Warping and distortion	Checking for size and beat	Stresses caused by the difference in specific volumes of the nitrided layer and the core	Prevention: 1. Nitriding to a minimum layer depth. 2. Avoid sagging of parts in the furnace. 3. Uniform heating and cooling of parts in the furnace
Cracking (scaling-off of the nitrided layer)	Visual inspection	Presence of distinct boundary between the nitrided layer and the core	Prevention: Slow cooling after nitriding. If there is a faulty part in the batch, all parts should be tempered at 570-580° C for 4-5 hours in the furnace with a permanent atmosphere of dissociated ammonium
Bulges on the surface	Visual inspection	Slag inclusions in the part surface	Prevention: Strict checking of steel for slag inclusions
Brittleness (surface pitting) of the nitrided layer	Visual inspection. Diamond pyramid hardness test and checking of indentations	Excessive saturation of the skin by nitrides as a result of coarse-grained structure and surface decarburisation on preliminary heat-treatment	Prevention: Step-nitriding. If any defects are detected in the batch all parts should be tempered in an atmosphere of dissociated ammonium at 570-580 ° C for 4-5 hrs or at 630-650° C for 2 hrs

Uneven hardness. Characteristic of parts subjected to local nitriding	Diamond pyramid hardness test	Local tinned areas on the nitrided surface	Prevention: Phosphating prior to nitriding and careful preparation of the surface of the articles
Insufficient or porous layer. Characteristic of anticorrosion nitriding	Testing by 1-min immersion in a 10% aqueous solution of blue vitriol	Insufficient holding time, great dissociation degree of ammonium, low temperature of the process	Correction: Repeated nitriding with shorter holding time. For small-sized threaded parts this defect is irreparable

3. *Defects in Cyaniding of Steel*

Pitting on high-temperature cyaniding	Visual inspection	Over 0.7-0.8% of sulphates in neutral bath salts	Prevention: Strict checking of neutral salts for sulphates
Residual austenite in the layer, low hardness after hardening. Characteristic of alloy steels	Hardness test	Inadequate cooling rate	Prevention: Oil hardening with air-blast cooling down to 600-650° C. Correction: Sub-zero treatment
Brittleness of cyanided layer of articles from high-speed steel	Inspection of the indentation after the diamond pyramid hardness test	Prolonged holding and heating in high-percentage baths. High ammonium content (above 40%) in gas cyaniding	Correction: Heating a saltpetre bath at 550-560° C with a 30-min holding

ature range, but in no case above the tempering temperature of the article. Approximate sulphiding rate is 0.1 mm per hour at 560°C. The duration of sulphiding of high-speed steel tools, depending upon tool size, is within the limits of 1 to 3 hours. In solid sulphiding process, the articles are packed in steel containers filled with a compound having the following composition: 1) ground iron sulphide—30-40%; 2) graphite—50-60%; 3) potassium ferrocyanide—10%.

The heating temperature is the same as for liquid sulphiding. Holding time in solid sulphiding is approximately three times greater than in the liquid process. After sulphiding, the parts are flushed in hot water and heated in an oil bath at 110-120°C in order to protect them against corrosion. The hardness of the articles after sulphiding remains practically unaltered.

6. CLEANING AND PICKLING OF ARTICLES AFTER HEAT-TREATMENT

Articles are cleaned from salts, oil, and dirt in an aqueous solution containing up to 3% caustic soda or 10% soda ash. The temperature of the solution is approximately 80-90° C. Flushing takes 5 min and longer. The solution is replenished at least every ten days.

The articles are descaled in sand- or shot-blasting installations and in pickling baths.

Sand-blasting makes use of dry river sand, with grains sized to 1-2 mm, the necessary air pressure being within 5-6 atmospheres.

Sand-blasting may be replaced, for the sake of improving the working conditions, by hydro-sandblasting, in which the articles are dressed by a mixture of 50% sand and 50% water. This mixture is atomised by high-pressure air supplied to the mixer outlet.

Hydraulic cleaning using a 150-atmosphere water jet may also be used to dress larger articles.

Shot-blasting uses shots 0.5-2.0 mm in diameter.

Ferrous metals are pickled in a 5-18% aqueous solution of sulphuric acid or 7-20% aqueous solution of hydrochloric acid. To avoid over-pickling, the solution carries 1% of the "KC" or 0.5% of the "Ж" organic additions (by volume of the pickling solution). The addition is effective for 100-150 hours. Pickling time ranges from 30 to 60 min, the temperature averaging 40-90°C for the sulphuric acid and 30-60°C for the hydrochloric acid. The temperature should be increased as acid concentration decreases. The minimum permissible acid content of the working bath is 3-4%.

Stainless steels are pickled at 40-50°C in a bath composed of: 47% hydrochloric acid, 5% nitric acid and 48% water. They are then immersed in a 5% solution of nitric acid and held over for 3-5 min. Pickled articles are flushed in warm water, then in a 0.5% solution of caustic soda, and dried at 120-150°C to eliminate pickling brittleness.

Overpickling may occur when chemical descaling is applied; because of this, parts finished to size or designed with negligible machining allowance are to be electrochemically pickled in special shops.

7. ANTICORROSION PROTECTION FOR ARTICLES AFTER HEAT-TREATMENT

After heat-treatment associated with the use of salts, alkalis, water, and various other materials, which may cause corrosion of articles on long-term storage, the latter are given the anticorrosion treatment involving a 5-min dipping of cleaned, flushed and dried articles in a 20-30% aqueous solution of sodium nitrite; this done, the articles are wrapped in paper impregnated with the same solution.

In such a wrapping, the parts can be stored for a long period of time.

Chapter VI

HEAT-TREATMENT TECHNOLOGY

1. APPROXIMATE HEAT-TREATMENT SCHEDULES AND MECHANICAL PROPERTIES OF VARIOUS GRADES OF STEELS

Plain carbon steels (grades from Ст. 1 through Ст. 7) are heat-treated and case-hardened according to charts specified for structural steels with similar carbon content.

Free-cutting steel is heat-treated and case-hardened according to the same charts as above.

High-quality structural carbon steel, depending upon carbon content and application, can be normalised, annealed, hardened or carburised. In shop practice, steels with up to 0.5% carbon are normalised, while those with a higher carbon content are annealed to improve machinability. Cooling rate is 50-150°C per hour down to 500-600°C with subsequent air-cooling.

Annealing is to be carried out in the lower range of temperatures indicated in Table 70, while the upper temperature range is preferred for normalising.

One must bear in mind that steels of the medium-carbon grades (grades 45, 50, etc.) are inclined to cracking when hardened in water, and they should be quenched with intermediate transfer to oil bath.

Steels with high manganese content have a tendency to overheat, and because of this their heating and holding time should be as short as possible.

After tempering at 400-600°C, manganese steel should be cooled rapidly so as to prevent temper brittleness.

Steel castings. Large steel castings which acquire quite a coarse-grained non-uniform structure as a result of slow cooling are, first, homogenised at Ac_3+150-250°C, then annealed at normal temperature.

Medium- and small-size steel castings which are currently produced in great numbers by precision casting are, as a rule, annealed or normalised at Ac_3+20-50°C for hypoeutectoid steels and at Ac_1+20-30°C for eutectoid and hypereutectoid steels. Holding time on annealing and normalising should be increased by 1.5 times as compared to that specified for forgings and rolled blanks.

Castings can be, depending upon the specifications, subjected to *improving* (heavy duty machine parts) or hardened with subsequent low-temperature tempering (tools, etc.) according to usual schedules.

Steel castings subjected to any kind of heat-treatment are less ductile than forgings and rolled stock.

Table 70

Approximate Heat-treatment Schedules and Mechanical Properties of Quality Structural Carbon Steels

Grade	Heating temperature for hardening, normalising or full annealing, °C	Cooling medium	Tempering temperature, °C	Mechanical properties			
				Hardness		Tensile strength, kg/mm²	Elongation, %
				H_B	R_C		
Carbon Steels with Normal Manganese Content *Steels Subject to Carburising*							
08	900-960	Air	—	131	—	32	33
10	900-940	Air	—	137	—	34	31
15	890-930	Air	—	143	—	37	27
20	880-920	Air	—	156	—	41	25
Steels Subject to Improving							
25	860-900	Water	200-300	—	33-27	—	—
30	850-890	Water	200-300	—	35-30	—	—
			600	—		55	20
35	840-880	Water	300-400	—	50-41	—	—
			400-500	—	41-31	—	—
			500-600	—	31-23	—	—
40	820-860	Water	200-300	—	52-48	—	—
			300-400	—	48-41	—	—
			400-500	—	41-33	—	—
			500-600	—	33-22	—	—
45	810-840	Water	200-300	—	54-50	—	—
50			300-400	—	50-41	—	—
			400-500	—	41-33	—	—
			500-600	—	33-24	—	—
			600-700	—	24-15	—	—
55	790-830	Water	430-450	—	42-33	—	—
60	785-820	Water,	400	321	—	—	—
		oil	550-620	241-207	—	—	—
65	785-815	Water,	300-400	—	52-45	—	—
		oil	400-500	—	45-37	—	—
			500-600	—	37-28	—	—
70	770-815	Water,	400	—	46-39	—	—
75		oil	610-670	260-230	—	—	—
80	770-800	Water,	375-400	—	49-40	—	—
85		oil	560-600	—	33-26	—	—

Table 70 continued

Grade	Heating temperature for hardening, normalising or full annealing, °C	Cooling medium	Tempering temperature, °C	Mechanical properties			
				Hardness		Tensile strength, kg/mm²	Elongation, %
				H_B	R_C		
Carbon Steels with Increased Manganese Content							
Steels Subject to Carburising							
15Г	880-920	Air	—	163	—	40	24
20Г	860-900	Air	—	197	—	43	22
25Г	850-890	Air	—	197	—	43	22
Steels Subject to Improving							
30Г	840-880	Water	200-220	—	54-52	—	—
			400-500	—	38-33	—	—
			600	196	—	70	15
40Г	820-860	Water	600	235	—	80	15
50Г	800-840	Water, oil	200	—	50	—	—
			550-600	295-246		85	8
60Г	790-820	Water, oil	200-220	—	60-56	—	—
			380-420	—	46-40	—	—
			500-600	302-269	—	85	9
65Г	790-815	Water, oil	150-200	—	60-58	—	—
			200-300	—	58-54	—	—
			300-400	—	54-47	—	—
			400-500	—	47-39	—	—
			500-600	—	39-30	—	—
70Г	780-800	Water, oil	200-220	—	62-58	—	—
			400-450	—	46-40	—	—

Notes. 1. After carburising, steels are hardened and annealed, according to usual schedules.
2. Mechanical properties of steels mentioned in the table refer to samples 60-80 mm in cross-section.

It should be borne in mind that steel castings, supplied to the heat-treatment shops, show a decarburised outer layer, the decarburisation being sometimes very high. Decarburisation in the casting bay is caused by scales present in the moulding sand. When decarburisation is slight, the defect can be corrected by annealing in a carburising medium. Castings are rejected if there is considerable decarburisation.

Table 71

Approximate Heat-treatment Schedule and Hardness Number of Steel Used for Plough Shares

Grade of steel	Heating temperature on hardening, normalising or full annealing, °C	Cooling medium	Tempering temperature, °C	Rockwell hardness number, R_C
Л53	800-820	Water	180-250	58-55
			250-300	55-52
			300-350	52-50
			350-400	50-44

Structural alloy steels are either carburised or improved, depending on their carbon content. Alloy steels have lower heat conductivity, and because of this fancy-shaped parts should be heated slower than those from carbon steel.

Table 72 presents methods for softening alloy steel. Some grades of complex alloy chrome-nickel steels cannot be annealed and are softened only by means of high tempering with prolonged holding time. The parts are cooled down to 500°C within the furnace, and then in the air.

It is a customary practice in some plants to substitute high tempering for annealing for other grades of steel as well, as tempering is simpler than annealing, and gives good results. When one is not certain of the correctness of the forging procedure used for treating blanks, the latter should be normalised prior to tempering. Approximate heat-treatment methods for alloy steels are given in Table 73. Hardened parts from alloy steels containing chromium or manganese should be cooled in oil or air, after tempering, to prevent temper brittleness.

Spring steel is generally not ground, and special measures are, therefore, to be taken to prevent heat-treatment decarburisation. This applies especially to silicon steels which decarburise much quicker than other grades of steel. When hot-rolled, as well as heat-treated, spring steel is to be softened, high tempering at 660-700°C with minimum holding should be used. A tentative method for heat-treatment of spring steel is presented in Table 74.

Table 72

Softening Procedures for Alloy Structural Steels

Grade	Operation	Heating temperature, °C	Cooling rate conditions
30X, 35X, 38X, 40X, 45X, 50X	Annealing	800-860	40-50°C per hr
15XФ, 20XФ, 40XФ, 50XФ	Annealing	840-860	50-60° per hr
33XC, 37XC, 40XC	Annealing	860-880	40-60° per hr
40XГ, 35XГ2	Annealing	840-850	40-60° per hr
20XГC	Isothermal annealing	880-900	Isothermal holding at 660-680° C
25XГC	Isothermal annealing	870-890	Ditto
30XГC	Isothermal annealing	860-880	Ditto
35XГC	Isothermal annealing	850-870	Ditto
27CГ, 35CГ	Annealing	860-880	50-60° per hr
25HA, 30HA	Normalising, tempering	840-860 620-640	Air Air
13H2A, 13H5A, 21H5A	Tempering	620-640	Holding,5hrs
25H3, 30H3A	Tempering	650-670	Ditto
15XMA	Annealing	880-900	30-40° per hr
20XM	Annealing	860-880	Ditto
30XM	Annealing	840-860	Ditto
35XM	Annealing	830-850	Ditto
38XЮA, 38XMЮA	Annealing	860-880	60-80° per hr
35XMФA	Annealing	860-880	40-50° per hr
20XH	Annealing	840-860	30-40° per hr
40XH, 45XH	Annealing	800-820	30-40° per hr
50XH	Annealing	790-810	Ditto
12XH2, 12XH3, 12X2H4	Normalising, tempering	880-900 600-640	— —
20XH3, 30XH3, 37XH3A	Normalising, tempering	640-650	Prolonged holding
20XH4ФA	Annealing	850-860	30-40° per hr
13XHBA, 18XHBA, 18XHMA, 25XHBA	Tempering	650-680	Prolonged holding
12X2H3MA, 12X2H4MA, 20XHM, 33XH3MA, 40XHMA	Tempering	650-670	Holding for 5-6 hrs
45XHBФA	Annealing	850-870	40-50° per hr
18XГT	Normalising, tempering	900-930 670	— —

Table 73

Approximate Heat-treatment Schedules and Mechanical Properties of Alloy Structural Steels

Grade	Heating temperature for hardening and normalising, °C	Cooling medium	Tempering temperature, °C	Mechanical properties			
				Hardness		Tensile strength, kg/mm²	Elongation, %
				H_B	R_C		
35Г2	810-850	Oil	200-300	—	56-48	—	—
			300-400	—	48-38	—	—
			400-500	—	38-34	—	—
			550-620	241-217	—	75-85	15-18
40Г2	810-840	Oil	550-600	300-230	—	—	—
45Г2	800-840	Oil	300-400	—	49-43	—	—
			400-500	—	43-33	—	—
			500-600	325-262	—	—	—
50Г2	790-820	Oil	500-600	321-269	—	—	Up to 9
15X	780-820	Oil or water	200	200	—	70	10-11
20X	780-820	Oil or water	200	220	—	80	10
15XP	780-810	Oil or water	200	—	—	75	12
30X	840-870	Oil	540-380	207-229	—	75-80	14-18
35X	840-865	Oil	180-200	—	45-50	—	—
			480-520	—	28-31	—	—
35XP	860	Oil	560	—	—	95	12
38XA	830-860	Oil	180-200	—	45-52	—	—
			500-560	285-375	—	130-100	—
			560-660	200-285	—	100-70	—

Table 73 continued

Grade	Heating temperature for hardening and normalising, °C	Cooling medium	Tempering temperature, °C	Mechanical properties			
				Hardness		Tensile strength, kg/mm²	Elongation, %
				H_B	R_C		
40Х	825-860	Oil	200-300	—	54-52	—	—
			300-400	—	52-45	—	—
			400-500	—	45-36	—	—
			500-600	—	36-30	—	—
			600-650	—	30-27	—	—
40ХР	860	Oil	540	—	—	100	12
45Х	820-850	Oil	200-220	—	55-52	—	—
			500-580	280-302	—	100	8
			580-650	230-280	—	85	9
45ХЦ	840	Oil	520	—	—	105	9
50Х	815-845	Oil	500	300	—	110	8
15ХГ 20ХГ	} 800-820	Oil	180-220	220	—	90	12
18ХГТ	800-820	Oil	180-220	—	—	100	9
20ХГР	870	Oil	200	—	—	100	9
30ХГТ	850	Oil	200	—	—	150	9
40ХГ	860-880	Oil	200-250	—	53-45	—	—
			550-600	272-302	—	100	10
40ХГР	850	Oil	550-600	—	—	100	11
35ХГ2	820-860	Oil	220-250	—	53-45	—	—
			620-660	235-269	—	88	12
33ХС	900-930	Oil	250-270	—	⩾42	160	8
			620-640	⩾269	—	95	15
37ХС	900-930	Oil	250-280	—	55-52	—	—

			600-650	241-269	—	90-95	12
40ХС	900-920	Oil	240-260	—	55-52	175	7
			600-650	241-269	—	90	12
27СГ	910-940	Water	230	—	42-50	150	8
			475	302-363	—	100	12
			550	—	—	80	12
35СГ	870-900	Water	600-620	248-285	—	85	13
36Г2С	880	Air	—	—	—	75	12
15ХМ, 20ХМ	880-900	Oil	550	$\geqslant$ 235	—	80	12
30ХМ	860-890	Oil	460	$\geqslant$ 320	—	110	—
			560	$\geqslant$ 270	—	95	11
			650	$\geqslant$ 260	—	90	—
35ХМ	860-870	Oil	200-220	—	53-45	140	10
			560	$\geqslant$ 270	—	95	11
			600-650	$\geqslant$ 260	—	90	16
35Х2МА	870	Oil	620	$\geqslant$ 300	—	105	8
38ХВА	850	Oil	550-620	—	—	100	12
15ХФ, 20ХФ	780-800	Water	180-200	$\geqslant$ 220	—	80	12
40ХФА	840-880	Oil	450-500	—	42-35	—	—
			620-680	$\geqslant$ 255	—	90	10
20ХН	840-870	Oil	200	—	—	100	10
			500	—	—	80	14
40ХН	800-840	Oil	180-200	—	45-50	150	8
			550-600	255-286	—	85-95	14-16
45ХН	800-830	Oil	250	—	58-50	—	—
			530	—	—	100	10
50ХН	790-820	Oil	500	—	—	110	8
12ХН2	780-800	Oil	180-200	$\geqslant$ 220	—	80	12
12ХН3А	780-800	Oil	180-200	$\geqslant$ 260	—	95	10
20ХН3А	820-840	Oil	500	$\geqslant$ 292	—	95	11
12Х2Н4А	780-800	Oil	180-200	$\geqslant$ 300	—	110	10
20Х2Н4А	860	Oil	180	—	—	130	9

Table 73 continued

Grade	Heating temperature for hardening and normalising, °C	Cooling medium	Tempering temperature, °C	Mechanical properties			
				Hardness		Tensile strength, kg/mm²	Elongation, %
				H_B	R_C		
30ХН3А	810-840	Oil	530	⩾292	—	100	9
37ХН3А	810-840	Oil	200-220	—	52-45	160	—
			525-575	321-387	—	110	10
45ХНМФА	860-880	Oil	390-420	—	49-44	150	7
			550-600	—	39-35	110	9
			600-650	—	35-25	90	10
36ХН1МФА	850-860	Oil	590	⩾ 331	—	115	17
30ХНВА	860	Oil	530	—	—	100	10
38ХНВА	870	Oil	580	—	—	110	12
40ХНВА	830-850	Oil	200-220	—	53-48	165	9
40ХНМА			610	⩾302	—	110	12
30Х2НВА	860	Oil	580	—	—	100-120	10-12
38ХН3ВФА	850	Oil	550-620	—	—	120	12
20ХН4ФА	850	Oil	630	—	—	90	12
38ХН3МФА	850	Oil	550-620	—	—	120	12
15ХГНТ	820-850	Oil	180	—	—	95	11
15Х2ГН2Т	850	Oil	180	—	—	100	11
15Х2ГН2ТРА	770-810	Oil	170	—	—	105	12
18ХГН	860	Oil	180	—	—	100	12
25Х2ГНТА	840-860	Oil	180	—	—	150	10
30ХГНА	880	Oil	500	—	—	110	10
38ХГН	850	Oil	570	—	—	90	12
30Х2ГН2	870	Oil	200	—	—	150	10
18ХСНРА	860	Oil	530	—	—	100	10

20ХГСА	870-900	Oil	200	—	—	145	10
			500-520	228	—	80	10
25ХГСА	890-910	Oil	200	400	—	150	5
			500	310	—	110	6
30ХГСА	890-910	Oil	225-250	—	50-46	—	—
			480-520	337-390	—	120-140	—
			540-580	285-315	—	100-110	—
			600-640	235-265	—	80-90	—
			640-680	211-235	—	70-80	—
35ХГСА	860-880	Oil	200-250	—	53-46	—	—
			640-660	$\geqslant 235$	—	76	16
30ХГНСА	890-910	Oil	200-300	—	50-46	160-180	—
38ХЮ	930	Oil	650	$\geqslant 260$	—	95	10
38ХМЮА	930-950	Oil	600-670	$\geqslant 286$	—	100	15
38ХВФЮ	930	Oil	640	—	—	100	10
13Н2ХА	860	Oil	180	—	—	60	15
15ХГНР	830-850	Oil	180-200	—	38-26	110	10
20ХГНР	810-830	Oil	180-200	—	44-33	130	10

Table 73 continued

Grade	Heating temperature for hardening and normalising, °C	Cooling medium	Tempering temperature, °C	Mechanical properties			
				Hardness		Tensile strength, kg/mm²	Elongation, %
				H_B	R_C		
14ХГ2НР	820-840	Oil	180-200	—	44-33	110	10
14ХГ2СР	830-850	Oil	180-200	—	44-33	110	10
15ХНГ2ВА	880-920	Oil	200	—	—	—	—
	810-830	Oil	180-200	—	47-35	115-120	12
15Х2Г2СВА	880-920	Oil	200	—	—	—	—
	830-850	Oil	180-200	—	47-35	115-120	12
35Х2ГСВА	880-890	Oil	200	555-477	—	200	8
			460	477-401	—	150	9
			600	341-286	—	105	12
			650	286-241	—	—	—

Note. The mechanical properties of carburised steels refer to the core, their hardness number being within 56-62 R_C.

Table 74

Approximate Heat-treatment Schedules and Hardness Numbers of Spring Steels

Grade	Heating temperatures for hardening and normalising, °C	Cooling medium	Tempering temperature, °C	Hardness number, R_C	Remarks
55	790-830	Water	430-450	33-42	
65	785-815	Oil	300 400 500 600	52 45 37 28	
70	780-815	Oil	380	—	
75	780-815	Oil	380	39-46	
85	770-800	Oil	375-400	40-49	
65Г	790-815	Oil	380-430	42-47	
55ГС	790-820	Oil	390-420 580	39-46 25-31	
55C2	850-890	Oil	480-500	39-43	
60C2	840-870	Oil	400-510	43-50	
60C2A	840-870	Oil	400-425	40-49	For wire up to 13 mm in dia
	820-840	Water	400-425	40-49	For wire above 13 mm in dia
63C2A	860	Oil	400-510		
70C3A	850	Oil	400-510		
50XГ, 50XГA	840-870	Oil	450-480	41-43	
60C2XA	860	Oil	420		
60C2XФA	840	Oil	450		
65C2BA	840	Oil	450		
60C2H2A	840	Oil	—		
55CГ	880	Oil	400-510		
60CГA	860	Oil	400-510		
50XФ	840-870	Oil	475		
50XФA			370-420	42-50	
50XГФA	850-880	Oil	550	39-43	
58CH2A	875-900	Oil	400-425	46-49	

Table 75

Spring Steel Not Subject to Hardening

Description	Mechanical properties
Spring steel wire, heat-treated, from 1.2 to 5.5 mm thick	Tensile strength from 180 to 130 kg/mm^2 *
Carbon spring steel wire, from 0.14 to 8 mm thick:	Tensile strength:
grade I	from 310 to 150 kg/mm^2
grade II	from 270 to 140 kg/mm^2
grade III	from 225 to 110 kg/mm^2
Steel spring band, heat-treated, from 0.08 to 1 mm thick:	
1П (first grade of strength)	H_V 375-485
2П (second grade of strength)	H_V 486-600
3П (third grade of strength)	H_V over 600

* Depending on wire thickness.

Table 76

Approximate Heat-treatment Schedule for Ball-bearing Steel

Grade	Annealing		Hardening		Tempering	
	Heating temperature, °C	Hardness number, H_B	Heating temperature, °C	Minimum hardness number, R_C	Heating temperature, °C	Hardness number, R_C
ШХ6	780-800	170-207	800-825	62	150-170	60-62
					200-220	56-58
ШХ9	780-800	170-207	825-840	62	150-180	60-62
					200-260	60-55
					260-320	55-50
ШХ10	820-830		840-850		400	50-45
ШХ15	780-800	170-207	835-855	62	150-200	64-61
					200-300	61-56
					300-400	56-49
					400-500	49-41
					500-600	41-28
ШХ15СГ	780-800	170-207	815-835	62	170-200	61-65

Note. Oil serves as a cooling medium for ball-bearing steels, while kerosene is used for plain-shaped articles requiring high hardness.

Ball-bearing steel. Ball-bearing steel is heat-treated according to procedures recommended in Table 76. On annealing, the work, following heat soaking, is cooled to 500-550°C at a rate of 30°C per hour for grade ШХ15СГ steel and below 40°C per hour for grades ШХ6, ШХ9, ШХ15, after which the blanks are cooled in the furnace with the power switched off. Isothermal annealing is also being applied, according to the following sequence of operations: heating to 800°C, holding till heat soaking is complete, cooling down to 700-720°C, holding for 3-4 hrs, cooling in the furnace down to 400-450°C, followed by cooling in the air.

If no correction of structure is required and the annealing aims only at softening, high tempering at 680-700°C for 3-4 hrs may then be successfully applied.

When hardening large parts from the ШХ15 steel, cooling should be effected in kerosene down to room temperature in order to ensure hardness above $R_C = 60$. In this case all sharp changes of section and sharp grooves are to be covered with a mixture composed of asbestos and clay, so as to prevent cracking.

Electric steels and alloys are annealed to improve their magnetic properties. Best results are obtained with vacuum annealing (Fig. 21). If no vacuum installation is available, the work is to be annealed in containers with solid protective media—white mountain sand, asbestos powder, aluminium oxide, etc. The protective mixture should be calcined prior to use in order to eliminate all moisture. Fig. 22 shows the packing of the containers. When a thin oxide skin is desirable, the parts are annealed in the same packets but with no protective mixture. Hydrogen annealing did not find wide application, because of explosion hazards and possible surface decarburisation.

Annealed parts are not to be distorted, dropped or hammered, as this lowers their magnetic properties.

When cutting or stamping of permalloy is difficult, because of strain-hardening, the alloy should be annealed at 600-650°C (holding for 1-2 hrs and cooling at a rate of 100-200°C per hour).

Annealing schedules for electric steels and permalloys are given in Table 77.

Magnetic steel is heat-treated according to schedules given in Table 78 in order to ensure the requisite magnetic properties. Holding time is counted off as soon as steel is heated to the required temperature.

A special post-rolling softening treatment intended to obtain a structure, ensuring best magnetic properties after hardening, is practised in some metallurgical plants. This must be taken into account by the users who should not re-anneal the stock as this will change the steel structure and entail (after hardening from normal temperatures) worsening of magnetic properties of steel.

When bending magnets, the work should be heated below 700°C for grades ЕХ5К5 and Е7В6, 750°C for grades ЕХ and ЕХ3 and 800°C for grade ЕХ9К15М, in order not to impair magnetic properties of steel.

Heat-treatment schedules for cast magnets are presented in Table 79.

Stainless steel, on annealing, is to be cooled to 250-300°C within the furnace. Holding time on heating should be cut to a minimum so as

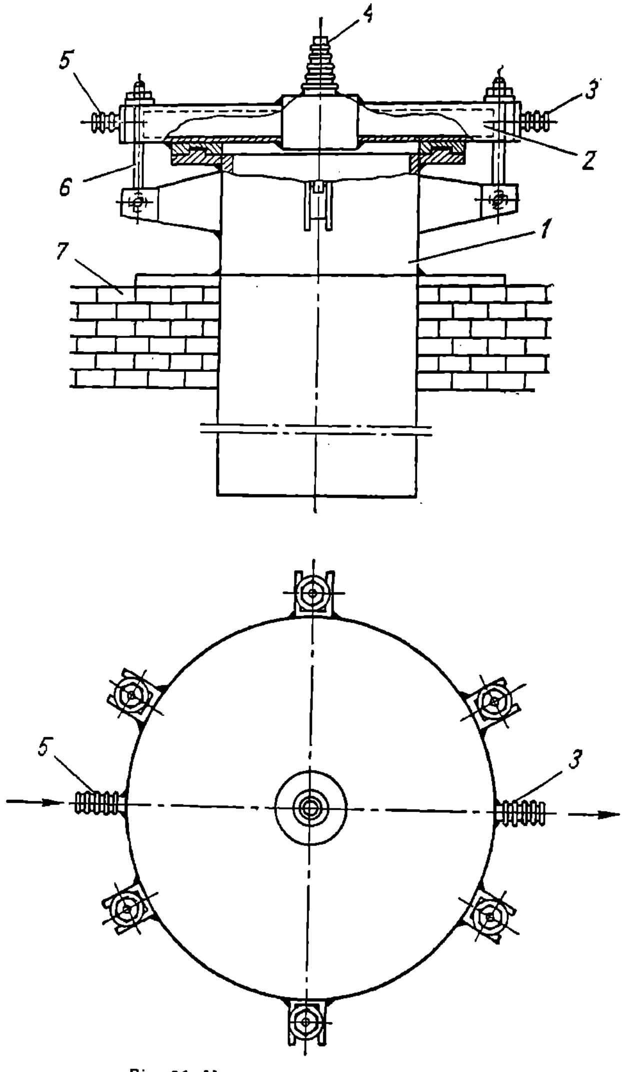


Fig. 21. Vacuum annealing installation:
1 — muffle; 2 — water-cooled muffle lid; 3 — water outlet nipple; 4 — air exhaust nipple; 5 — water inlet nipple; 6 — coupling bolts; 7 — furnace lining

to prevent grain growth. Depending on steel grade, the hardening procedure aims at toughening or increasing ductility and chemical resistance (tables 80 and 81).

It should be noted that hardening always increases the corrosion resistance of steel. Chromium stainless steels are characterised by temper brittleness, and for this reason, they are to be cooled in water or oil after tempering.

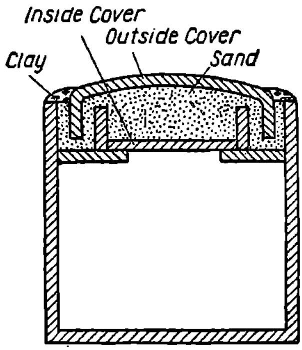


Fig. 22. Containers for oxidation-free annealing

Manganese wear-resistant grade Г13 steel is given a prolonged tempering at 600-650°C in order to improve its machinability.

Grade Г13 acquires high wear resistance after hardening in water at 1050-1100°C. Holding time on heating is 2-3 hours.

Given below are approximate mechanical properties obtained after hardening:

Tensile strength σ_b=70-100 kg/mm^2,
elongation δ=25-45%,
specific resilience a_k=20-25kgm/cm^2,
Brinell hardness number H_B= 197-212.

After tempering at 400-450°C, the hardness of the Г13 steel may reach as high as H_B=400. This steel has a tendency to decarburise. Because of its very low heat conductivity, the steel should be heated slowly up to 600°C, to prevent cracking.

Carbon tool steel. The work is cooled from annealing temperature at a rate of 20-50°C per hour down to 550°C, then the cooling is continued in the air.

This steel acquires best machinability and minimum hardness after sub-critical annealing (spheroidising).

Sub-critical annealing (spheroidising) is realised by heating and holding the said steel at 730-750°C, then cooling it down to 500-550°C at a rate of 20-30° C per hour, and, finally, cooling it in the air.

Carbon tool steel is "high" tempered at 680-700°C with prolonged holding and subsequent air-cooling, to lower hardness and remove stresses.

Tools are cooled, following hardening, chiefly in water and, subsequently, in oil. Small-sized tools are hardened in oil or kerosene (Table 82).

Alloy tool steel. The work is first cooled from annealing temperature at a rate of 30-40°C per hour down to 550°C, and then in the air. In case of isothermal annealing, the steel can be air-cooled from isothermal holding temperature. When only decrease in hardness and stress removal are necessary, the work is high tempered at 650-680°C and then air-cooled.

Because of low heat conductivity, fancy-shaped tools should be heated slowly.

Table 77

Annealing Schedules for Electric Steels and Permalloys

Grade of steel or alloy	Purpose of annealing	Heating temperature, °C	Holding time, hrs	Cooling conditions	Equipment and materials required
Steels: Э31, Э11, Э42, Э45, Э46, Э47, Э48	Improvement of magnetic properties and formation of oxide skin	830-870	3	50° C per hour. Parts are discharged from the container at 150° C	Furnace and heat-resisting steel box
	Improvement of magnetic properties without formation of oxide skin (bright annealing)	860-900	3-4	Ditto	Furnace. Heat-resisting steel box. Protective atmosphere
	Considerable improvement of magnetic properties due to coarse-grained structure and removal of detrimental impurities from surface layer (no oxide skin after annealing)	1000-1050	10-20	60-70° C per hour	Furnace. Vacuum or hydrogen annealing installation

Э310	Considerable increase in magnetic properties (no oxide skin after annealing)	780-820	3-4	Cooling in the furnace. Discharge at 100° C	Furnace. Vacuum or hydrogen annealing installation
Permalloys: iron-nickel alloys of various grades	Improvement of magnetic properties and formation of oxide skin	1170-1230	10	Slow cooling within the furnace to 650° C, then in an air jet	Furnace
	Improvement of magnetic properties. No oxide skin after annealing	1000-1100	8-15	Slow cooling within the furnace to 200° C, under vacuum	Furnace. Vacuum or hydrogen annealing installation
Э, ЭА, ЭАА	Improvement of magnetic properties	850-930	3-4	100-150° C per hour to room temperature	Furnace. Vacuum annealing installation or container from heat-resistant steel, and protective mixture

Note. When no heat-resistant steel is available, the container should be made of plain structural steel. When annealing with the formation of oxide skin is contemplated, the parts are packed into containers without sand, with the packing being loose so that the annealing metal should occupy 20-25% of the volume of the container.

Table 78

Heat-treatment Schedules for Magnetic Steels

Grade of steel	Normalising		Tempering		Hardening			
	Heating temperature, °C	Holding time, min	Heating temperature, °C	Holding time, min	Preheating temperature, °C	Final heating temperature, °C	Holding time, min	Cooling medium
EX	1000	5	—	—	500-600	850	10-15	Oil
EX3	1050	5	—	—	500-600	850	10-15	Ditto
E7B6	1200-1250	—	—	—	500-600	820-860	5	Ditto
EX5K5	1150-1200	—	—	—	500-650	950	10	Ditto
EX9K15M	1200-1240	5	700	30	—	1030-1050	10	Ditto

Note. The magnets are aged for 5-8 hours in boiling water to stabilise their structure and magnetic properties.

Table 79

Heat-treatment Schedules Recommended for Cast Permanent Magnets

Grade of alloy		Hardening or normalising temperature, °C	Cooling medium	Tempering temperature, °C	Comments
New	Old				
АН1	АЛНИ1	1200	Boiling water	—	Normalising is applied to thin magnets
АН2	АЛНИ2	1200	Ditto	550	
АН3	АЛНИ3	1100	Air	—	
АНК	АЛНИСи	1200	Ditto	—	Slow cooling for thick magnets
АНКо1	АЛНИКо12	1250	Ditto	—	
АНКо2	АЛНИКо15	1300	Ditto	—	
АНКо3	АЛНИКо18	1300	Ditto	600 *	Cooling from 1300° C is carried out in a magnetic field of not less than 1,500 oersteds, cooling rate not exceeding 5° C per second, down to 500° C*
АНКо4	АЛНИКо24 (МАГНИКО)	1300	Ditto	600	

* The cooling rate is regulated, depending on volume and shape of the part, by wrapping it, prior to cooling, in asbestos paper.

Steel with high silicon content shows great tendency to decarburisation and, due to this, tools from grade 9XC and other similar steels, which are not subjected to grinding after heat-treatment, should be carefully protected against burning-out of carbon.

It is not recommended to cool the work within the furnace after tempering (tables 83 and 84).

Table 80

Annealing Schedules Recommended for Corrosion-resistant and Non-scaling Steels

Grade of steel	Annealing or tempering temperature, °C		Mechanical properties	
			Tensile strength, kg/mm², minimum	Elongation, %, minimum
0X13, 1X13	Ann.	860-880	40	21
	Temp.	740-800		
2X13	Ann.	860-880	50	20
	Temp.	740-800		
3X13	Ann.	860-880	50	15
	Temp.	740-800		
4X13	Ann.	860-880	56	15
	Temp.	740-800		
X17, 0X17T (ЭИ465)	Temp.	740-780	50	18
X25T, X28 (ЭИ439, ЭИ349)	Temp.	740-780	54	17
X15H9Ю (ЭИ904)	Norm.	1040-1080	<110	20
X5	Norm.	850-870	40	24
4X9C2 (CX8)	Norm.	850-870	75	15
X6CЮ (ЭИ428)	Temp.	750-800	45	20
1X12CЮ (ЭИ404)	Norm.	800-850	50	15
X18CЮ (ЭИ484)	Norm.	800-850	50	20

Notes. 1. Abbreviations used: temp. — tempering; ann. — annealing; norm. — normalising.

2. Either annealing or tempering is applied to steel grades 1X13 through 4X13.

Table 81

Hardening Schedules Recommended for Corrosion-resistant and Non-scaling Steels

Grade	Hardening		Tempering	Mechanical properties		
	Heating temperature, °C	Cooling medium	Heating temperature, °C	Tensile strength, kg/mm²	Elongation, %	Hardness number, R_C
0X13	1000-1050	Oil	700-800	60	20	—
1X13	1000-1050	Oil or air	700-790	60	20	—
2X13	1000-1050	Ditto	660-770	66	16	—
3X13	1000-1050	Ditto	200-300	—	—	51-50
			300-500	—	—	50-48
			500-550	—	—	48-45
			550-600	—	—	45-30
			600-700	—	—	30-21
4X13	1000-1050	Ditto	200-300	—	—	52-51
			300-500	—	—	51-50
			500-550	—	—	50-46
			550-600	—	—	46-31
			600-700	—	—	31-20
9X18	1000-1050	Ditto	100-200	—	—	59-54
			200-500	—	—	54-52
			500-600	—	—	52-42
1X17H2 (ЭИ268)	970-1040	Ditto	275-350	110	10	—
4X10C2M (ЭИ107)	1010-1050	Oil or air	720-780	95	10	—
2X13H4Г9 (ЭИ100)	1070-1130	Air	—	65	35	—
X15H9Ю (ЭИ904)	925-975	Air, then from —30 to —70° C	375-500	120	10	—
X17H7Ю (ЭИ973)	1030-1070	Air	1) 740-760 2) 550-600	85	10	—
0X20H14C2 (ЭИ732)	1000-1150	Air or water	—	55	40	—

X20H14C2 (ЭИ211)	1000-1150	Air or water	—	60	35	—
0X21H5T (ЭИ53)	950-1050	Air	—	60	20	—
1X21H5T (ЭИ811)	950-1050	Ditto	—	60	20	—
0X21H6M2T (ЭИ54)	950-1050	Ditto	—	65	20	—
X23H13 (ЭИ319)	1100-1150	Oil, water or air	—	50	35	—
X14Г14H3T (ЭИ711)	1000-1080	Ditto	—	65	35	—
X17Г9AH4 (ЭИ878)	1050-1100	Ditto	—	70	40	—
X17H13M2T (ЭИ448)	1050-1100	Ditto	—	52	40	—
0X17H16M3T (ЭИ590)	1050-1100	Ditto	—	50	35	—
00X18H10 (ЭИ842)	1050-1100	Ditto	—	45	40	—
0X18H10	1050-1100	Ditto	—	48	40	—
X18H9	1050-1100	Ditto	—	50	45	—
2X18H9	1050-1100	Ditto	—	58	40	—
X18H9T	1050-1100	Ditto	—	55	40	—
0X18H10T (ЭИ914)	1050-1100	Ditto	—	50	40	—
X18H10T	1050-1100	Ditto	—	52	40	—
X18H12T	1050-1100	Ditto	—	55	40	—
0X18H12Б (ЭИ402)	1050-1100	Ditto	—	50	40	—
4X18H25C2	1100-1150	Ditto	—	65	25	—
X23H18 (ЭИ417)	1100-1150	Ditto	—	50	35	—
0X23H28M2T (ЭИ628)	1100-1150	Ditto	According to specifications			
0X23H28M3Д3T (ЭИ943)	1100-1150	Ditto				
X25H16Г7AP (ЭИ835)	1100-1150	Ditto	—	70	40	—
X25H20C2 (ЭИ283)	1100-1150	Ditto	—	60	35	—
1X25H25TP (ЭИ813)	1100-1150	Ditto	—	50	35	—
X28AH * (ЭИ657)	850-950	Water or air	—	54	17	—
X14Г14H *	1050-1070	Water	—	70	35	—
X17H13M3T * (ЭИ432)	1050-1080	Water or air	—	54	35	—
X17AГ14 * (ЭИ213)	1050-1070	Water	—	70	35	—
0X18H11 * (ЭИ684)	1050-1080	Water or air	—	52	35	—

* Data apply only to sheet steel; for other grades of steel, the heat-treatment schedules and mechanical properties listed hold good for specimens made from heat-treated blanks of quality steel.

Table 82

Approximate Heat-treatment Schedules and Hardness Numbers of Carbon Tool Steels

Grade	Annealing		Hardening			Tempering	
	Heating temperature, °C	Hardness number, H_B, maximum	Heating temperature, °C	Cooling medium	Hardness number, R_C	Heating temperature, °C	Hardness number, R_C
У7, У7А	740-760	187	800-830	Water, then oil	61-63	160-200	63-60
						200-300	60-54
						300-400	54-43
						400-500	43-35
						500-600	35-27
У8, У8А, У8Г, У8ГА	740-760	187	790-820	Ditto	62-64	160-200	64-60
						200-300	60-55
						300-400	55-45
						400-500	45-35
						500-600	35-27
У9, У9А	740-760	192	780-810	Ditto	62-65	160-200	64-62
						200-300	62-56
						300-400	56-46
						400-500	46-37
						500-600	37-28
У10, У10А	750-770	197	770-800	Ditto	62-65	160-200	64-62
						200-300	62-56
						300-400	56-47
						400-500	47-38
У11, У12, У11А, У12А	750-770	207	760-790	Ditto	62-66	160-200	65-62
						200-300	62-57
						300-400	57-49
						400-500	49-38
У13, У13А	750-770	217	760-790	Ditto	62-66	160-200	65-62

High-speed steel. High-speed steel is annealed according to normal or isothermal procedures. In normal annealing the work is cooled at a rate of 30-40°C per hour. Isothermal annealing is conducted as follows: heating to 830-850°C, holding for 1.5-2 hours, rapid cooling to 720-750°C, holding for 3-5 hours, followed by air-cooling (Table 84). The steel is also high tempered at 720-750°C with subsequent air-cooling, to lower its hardness.

High-speed steel possesses low heat conductivity and, because of this, the tools should be preheated to 800-850°C on hardening. Preheating may be omitted for regular-shaped and small-sized parts.

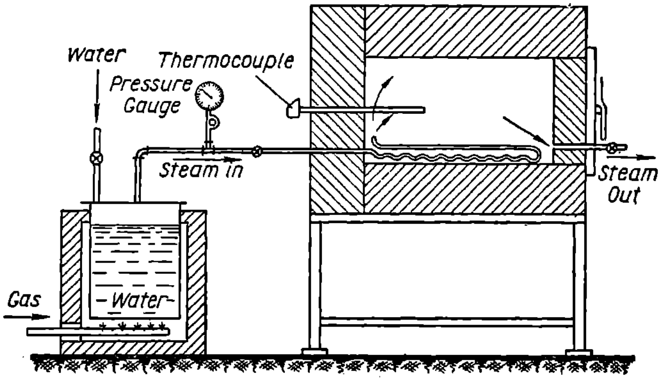


Fig. 23. Schematic view of a steam-treatment installation

The work is preheated either in special furnaces of by twofold or threefold dippings for 2-4 sec in the same bath wherein the final heating is carried out.

The work is hardened in oil, molten salt or air. Air-cooling results in low durability and can be recommended only for long thin tools with a view to diminish distortion (Table 85). Hardening in molten salts is effected at 250-500°C with subsequent air-cooling Tempering can be either single-stage with holding for 2-3 hours, or two-stage with 1-hour holding period for each stage.

Steam heat-treatment (tempering) of high-speed steel, recommended currently, consists of the following steps: 1) fully finished (including sharpening) tools are charged into an air-tight furnace, heated to 350-370°C, after which steam is admitted into the furnace and the tools are held at the said temperature for 30 min; 2) the tools are then heated to 540-580°C (steam being introduced continuously) and held for 20-30 min at the above temperature. The work is first cooled in air down to 50-70°C, and then heated in oil to 40-50°C.

This treatment results in the formation of oxide film Fe_3O_4, dark blue in colour, which imparts appreciable corrosion resistance to the tools, as well as improves to some extent their service behaviour.

Table 83

Approximate Heat-treatment Schedules and Hardness Numbers of Alloy Tool Steels

Grade	Annealing		Hardening			Tempering	
	Heating temperature, °C	Hardness number, H_B	Heating temperature, °C	Cooling medium	Hardness number, R_C	Heating temperature, °C	Hardness number, R_C
7X3, 8X3	800-820	229-187	820-860	Oil	61-63	150-200 200-300 300-400 400-500 500-600	62-60 60-58 58-55 55-50 50-39
9X	780-800	217-179	820-850	Ditto	64-62	150-250	—
X	780-800	229-187	835-855	Ditto	65-62	150-200 200-300 300-400 400-500 500-550	64-61 61-55 55-49 49-41 41-35
X09	780-800	229-179	825-850	Ditto	65-62	150-170 170-250 250-320	62-60 60-55 55-50
X05	780-800	241-187	780-800 800-825	Water Oil	65-62 65-63	200-300 300-400 400-500	62-55 55-50 50-41

X12	850-870	269-217	950-1000	Oil or air jet	64-62	200-300 300-400 400-500 500-600 600-700	62-59 59-58 58-56 56-50 50-43
Φ	760-780	217-179	780-820 820-840	Water Oil	64-62 62-60	180-200	64-60
B1	780-800	229-187	780-800 810-830	Water Oil	63-61 62-60	150-200 200-300 300-350	60-58 58-52 52-48
XΓ	780-800	241-197	800-840	Oil	66-62	150-200 200-300 300-400 400-500 500-600	64-61 61-58 58-52 52-44 44-35
4XC	820-840	207-170	880-900	Ditto	53-56	200-250 250-350 350-450 450-550 550-650	52 52-50 50-46 46-38 38-31
6XC	820-840	229-187	840-860	Ditto	62 min	150-200 200-300 300-400 400-500 500-600	62-60 60-55 55-52 52-42 42-36

Table 83 continued

Grade	Annealing		Hardening			Tempering	
	Heating temperature, °C	Hardness number, H_B	Heating temperature, °C	Cooling medium	Hardness number, R_C	Heating temperature, °C	Hardness number, R_C
9XC	790-810	241-197	850-880	Oil	65-61	150-200 200-300 300-400 400-500 500-600	64-63 63-59 59-54 54-47 47-39
XГC	780-810	255-207	820-840	Ditto	62 min	—	—
8XФ	800-820	207-170	800-850	Water	64 min	200-220	64-62
85XФ	770-780	207-170	840-860	Oil	62-63	200-400	60-50
65X	—	—	820-840	Ditto	61-63	300-325	51-56
4XB2C	800-820	217-179	860-900	Ditto	56-53	200-300 300-400 400-500 500-600	53-51 51-49 49-42 42-33
5XB2C	800-820	255-207	860-900	Ditto	56-54	150-200 200-300 300-400 400-450	54-52 52-48 48-42 42-36

6ХВ2С	780-800	285-229	860-900	Oil	60-54	200-300 300-400 400-500 500-600	58-53 53-49 49-43 43-35
5ХВГ	760-780	217-179	830-860	Ditto	58-56	200-300 300-400 400-500 500-600	55-52 52-47 47-43 43-35
9ХВГ	780-800	241-197	800-830	Ditto	64-62	170-230 230-275	62-60 60-56
ХВГ	780-800	255-207	820-850	Ditto	65-63	150-200 200-300 300-400 400-500 500-600	63-62 62-58 58-52 52-46 46-37
3Х2В8	860-880	255-207	1075-1125	Oil or air jet	52-49	150-200 200-300 300-400 400-500 500-575 575-700	52-49 49-48 48-46 46-45 45-48 48-40
4Х8В2	820-840	255-207	1025-1075	Ditto	54-51	500-600	48-40
ХВ5	780-800	285-229	800-820 820-860	Water Oil	67-64	200-300 300-400 400-500 500-600	64-60 60-53 53-48 48-40

Table 83 continued

Grade	Annealing		Hardening			Tempering	
	Heating temperature, °C	Hardness number, H_B	Heating temperature, °C	Cooling medium	Hardness number, R_C	Heating temperature, °C	Hardness number, R_C
X12M	850-870	255-207	1000-1050	Oil or air jet	65-62	150-200 200-300 300-400 400-500 500-600	63-62 62-59 59-57 57-55 55-47
			1115-1130	Ditto	48-45	500-520 repeated 3-5 times	59-62
5XHM	790-820	241-197	820-860	Oil	60-58	150-200 200-300 300-400 400-500 500-600	60-58 58-53 53-48 48-43 43-35
5XГM	790-810	241-197	820-850	Ditto	58-53	200-300 300-400 400-500 500-600	57-52 52-46 46-40 40-34

5XHT	790-820	235-192	830-860 with air-blast cooling to 720-760	Oil	58-53	400-500 500-600	47-40 40-33
X12Φ1	850-870	255-207	1040-1080	Oil or air jet	64-62	100-200 200-400	63-59 59-57
			1115-1150	Ditto		520-550 repeated 3-5 times	62-61
5XHC	800-820	255-207	850-870	Oil	59-55	400-500 500-600	46-40 40-34
5XHCB	810-830	255-207	850-870	Ditto	59-55	500-600	41-35
5XHB	790-820	241-197	840-860	Ditto	59-55	400-500 500-600	47-41 41-34
45XHT *	850-870	241 max	870-890	Ditto	59-55	440-460	46-41
45XHB *	850-870	241 max	870-890	Ditto	—	440-460	46-41

* Data refer to cast die cubes.

To ensure adequate finish, the work is treated with superheated steam; to do this, steam is superheated in a tube, situated inside the furnace, prior to being admitted to the muffle.

Any type of boiler, of sufficient capacity, heated by any fuel can serve as a source of steam. Diagram of a steam-treatment installation is presented in Fig. 23.

Recommended steel grades, tempering temperatures, and tool hardness numbers are presented in Table 86.

Table 84

Technological Schedules for Isothermal Annealing of Tool Steels

Grade	Initial heating		Isothermal holding		Hardness number, H_B
	Temperature, °C	Holding, hrs	Temperature, °C	Holding, hrs	
Х12	850-870	1.5-2.5	720-750	3-5	288-255
Х12М					217-255
Х, ШХ15, ШХ12	770-790	1.5-2.5	670-720	3-4	197-228
9ХС	780-810	1.5-2.5	680-720	3-4	207-241
ХГ	790-810	1.5-2.5	700-730	3-4	217-255
ХВГ	770-790	1.5-2.5	700-730	3-4	197-228
В1	750-770	1.5-2.5	670-700	3-4	187-228
3Х2В8	790-820	1.5-2.5	710-740	3-4	187-228
У11, У11А, У12, У12А	750-770	1.5-2.5	640-680	1-2	187-207
У10, У10А	750-770	1.5-2.5	620-660	1-2	179-197
У9, У9А	750-770	1.5-2.5	600-650	1-2	170-187
Р18	830-850	1.5-2.5	720-750	3-5	217-255
Р9					228-255
Р18К5, Р18К10	850-870	1-2	730-750	4-6	217-269

In Table 86 hardening temperatures and cooling media are not indicated. These data are given in tables 70, 72, 81, 82, 84. Hardness numbers of tools are given in accordance with the Soviet Standards, while those of machine parts—according to specialised handbooks.

Table 85

Approximate Heat-treatment Schedules for High-speed Steels

Grade	Annealing		Hardening			Tempering	
	Heating temperature, °C	Hardness number, H_B	Heating temperature, °C	Cooling medium	Hardness number, R_C	Heating temperature, °C	Hardness number, R_C
P9	830-860	207-255	$\frac{1230-1250}{1210-1240}$	Oil, molten salt at 450-550°C, air. For very intricate tools, having a tendency to crack—oil at 200°C with subsequent cooling down in oil	61-63	540-580	⩾62
P9Ф5	840-860	293	$\frac{1240-1260}{1220-1250}$		62-64	575-585	64-66
P10K5Ф5	840-860	293	$\frac{1230-1250}{1210-1240}$		62-64	575-585	65-67
P9K10	840-860	293	$\frac{1230-1250}{1210-1240}$		62-64	575-585	65-66
P14Ф4	840-860	293	$\frac{1250-1270}{1230-1260}$		62-64	575-585	65-66
P18	830-860	207-255	$\frac{1280-1300}{1250-1290}$		62-64	540-580	⩾62
P18Ф2	840-860	293	$\frac{1280-1300}{1260-1290}$		63-65	575-585	65-66
P18K5Ф2	840-860	293	$\frac{1280-1300}{1260-1290}$		63-65	575-585	64-66
P18K5, P18K10	See Table 84		1280-1320		60-64	550-570	62-65

Notes. 1. On annealing the cooling rate is 20-25°C per hr.
2. The hardening temperatures given as numerators refer to cutters and those given as denominators—to fancy-shaped tools; the lower temperatures apply to thin tools, whereas the upper range—to the larger tools.
3. Tempering procedures are repeated from 2 to 4 times for tools made of steel grades P9Ф5, P10K5Ф5 and P14Ф4, and 2-3 times for the remaining grades, the holding time lasting 1 hour in each case.

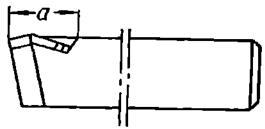
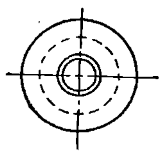
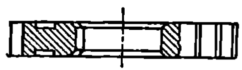
2. PRACTICAL HINTS ON HEAT-TREATMENT OF ARTICLES

Cutting tools. Long, slender tools should be suspended on heating. When using chamber furnaces, the tools mentioned above should be placed on special supports (Fig. 24) which ensure rectilinearity of the tool on heating. Welded tools should be heated below the welding seam. When heating large tools in electrode-salt baths, care should be taken to prevent contact between the tools and the electrodes so as to avoid sticking.

Upon air-cooling, tools should not be placed on the floor or plates, but suspended or driven into sand boxes by their shanks.

Table 86

Tools: Steel Grades Recommended for the Manufacture of, Approximate Tempering Temperatures and Hardness Numbers

Type of too	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
		Cutting Tools		
 Tool with a welded bit	P18, P9	540-580	61-65	
 Circular tool	P18, P9, ЭИ347 У11А, У12А, ХВГ 9ХС	540-580 150-180 180-200	62-65 61-64 61-64	
 Grooving cutter	P18, P9, ЭИ347 9ХВГ, Х, У10А, У11А 9ХС	540-580 150-180 180-200	62-65 61-64 61-64	

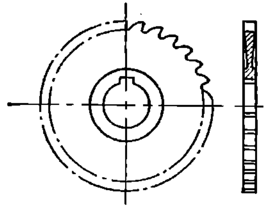
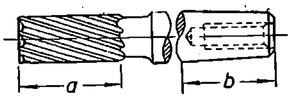
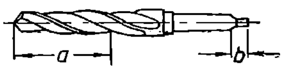
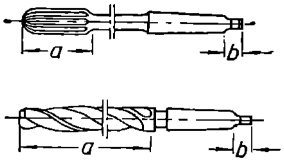
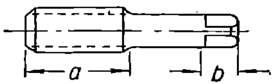
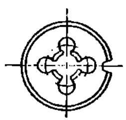
 Slitting cutter	P18, P9, ЭИ347 У12А, Х12М 9ХС	540-580 180-240 } 200-250 }	Below 1 mm 60-63 Above 1 mm 61-64 Below 1 mm 58-62 Above 1 mm 60-64	
 End milling cutter	P18, P9, ЭИ347 У10А, У11А, Х, ХГ 9ХС	540-580 150-180 180-200	62-65 61-64 61-64	30-45 30-45 30-45
 Twist drill	P18, P9, ЭИ347 У10А, У11А, У12А ХВГ, ШХ12, Х, 9ХС	540-580 150-220 180-240	Below 5 mm 60-64 Above 5 mm 62-65 Below 10 mm 59-63 Above 10 mm 61-64	30-45 30-45

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section a	Shank b
 Reamer. Counterbore	Р9, ЭИ347 У10А, У11А, У12А, Х, ХВГ 9ХС	540-580 150-220 180-240	Below 6 mm 61-63 Above 6 mm 62-65 Below 8 mm 59-63 Above 8 mm 60-64	30-45 30-45
 Tap	Р18, Р9, ЭИ347 У10А-У12А, Ф Х, ХГ, ХВГ, 9ХВГ, ШХ12 9ХС	540-580 160-220 200-270	Below 6 mm 61-63 Above 6 mm 62-65 59-62	Below 4 mm 35-62 From 4 to 8 mm 35-55 Above 8 mm 30-45
 Round threading die	У10А-У12А, Х, ХГ, 9ХВГ, Ф 9ХС	180-220 220-280	58-62	

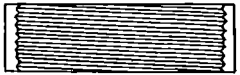
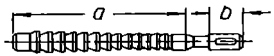
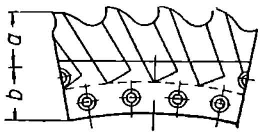
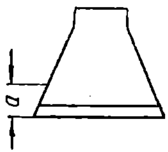
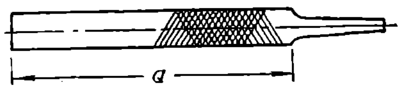
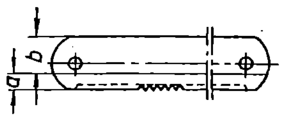
 Knurl	X12M, X12 X12Ф1	250-300 200-240	58-61	
 Broach	P18, P9 X12M, X12Ф1, XBГ, X, XГ, 9XBГ	540-580 160-190	62-65 61-64	35-45 35-45
 A segment of disk saw for metals	P18, P9, ЭИ347	540-580	61-65	45 max
 File chisel	P18, P9	540-580	61-64	

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
 File	У7-У13, ШХ6, ШХ9, ШХ12		Should stick to a plate with hardness number above $R_C=54$ Files for sharpening saws should stick to a plate whose hardness is above $R_C=57$	35 max
 Hack saw blade	У8-У12 9XC	180-220 220-250	58-61 58-61	40-45

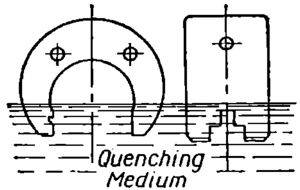
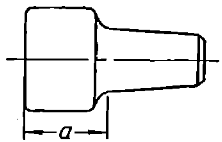
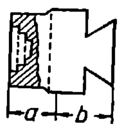
	Measuring Tools			
 External gauges  Internal gauges	У10А-У12А, ХГ, ХВГ, ХО9, ШХ15, 10, 15, 20, 15Х, 20Х, 15ХГ	150-180	56-64	
	Hot Stamping Dies			
 Hot stamping die	У7А, У8А 5ХНМ 5ХГМ 5ХНТ 7Х3 30ХГС 4ХС, 35ХГС 4ХВ2С	400-430 500-600 500-600 485-550 560-600 460-520 600-650 530-600	40-43 35-44 33-41 35-41 39-44 30-34 30-34 31-38	Lower by 50-100 H_B as compared to the working section

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
	5XB2C	425-475	32-39	
	6XB2C	550-600	35-40	
	3X2B8	600-700	39-49	
	4X8B2	500-575	40-48	
Hot cutting knives	6XC	300-420	52-56	
Casting Dies				
	3X2B8	500-575	46-50	
	4X8B2	500-540	46-50	
	5XHM	400-500	43-48	
	5XГM	400-450	43-46	
	4XB2C	450-500	40-44	
	5XB2C	350-400	42-45	
Cold Stamping Dies				
	У8, У9	220-300	54-60	
	У10-У12	250-320	54-60	
	X12M	275-520	54-60	
	X12Ф1	200-400	54-60	
	XГ	250-400	56-60	
	XO9	200-250	56-60	
	9XC	275-400	54-60	
	6XC	250-400	52-58	
Cold cutting knives				

Fitter's Tools

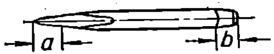
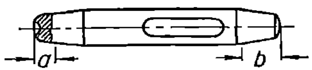
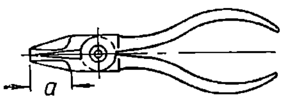
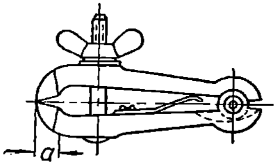
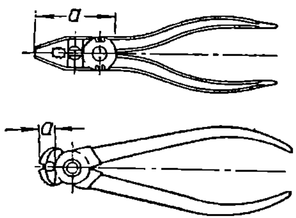
 Chisel	У7, У8	250-320	52-57	32-40
 Centre punch	У7, У8	250-320	52-57	32-40
 Rivet set	У7, У8	300-360	48-54	32-40
 Pliers	45, 50	300-380	42-50	

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
 Hand vice	45, 50	300-380	42-50	
 Combination pliers and cutting nippers	У7, У8	200-320	52-60	

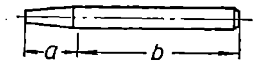
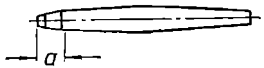
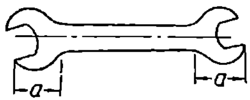
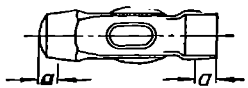
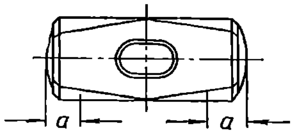
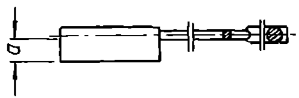
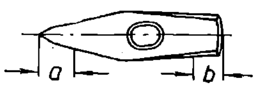
 Stamp	У7, У8	250-300	54-58	40-45
 Screwdriver	50, 60 У7, У8	280-350 320-370	46-52	
 Spanner	Ст. 3, 15, 20 40, 50 40X	320-380 370-420 400-450	48-54 40-45	
 Fitter's hammer	У7, У8	270-350	49-56	

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
Blacksmith's Tools				
 Sledge hammer	У7	270-350	49-56	
 Anvil chisel	50	200-250	48-52	—
 Blacksmith's chisel	У7	270-340	50-56	30-40

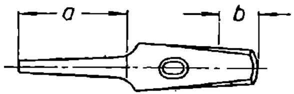
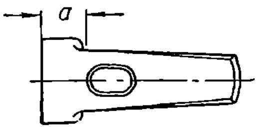
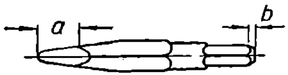
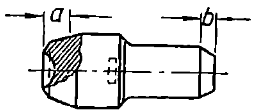
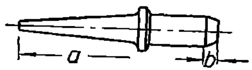
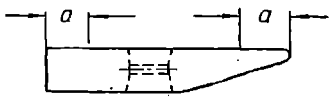
 Blacksmith's punch	У7	270-340	50-56	30-40
 Blacksmith's flatter	У7	270-340	50-56	
Pneumatic Tools				
 Pneumatic chisel  Pneumatic punch	У7, У8, 4ХВ2С	230-270	56-59	40-50

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
 Pneumatic rivet set  Drift	У7, У8	270-300	53-56	40-50
Coppersmith's and Tinsmith's Tools				
 Roofing hammer	У7	330-380	45-50	

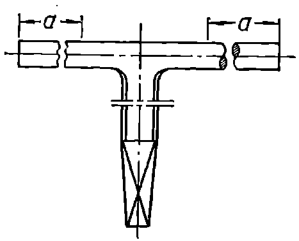
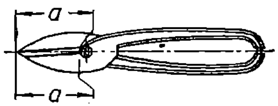
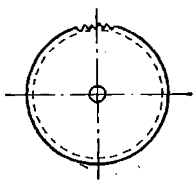
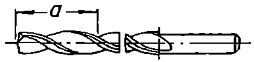
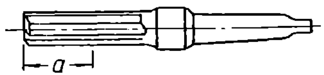
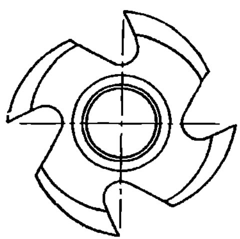
 Beak iron	У7	330-380	45-50	
 Hand shears	У7	200-320	52-60	
Woodworking Tools				
 Circular saw	85ХФ, 65Х, ШХ6, У8А	450-500	40-42	

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
 Twist drill  End milling cutter	У8-У10, 85ХФ, 65Х 6ХВ2С, ХГ	250-275 240-280	56-58	
 Gang milling cutter	У8, У10 85ХФ, 65Х, 6ХВ2С, ХГ	250-275 240-280	56-58	

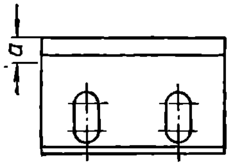
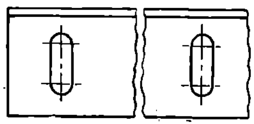
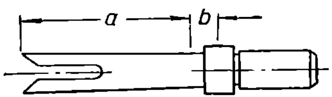
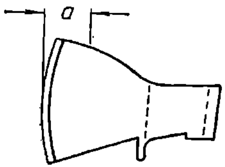
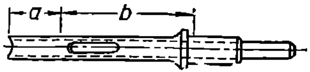
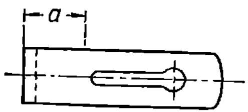
 Planing cutter	У7, У8, У9 85ХФ, 65Х, 6ХВ2С	230-275 220-280	56-59	
 Scoring knife	У7, У8, У9 85ХФ, 65Х	330-375 400-450	45-50	
 Solid lathe gouge	У8, У9, 65Х	250-275	56-58	40-45

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
 Chip axe	У7, У8, У10	260-340	50-56	
 Hollow lathe gouge	У8, У9, 65X	320-350	50-52	40-45
 Planing bit	У8, У9	200-320	53-60	

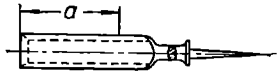
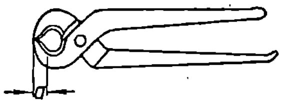
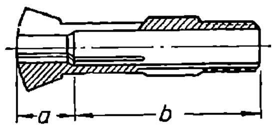
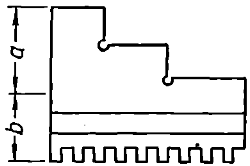
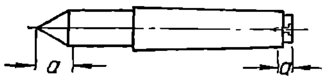
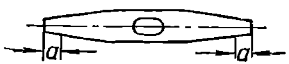
 Chisel	У8, У9, 65Х	250-320	53-58	
 Auger bit	У7, У8	360-420	44-48	
 Joiner's tongs	У7	330-400	43-50	
Parts of Fixtures and Gripping Tools				
 Collet	У8, У10, 65Г	200-250	58-62	40-45

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
 Chuck jaw	45 40X	300-350 350-400	45-50 45-50	35-42 35-42
 Centre	У7-У10	250-300	55-58	55-58
Track Tools				
 Spike hammer	Ст.6, Ст.7	300-350	45-50	

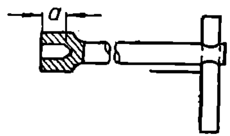
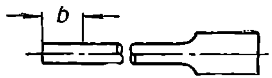
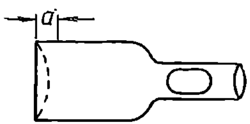
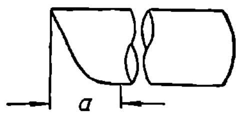
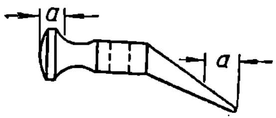
 Socket wrench	Cт.5	200-300	35-40	
 Tamping pick	Cт.6, Cт.7	300-350	45-50	
 End pick	Cт.6, Cт.7	300-330	47-50	
 Sleeper axe	Cт.6, Cт.7	200-300	49-56	

Table 86 continued

Type of tool	Recommended steel grades	Temperature for tempering the working section	Hardness number, R_C	
			Working section *a*	Shank *b*
 Pickaxe	Ст.5	200-250	38-42	
Harness-maker's Tools				
 Saddler's knife	65, 70, У7, У8	320-360	49-53	
 Cutter's knife	65, 70, У7, У8	280-320	53-56	

 Saddler's hammer	45, 50	350-420	40-46	33-42
Bricklaying Tools				
Blocking chisels, Planishing hammers, Trowels	У7-У10	300-400	42-52	
Plumbs	Ст.5	200-250	45-50	
Brick hammer, brick axe, pickaxe	50-70	350-420	43-51	
Pointed and flat crowbars	Ст.5-Ст.7	200-300	48-52	

Notes. 1. Cylindrical shanks of drills, reamers and cutters are not subjected to hardening.

2. Pneumatic tools such as cape chisels, caulking chisels and file chisels are treated in the same manner as pneumatic chisels, while dollies and strikers are treated in the same fashion as pneumatic rivet sets.

3. Tinner's tools such as formers, embossing dies, scrapers, etc., are treated in the same manner as beak irons.

Small-sized cylinder-shaped tools, up to 6-8 mm in diameter, are hardened by the use of a smoothing iron (employed as a chill bar) (Fig. 25).

Thin, slender tools made from high-speed steel are hardened between plates, which, when not positively cooled on the inside, should be greased prior to the hardening procedure.

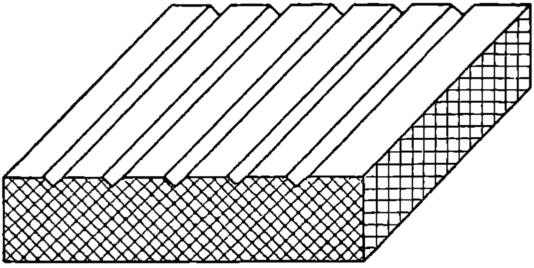


Fig. 24. Brick with grooves for heating of cylinder-shaped parts in horizontal position

Tools from grade 9XC and other silicon steels, which are not ground, should be carefully protected against decarburisation.

Tools hardened in water should be immersed therein very quickly so as to avoid cracking in that part of the tool which is dipped first.

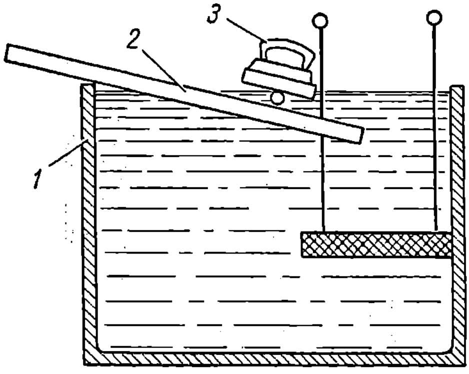


Fig. 25. Schematic view of "iron" hardening: 1 — bath; 2 — plate, 3 — iron

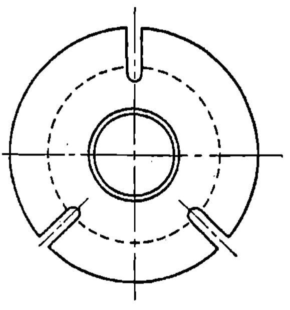


Fig. 26. Cutter from carbon steel, slotted prior to hardening

Round cutters from carbon steel should be slotted by a 1-mm cutter to prevent cracking on hardening (Fig. 26).

Tools with sections varying step by step should be quenched with the thick end down. Articles with blind holes should be cooled with the orifice oriented upwards or in a special installation with the aid of a water jet.

Tools with the cutting ends, when heated in salt baths, are heat treated as follows: for carbon and alloy steels—first the shank, then the cutting edge, while for high-speed steel the sequence is reversed.

Prior to re-hardening the articles should be annealed, this being of utmost importance for high-speed steel articles in order to prevent coarse-grained flake-like fracturing.

When testing files for hardness by the use of a hardened steel plate, it may occur that the file slides on one side and sticks on the other, i. e., one side is soft, the other hard.

In most cases, this failure occurs because of excessive hardness of the pad on which the file is cut.

File dents when placed on the hard pad are dulled if the file is struck on the opposite side. If the pad is made of a material which takes on cold working (aluminium, etc.), it should be periodically annealed (the periodicity being set from practice). One of the Soviet research institutes recommends grade MГ1 magnesium, which takes no cold working, as a pad material. An alloy consisting of 87% lead and 13% antimony is also used.

Annular cracks in welded tools. Cracks, situated at about 1 to 3 mm from the seam, can often be observed in high-speed welded tools.

These cracks are caused by rapid cooling of the tools from the welding temperatures and the subsequent air hardening of the seam area of the high-speed steel.

To prevent cracks, the blanks, after welding, should be charged into a furnace heated to 740-760°C. After charging, the furnace is cooled to 500-600°C and the blanks are then discharged.

Hot stamping dies. On hardening, small- and medium-sized dies can be charged into a furnace heated to requisite temperature, while large dies should be introduced into a furnace heated to 750-700°C.

When no spraying is available in the quenching tank, the die should be immersed with the face up. Dies from carbon steel are preliminarily normalised to increase the depth of hardening. For forging hammer dies the hardness of the shank should be by 50-100 H_B less than that of the working section. The shanks are usually tempered through holding on the plates or at the opened furnace doors.

Dies should be tempered while still hot, immediately upon withdrawal from the quenching tank. When high tempering is applied, it is not recommended to place the dies immediately in the furnace heated to tempering temperatures.

Pressure casting dies. The most durable material for pressure casting dies is grade 3X2B8 steel. It endures well the tempering at 600°C. Die performance shows that the higher the die surface hardness, the better is its wear resistance and the less the liquid metal sticks to its sides. The best means of die case-hardening should be recognised nitriding and cyaniding, as they cause minimum distortion.

Technology of casting die manufacture from grade 3X2B8 steel, which is cyanided, is as follows: (1) preliminary machining of the blank; (2) heat-treatment—hardening from 1075-1125°C and tempering at 700-720°C to 30-34 R_C; (3) final machining; (4) gas, liquid or solid cyaniding (at 560-580°C to a depth of about 0.08-0.10 mm); washing in kerosene and wiping dry. The hardness of cyanided die is above 60 R_C. Stresses appearing in the die during the operations, and casting cracks can be prevented by giving the dies periodical temperings after predetermined intervals of operation.

Cold stamping dies. Dies hardened in water should be protected against cracks at fastening apertures (Fig. 27) by 2-3-fold water dipping of the areas mentioned. To avoid warping when treating punches from

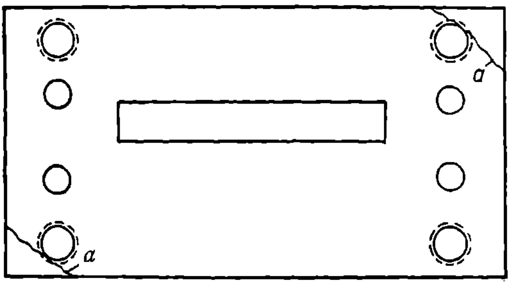


Fig. 27. Hardening cracks through auxiliar orifices of a die—*a*, cracks

carbon steel, the shanks should be cooled first, and then the whole article immersed with the face oriented upwards.

The hardness of the perforating punches should gradually shade off from R_C=54-58 on the working end to R_C=40-44 on the shank.

Measuring tools. While hardening measuring tools it should be borne in mind that if correct technology is not strictly followed, this leads to greater distortion and warping. Improving of gauges after roughing, as well as hardening in hot media, yields good results and brings down distortion.

Measuring tools are tempered twice: the first time, after hardening, to remove internal stresses, and, the second time, after grinding, to relieve post-grinding stresses and to prevent distortion during storage (artificial ageing). The ageing temperature should not exceed that for the first tempering procedure. The duration of ageing is from 2 to 5 hrs depending on the size of the tool, from the moment the latter has been heated through. Tools of long, slender form should be hooked up on heating.

The following data may be used to determine the carburising depth in relation to tool thickness:

Tool thickness, mm	3-5	5-10	10-15	Up to 20 and over
Carburising depth, mm	0.3-0.5	0.5-0.8	0.6-0.9	0.8-1.0

Woodworking tools. Disk saws are oil-hardened while being placed vertically. As soon as the saw cools down to about 400-300°C, it is extracted from the tank and clamped between two plates till it cools down entirely. The saws are tempered when gripped in screw clamps. It is recommended to tighten screw clamps to arrive at an effective straightening of the saw on tempering.

The gradual transition from the thin section to the thick one in lathe gouges, as well as the sides next to the aperture in a hollow gouge should be hardened so as to obtain minimum hardness.

Fitter's tools. Built-up tools such as flat- and round-nosed pliers, nippers and hand vice should be assembled and hardened with the jaws open. The jointed sections should not be hardened.

To prevent cracking, cutters and combination pliers are quenched in kerosene or oil, while providing effective mixing of the bath. Large combination pliers should first be quenched in water and then transferred to oil. Hand shears are to be quenched in a disassembled state. The opening for the rivet should neither be heated nor hardened. The work is to be cooled in kerosene or oil.

When only the ends of carbon-steel tools (chisels, hammers, etc.) heated throughout are to be hardened, these ends are quenched by the alternating method.

In this hardening method, first, the thin part is quenched, then the thick one, or vice versa. When hardening the thin part first, it should be immersed to a greater depth than that required; if the thick part is hardened first, the work should be heated up to the upper temperature range.

Spanners, according to Soviet Standard ГОСТ 2838-54, can also be manufactured from carburised steels, the depth of the case being 0.3-0.5 mm for spanners 2.5 to 4 mm thick and 0.6-1.0 mm for those from 5 to 8 mm thick.

Heat-treatment of springs. When heat-treating springs, effective steps should be taken to prevent cracking, especially of those of the smaller dimensions.

Holding in the furnace should be as short as possible. Small springs should be placed onto a heated pan. Springs from wire over 6 mm in diameter should be tempered at 670-700°C prior to hardening. Large spiral springs should be heated, on hardening and tempering, in special devices to prevent distortion. Prior to tempering, the springs are to be degreased. Best tempering results are obtained in saltpetre baths, holding time being from 10 to 12 minutes. When electric or flame furnaces are employed, tempering should take 20-40 min.

Brittleness, which develops in springs as a result of pickling or application of an anticorrosive coating (pickle brittleness), is eliminated by heating for 1-2 hrs at 150-180°C.

When the above treatment does not remove the increased brittleness, the springs should be annealed, and then the entire heat-treatment procedure repeated.

The thermo-mould method is the best means to manufacture flat springs from a heat-treated band. The spring band sheared to requisite profile is clamped in a device, shaped to finished spring, then heated for 20-30 min at 350-400°C, after which it is air-cooled together with the device. When the spring, upon discharge, is not up to the required profile, the configuration of the device must be corrected by the trial method. The said clamping devices are of the multiple-recess type.

Repairing worn plug gauges. Worn small-sized plug gauges from alloy and high-carbon steels can be repaired through tempering in an oil bath at 210-230°C. As a result of this treatment, the diameters of the gauges grow because of the disintegration of residual austenite (Table 87).

Table 87

Heat-treatment Schedule for Repairing Thread Plug Gauges from Alloy and High-carbon Steels

Plug diameter, mm	Heating temperature, °C	Holding time, hrs
Below 25	225-235	2-5
25-35	225-235	
35-40	215-225	
40-60	205-215	
60-80	205-215	
80-150	200-210	

Straightening of hardened articles. When hardened and tempered articles warp beyond the tolerated allowances, they are to be subjected to straightening.

Tools from any grade of tool steel up to 15 mm in diameter or thickness, hardness numbers being $R_C = 50$ and above, are straightened through brief, but not heavy hammering over the entire length on the concave side except for the cutting edges and threads, until full straightening is achieved. The tool should be laid on a hardened plate, while straightening is carried out. The configuration of the hammer striker should not be pointed in order to avoid indentations which cannot be removed by subsequent grinding.

Tools from high-speed steel are hand-straightened while hot, immediately after hardening; those larger than 15 mm in diameter are straightened under a press, being heated to 500-550°C. When trueing a tool the latter is bent in the direction opposite to that of the detected convexity, to a degree slightly in excess of that of the true shape; after a predetermined holding (determined from practice) and cooling, the work is discharged and inspected. If the procedure has not given satisfactory results, it is repeated. The heating temperature (500-550°C) is checked by the thermocolours.

Articles whose hardness numbers do not surpass $R_C = 50$ are press-straightened while either cold, or preheated to tempering temperatures.

Files from high-carbon steel are effectively straightened by the use of a mallet or a special device, the hardening procedure being discontinued at 140-180°C.

Half-round files, prior to hardening, are curved in the direction opposite to the flat face.

Flat, long articles are removed from oil at 150-200°C and inserted for straightening into special slotted plates (the slots being thicker than the articles by 0.1-0.15 mm), and re-cooled therein.

All articles without exception are re-tempered to remove stresses immediately after press or mallet cold straightening.

Normalising, straightening and repeated hardening with the use of all means to prevent warpage should be carried out in the following instances:

1. When warpage is excessive, the shape of the article prohibiting trueing (cutting edges or through threads, sharp changes in section, etc.).
2. When the article does not yield to trueing.
3. When large-sized carbon or alloy steel tools display excessive warpage

Thermal straightening (thermo-trueing). Thermal straightening can be used whenever there is a need to straighten warped plates (Fig. 28).

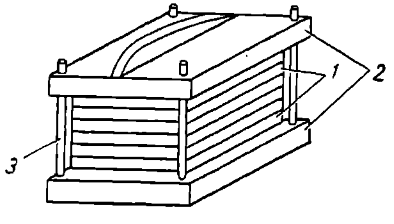


Fig. 28 Arrangement of plates in thermal straightening:
1 — plates; 2 — clamps; 3 — bracing bolts

A packet of plates is clamped in a device and is held till heat-soaked in a furnace, the temperature being in the 240-280°C range for aluminium plates, and 400-600°C for those made of brass. The upper temperature range is used for straightening thicker plates.

A list of steel grades recommended for the manufacture of parts of lathes, automobiles and agricultural machinery, as well as tempering schedules and requisite hardness numbers, are given in Tables 88, 89 and 90.

Table 88

Steel Grades Recommended for the Manufacture of Spare Parts of Lathes and Presses, Their Tempering Temperatures and Hardness Numbers

Name of parts and working conditions	Steel recommended	Tempering temperature, °C	Hardness numbers	
			Rockwell	Brinell
Gears				
Gears working at high peripheral velocities (4 m/sec and over), considerable bending and impact loads (gearbox gears of turning, turret and other lathes, as well as various other assemblies)	20X 15 20 12XH3 13XHBA	180-200 180-200 180-200 180-200 180-200	56-62 56-62 56-62 56-62 56-62	
Gears working at medium peripheral velocities (2-4 m/sec), medium specific and light impact loads (individual gearbox gears of high-speed lathes, gearboxes, etc.)	40X 45X	320-400 320-400	45-50 45-50	
Gears working at low peripheral velocities (up to 2 m/sec) and medium specific loads (gearbox gears, countershaft gearing, pump gears, etc.)	40X 35X 38XA 45X	620-670 620-670 620-670 600-650		228-260 200-260 200-260 228-280
Gears working at low peripheral velocities (up to 1 m/sec) and medium specific loads (link and apron gears, etc.)	45 40	580-620 550-600		228-250 228-250
Non-critical gears working at low peripheral velocities (up to 0.3 m/sec) and low specific loads (changeable gears, quadrant gears, etc.)	45 50	Subject only to normalising		179-207

Spindles

Heavy-duty spindles working in rolling and sliding friction bearings (spindles of turret and automatic lathes, etc.)	13XHBA	180-200	56-62	
	20X	180-200	56-62	
	15	180-200	56-62	
	20	180-200	56-62	
	12XH3	180-200	56-62	
Spindles requiring high hardness (working in rolling friction bearings) as well as those working at medium loads in sliding friction bearings (tapered spindles of drilling, milling and other lathes)	40X	320-400	45-50	
	45X	320-400	45-50	
	Local hardening is optional			
Spindles working under light and medium load conditions in sliding friction bearings (spindles of turning, drilling and other lathes)	45	350-400	40-45	
	50	350-400	40-45	
Spindles (working in rolling friction bearings), requiring increased hardness and adequate fatigue endurance (spindles of turning and gang lathes, etc.)	40X	450-500	35-42	
	35X	400-450	35-42	
	38XA	420-470	35-42	
	XΓ	530-600	35-42	
	45X	450-500	35-42	
Spindles (working in rolling friction bearings, under medium loads), requiring increased strength	40X	620-670		228-260
	35X	620-670		200-260
	38XA	620-670		200-260
	45X	600-650		228-280
Light-duty spindles working in rolling friction bearings	45	580-620		228-250
	40	550-600		228-250

Table 88 continued

Name of parts and working conditions	Steel recommended	Tempering temperature, °C	Hardness numbers	
			Rockwell	Brinell
	Shafts			
Shafts working at high peripheral velocities (3 m/sec and over) and increased bending loads (gearbox shafts)	20X	180-200	56-62	
	15	180-200	56-62	
	20	180-200	56-62	
Shafts working in sliding friction bearings at peripheral velocities up to 3 m/sec (feed gearbox shafts, countershafts, etc.)	40X	320-400	45-50	
	45X	320-400	45-50	
Shafts working in sliding friction bearings at peripheral velocities up to 2 m/sec (shafts of change-gearboxes, feed gearboxes, etc.)	45	350-400	40-45	
	50	350-400	40-45	
Heavy-duty splined and plain shafts, requiring adequately high strength and wear resistance	40X	450-500	35-42	
	35X	400-450	35-42	
	38XA	420-470	35-42	
	45X	450-500	35-42	
Shafts (working in rolling friction bearings) requiring increased strength (shafts of tumblers, quadrants, feed gearboxes, etc.), as well as multisplined shafts working under medium-load conditions	40X	620-670		228-260
	35X	620-670		200-260
	38XA	620-670		200-260
	45X	600-650		228-280
Shafts working in rolling friction bearings at light loads, as well as non-critical lightly loaded splined shafts	45	580-620		228-250
	40	550-600		228-250
	Bushings			
Medium-duty bushings working at high speeds and requiring increased strength, high wear resistance and toughness	20X	180-200	56-62	
	15	180-200	56-62	
	20	180-200	56-62	

Heavily loaded bushings requiring high strength and adequate wear resistance	40X	320-400	45-50	
	45X	320-400	45-50	
Jig bushings	XГ	180-250	59-63	
Worm Shafts				
Heavy-duty worm shafts requiring high wear resistance	20X	180-200	56-62	
	15	180-200	56-62	
	20	180-200	56-62	
Non-critical lightly loaded worm shafts of hand-driven mechanisms	40X	620-670		228-260
	35X	620-670		200-260
	38XA	620-670		200-260
	45X	600-650		228-280
Claw clutches requiring high resistance to crushing (running engagement) and increased tensile strength	20X	180-200	56-62	
	15	180-200	56-62	
	20	180-200	56-62	
Non-critical claw clutches	40X	620-670		228-260
	35X	620-670		200-260
	38XA	620-670		200-260
	45X	600-650		228-280
Cams, rollers, eccentrics, pawls of ratchet mechanisms, formers, stators of hydropumps and other parts subject to wear and requiring constancy of dimensions while in service	ШХ12	180-220	59-63	
	ШХ15	180-220	59-63	
Locating rings	45	350-400	40-45	
	50	350-400	40-45	
Engaging pins in presses	37XH3A	180-200	Above 50	
	40XHMA	180-200	Ditto	
	50XH	180-200	Ditto	
	45XH	180-200	Ditto	

Note. **Hardening schedules for steel grades mentioned in the above table are presented in Tables 61, 64, 67.**

Table 89

Steel Grades Recommended for the Manufacture of Some Automobile Parts and their Approximate Hardness Numbers

Name of parts	Steel grade	Hardness number, R_C	Remarks
Bushings	20, 18ХГТ	56-62	Carburise to 0.7-1.0 mm
Crankshafts	45	56	Surface hardening of journals
Camshafts	45	Ditto	Ditto
Inlet valves	40Х	22-28	
Exhaust valves	СХ8, ЭИ107	45	Thrust ring to be hardened
Piston rings	Pearlitic cast iron	98-106 R_B	Thermal stabilising on a mandrel in expanded state at 580-600°C for 30 min
Standard parts, bolts, nuts, etc.	40Х, 45	28-35	
Standard parts subject to friction	20Х, 20	50-60	Carburise to 0.6-1.0, working section to be hardened
Piston pins	15Х, 20	56	Carburise to 0.7-1.2 mm
Spherical pins	18ХГТ, 12ХН3А	56	Carburise to 1.0-1.5, the head to be hardened
Spring pins	20, 20Х	56	Carburise to 1.0-1.3 mm, the thread to be tempered to 35-40
Pivots of rotating cam	12ХН3А, 12Х2Н4А, 20Х3	56	Carburise to 0.7-1.2 mm

Table 90

Steel Grades Recommended for the Manufacture of Some Agricultural Machinery Parts and Their Approximate Hardness Numbers

Name of parts	Steel grade	Hardness number, R_C	Remarks
Share sidewalls and skim coverer of potato planter	65Г	38-50	
Bushings of self-propelled combines	35	45-50	Carburise to 0.6-1.0 mm to a length of 20 mm
Medium-duty shafts and axles	45-40 Ст.5	30-40 40-45	Depending on loads
Heavy-duty shafts and axles	Ditto	52-58	HF hardening
Field disks for ploughs, harrows, etc.	Ст.6, Л53 65Г, 70Г	35-50	
Twine holder	У9	40-50	Local hardening
Chain links for elevators of potato diggers	65Г	38-45	Ditto
Teeth of thrashing drums and concaves	45, Ст.6	42-52	Ditto
Teeth of traverse rakes	65Г, 70Г	37-46	Pin hardness number >269 H_B
Chain wheel of combine drum shaft	15	54-62	Carburise to 1.0-1.5 mm
Ridger mouldboard vanes	Ст.5	33	
Agricultural scythes	У7А, У8А	40-50	
Crosspiece of Hooke's joint and cross-piece of universal joint	Ст.2	40-55	Carburise to 0.8-1.2 mm

Table 90 continued

Name of parts	Steel grade	Hardness number, R_C	Remarks
Teeth of various types of cultivators	65Г, 70Г	38-50	Blade area to be quenched
Various types of plough-shares	Л65, 50, Ст.6	38-50	Working section to be quenched
Beaters, crushers	Ст.2	56-62	Working section to be carburised and quenched
Points of harrows and seeders	Л53, Ст.5	38	Working section to be quenched
Knives of feed mincers	У9, 65Г, 70Г	46-56	Ditto
Knives of beet-lifting machines	У9	45	
Knives of sheafer knotter	У9	50-58	Working section to be quenched
Knives and combs of sheep shearing machine	У2А, УВА	60	
Various types of mould-boards	Ст.2	50	Carburise to 1.0-1.5 mm
Ginning and lintering saws of cotton scrapers	85	30-35	
Plates and pawls of plough automatic device	Ст.2	45-50	Carburise
Pins of self-propelled combine	40	35-40	
Sections of harvester cutting devices	У9	50-60	Working section to be quenched
Spring mountings of cultivators	65Г, 70Г	38-47	
Slide block of self-propelled combine	40	45-50	
Worm shafts of high strength and wear resistance	40Х	38-45	
Worm shafts of high wear resistance	20, Ст.2	50-58	Carburise to 0.8-1.2 mm

Chapter VII

HEAT-TREATMENT OF CAST IRON

Cast-iron articles, depending on specifications, may be annealed, normalised, hardened, tempered or case-hardened.

Low-temperature annealing. Natural ageing, consisting of a prolonged maturing of articles in storehouses, was employed as a means of removing stresses in cast-iron articles. This was a long-term operation

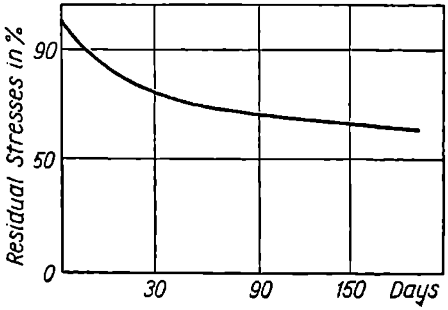


Fig. 29. Lowering of internal stresses in relation to the duration of natural ageing of cast iron

which, all things considered, did not remove all the stresses entirely (Fig. 29).

Currently, a low-temperature annealing procedure, relieving all the stresses completely, has been successfully applied (Fig. 30); this procedure is carried out according to a schedule which is the same for all grades of cast iron: the articles are charged to a furnace heated to maximum 250-300°C, the furnace temperature is then raised and the said work is held over for a period ranging from 2 to 8 hrs, depending on its size and shape; after this, the furnace is cooled at a rate of 20-30° C per hour down to 200-150°C, and the articles are discharged in the air.

Low-temperature spheroidising annealing. This procedure is generally used for extra-tough and malleable cast irons; it greatly increases ductility, resilience and antifriction properties. This treatment is rarely applied to grey cast iron, as along with a lowering of hardness and improvement of machinability it brings down sharply its mechanical properties.

The annealing schedule comprises: heating (gradual for fancy-shaped parts) to 670-700°C, holding from 1 to 4 hrs and cooling with the furnace.

Spheroidisation of white cast iron. This process is employed to reduce hardness and to improve machinability of white cast iron. The work is heated to 850-950°C and, after a through heat soaking, cooled with the furnace; larger articles are air-cooled.

To remove the whitening effect in the thin sides of castings from extra-tough cast iron, the articles are annealed according to the following schedule: heating to 800-850°C, holding for 2-4 hrs, cooling to 650°C, holding for 4-6 hrs and cooling with the furnace to 200-175°C.

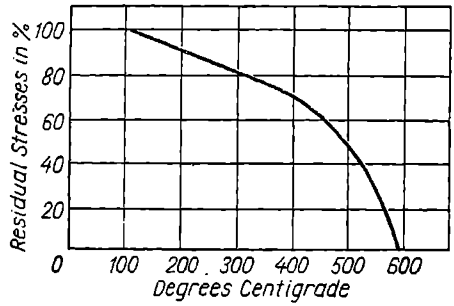


Fig. 30. Effect of heating temperature on removal of internal stresses according to published data

Normalising. It is employed to increase strength and wear resistance of grey cast iron. On normalising, the article is heated to 850-900°C and, after a through heat soaking, cooled. Intricate parts should be tempered, after normalising, at 600-650°C.

Hardening is intended to increase hardness, strength and heat resistance of articles made of grey cast iron.

The hardening temperature in oil is 830-870°C, and in water 800-820°C. Odd-shaped parts, prior to hardening, are heated slowly whereas simple-shaped parts are heated rapidly by charging them into the furnace heated to the requisite temperature. When initial structure is ferritic, holding time is increased. Isothermal hardening of grey cast iron, which markedly reduces cracking and warping, is carried out at 830-900°C through immersion in a bath at 200-400°C.

Tempering. Tempering of cast-iron parts, after hardening, is imperative. The process temperature is from 200 to 500°C, depending on properties required. When maximum wear resistance is needed, the work is tempered at 200-250°C. The best combination of strength and wear resistance is attained in the 350-450°C range, the hardness averaging H_B=321-418.

Testing cast-iron articles for hardness. Rockwell hardness test, after quenching, fails to bring forth the exact picture of the hardening effectiveness, because of presence of graphite in the cast iron. Fig. 30 *a* illustrates an indentation produced by the Rockwell testing machine on the hardened surface of a tractor cylinder bushing, the load applied equalling 60 kg. To ascertain what amount of graphite is included in the indentation area of the diamond cone, a circle of equal diameter is drawn next to the indentation. The hardness number of the said bushing is 45 units R_{C150}, while the hardness number of its metallic base determined by the ПМТ-3 device equals 62 R_{C150}. It is evident that the $R_C=45$ is an average hardness number, which is a function not only of the degree of hardening but also of the amount of graphite (Brinell hardness number of only 6-10 kg/mm^2) present in the cast iron.

Table 91

Causes and Correction Methods for Annealing Defects in Grey and Malleable Cast Irons

Defect	Detection	Chief cause	Correction methods
Low hardness of grey cast iron after stress-relieving annealing	Hardness test	Disintegration of cementite on heating above 600°C	Normalising at 900-950°C for plain-shaped parts and subsequent stress-relieving tempering
High hardness of white cast iron after annealing	Ditto	Insufficient temperature and/or holding on annealing	Repeated annealing at normal temperature and adequate holding time
Free structural cementite in malleable cast iron	Microstructure checking	Low temperature or insufficient holding at the 1st stage of spheroidising	Repeated annealing according to set schedule
Excessive amounts of lamellar pearlite in malleable iron	Ditto	Non-compliance with cooling schedule or insufficient holding at the 2nd stage of spheroidising	Repeated annealing at 710-730°C
Lamellar graphite in malleable iron	Ditto	Presence of free graphite in malleable iron	Irremediable defect

Improving of extra-tough cast iron is effected according to the following schedule: hardening in oil from 870-900°C and tempering at 500-600°C.

Mechanical properties: tensile strength up to 120 kg/mm², yield point up to 100 kg/mm², Brinell hardness number—375.

Heat-treatment of white cast iron. Malleable cast iron is obtained by annealing white-iron castings according to a number of technological flowsheets, two of which are given below.

Flowsheet No. 1. The articles are packed into boxes and covered with dry river sand. The boxes are heated to 1000-1050°C in a furnace, kept there at the said temperature for 6-10 hours and cooled with the furnace down to 680°C. The cooling in the 760-680°C range is slow (2-3°C per hour), after which the cooling rate is immaterial. Prolonged holding at temperatures slightly below the A_1 point can be substituted for slow cooling.

Flowsheet No. 2. Heating of articles in an antioxidising medium up to 940-960°C, holding at the said temperature for 12 hours, cooling to 760°C, slow cooling (for 20-22 hrs) in the 760-680°C range, 10-hr cooling down to 550°C, subsequent cooling effected at any rate desired.

Table 91 lists various defects encountered in the heat-treatment of cast iron and the methods required to remedy them.

Chapter VIII

HEAT-TREATMENT OF NON-FERROUS METALS

Copper and copper-base alloys. Copper is annealed to remove cold working effects and to reduce hardness. To this end, copper is heated to 500-700° C and then cooled after heat soaking. Any rate of cooling will suit the case, the cooling being effected with the furnace, in the air or water; when the work is water-cooled, the scale flakes off more readily than with the cooling being effected in the furnace or air.

The post-annealing mechanical properties of pure copper are tensile strength $\sigma_b = 20$ kg/mm², relative elongation $\delta = 50\%$, Brinell hardness number $H_B = 35$ (approximate data).

Conventional designations for copper alloys are given in Table 92.

Table 92

Conventional Designations of Elements in Specifications for Copper and Nickel Alloys

Element	Designation	Element	Designation
Aluminium	А	Magnesium	Мг
Beryllium	Б	Manganese	Мц
Chromium	Х	Nickel	Н
Copper	М	Silicon	К
Iron	Ж	Tin	О
Lead	С	Zinc	Ц

Brasses (copper-zinc alloys). The chemical composition of brasses can be identified according to the designation of the alloy, namely: the letters indicate the elements contained in the brass, while the figures specify the percentage of these elements. The letter "Л" designates brass, while the subsequent letters stand for elements comprising the brass. The first figure designates the percentage of copper, the remaining figures specifying the percentage of the elements in the same sequence as these are included in the designation of the alloy. The amount of zinc is the balance to 100%.

Examples:

1. Л62—brass, copper—62%, zinc—38%.
2. ЛЖМц59-1-1—brass, copper—59%, iron—1%, manganese—1%, zinc—39%.

Brass is annealed to remove cold working effects and restore the structure. On annealing, the parts are charged to a furnace heated to the required temperature. Brasses, even when slightly distorted, tend to crack when stored in moist atmosphere; because of this, all articles and half-finished pieces should be subjected to low-temperature annealing at 300-350°C.

Intermediate annealing subsequent to the rolling of brass, as well as annealing of blanks are carried out at temperatures listed in Table 93. Brass castings which should display minimum deformation in machining and service are annealed at 300-350°C with a 2-4 hr holding. Castings from brass ЛК80-3Л should be homogenised at 750-760°C for 1-1.5 hrs in order to eliminate microporosity. When the said defect is highly pronounced, homogenising should be repeated twice (Table 93).

Table 93

Approximate Annealing Schedules and Mechanical Properties of Brasses

Name of brass	Designation	Annealing temperature, °C	Approximate mechanical properties		
			Tensile strength, kg/mm²	Elongation, %	Brinell hardness number
Tombac	Л96	540-600	24	52	59-63
Ditto	Л90	650-720	26	44	53
Semi-red brass	Л85	600-700	26	43	54
Ditto	Л80	600-700	31	52	53
Brass	Л70	600-700	33	55	
Ditto	Л68	520-650	33	56	52
Ditto	Л62	600-700	36	49	56
Ditto	Л59	600-670	39	44	
Aluminium brass . .	ЛА85-0.5	650-700	35	60	
Ditto	ЛА77-2	600-650	38	50	50
Ditto	ЛАН59-3-2	600-650	50	42	117
Nickel brass	ЛН65-5	600-650	38	65	65
Manganese brass . . .	ЛМц58-2	600-650	44	36	85
Iron-manganese brass	ЛЖМц59-1-1	600-650	47	36	80
Tin brass	ЛО90-1	650-720	28	40	57
Ditto	ЛО70-1	560-580	35	62	48
Ditto	ЛО62-1	550-650	38	37	85
	ЛО60-1	550-650	38	37	85
Lead brass	ЛС74-3	600-650	35	48	55
Ditto	ЛС64-2	620-670	34	60	50
Ditto	ЛС63-3	620-650	35	45	80
Ditto	ЛС60-1	600-650	35	50	
Ditto	ЛС59-1	600-650	42	43	75

Note. Cooling after annealing is effected in the air or within the furnace.

Bronzes. Depending on their chemical composition, bronzes belong to the tin or tinless varieties. Chief constituents of tin bronzes are copper and tin. Tinless bronzes are constituted by copper-bearing alloy comprising one or several additional elements: aluminium, silicon, manganese, etc. The chemical composition of bronzes is recognised by the designation of the alloy, as is the case with brasses.

On heat-treatment, the work can be charged to a furnace heated to the requisite temperature. Cooling, after annealing, can be carried out in the air or within the furnace. Annealing temperatures are adopted with relation to the thickness of the material. Temperatures lower by 10% as compared to those listed in Table 94 can be recommended for bands and small-sized wire (up to 0.5 mm).

Table 94

Annealing Schedules and Approximate Mechanical Properties of Bronzes

Name of bronze	Designation	Heating temperature, °C	Approximate mechanical properties		
			Tensile strength, kg/mm²	Elongation, %	Brinell hardness number
Tin-phosphor bronze	Бр.ОФ6.5-0.4	600-650	34-45	60-70	70-90
	Бр.ОФ4-0.25	600-650	34	52	55-70
Tin-zinc bronze . .	Бр.ОЦ4-3	600	35	40	60
Tin-zinc-lead bronze	Бр.ОЦС4-4-2.5	600	30-35	35-45	60
Aluminium bronze	Бр.А5	600-700	38	65	60
Ditto.	Бр.А7	650-750	42	70	70
Aluminium-iron bronze	Бр.АЖ9-4	700-750		40	110
Aluminium-manganese bronze . . .	Бр.АМц9-2	650-750	55	45	107
Aluminium-iron-manganese bronze	Бр.АЖМц 10-3-1.5	650-750	60-64	27-30	120
Aluminium-iron-nickel bronze . .	Бр.АЖН10-4-4	700-750	60	35	140-160
Beryllium bronze	Any grade	650-750	50	30	100
Silicon-manganese bronze	Бр.КМц3-1	600-680			80
Silicon-nickel bronze	Бр.КН1-3	650-750	45	12	
Manganese bronze	Бр.Мц5	700-750	30	40	80
Foundry bronzes of various grades		600-650			

Castings from a number of tin bronzes, which display leakage when tested for water-tightness, are consolidated through annealing according to the following schedule: heating to 700-710°C, holding for 2 hours for each 25 mm of thickness and cooling within the furnace.

Spring bronzes which are marketed in a strain-hardened state cannot be annealed to facilitate bending. In this case tempering at 300-320° C is sometimes permitted.

Beryllium bronzes should be quenched in water at 20°C as a maximum, while the transfer time from the furnace to the tank should be as short as possible. Slow quenching tends to impair springiness of this bronze. Dissociated ammonium is the best medium for the prehardening heating of beryllium bronze blanks.

Heating in dissociated ammonium makes it possible to detect the defects of the material prior to manufacturing of parts, as the hydrogen of the ammonium forms bulges or blisters on the blank surface by combining with the oxides of the metal.

When heating in a usual chamber furnace in air atmosphere the following precautions should be envisaged:

1. Pans which carry the articles should be free from dirt, oil and scale.

2. The articles should be piled on the pan uniformly. Heating in bulk impairs the quality of the articles.

Holding time of heated articles should average 8-12 min at 760-780° C.

Beryllium bronze is aged in an air furnace or saltpetre bath. Ageing time is approximately 2-3 hrs.

It should be pointed out that sensitive elements (diaphragms, bellows, etc.) manufactured from bronze Бр.Б2.5 do not show superior quality due to the fact that high beryllium content in the bronze frequently causes structural non-uniformity, increased brittleness, etc.

The Moscow Research Institute for Non-Ferrous Metal Working has recommended, for sensitive elements, a new grade of beryllium bronze, the БНТ1.9 whose chemical composition is: beryllium 1.8-2.1%, nickel 0.2-0.4% and titanium 0.1-0.25%.

Diaphragms and springs from the said bronze possess high fatigue endurance (durability) and lower hysteresis.

The heat-treatment schedule for БНТ1.9 bronze is the same as for bronze Бр.Б2.5. The low response of the former to heat-treatment conditions and its cost, being lower than that of the Бр.Б2.5 bronze, should be of interest.

Tempering time of grade X0.5 chromium bronze is accepted to be 6 hrs (Table 95).

Nickel is subject either to oxidising or bright annealing depending on requirements. Annealing temperature for nickel is in the 750-900°C range. Annealed nickel possesses a tensile strength σ_b of 50 kg/mm², elongation of 40%, Brinell hardness number H_B=70-90.

Bright annealing of nickel is carried out in the atmosphere of dried hydrogen from generator gas, of dissociated ammonium, etc. When controlled atmosphere is not available, bright annealing is effected as follows: parts or materials, subject to annealing, are placed into pots or boxes (cast-iron or steel), a small amount of charcoal is added thereto, the boxes are covered with lids, the seams are thoroughly luted with a mixture of ordinary clay and fireclay, and then charged to the furnace. After annealing the packets should not be opened until cold.

When annealing coils of wire, the latter, prior to packing, are dipped in a water solution of whiting and dried, to prevent sticking of coils.

Nickel alloys. The chemical composition of nickel and copper-nickel alloys can also be readily recognised by the alloy designation. When nickel is the basic element of the alloy, the first letter of the alloy designation is "H", while if copper is the basic element, the first letter of the alloy designation will be "M". The letters and figures that follow designate the elements and their percentage in the alloy.

Table 95

Approximate Hardening and Tempering Schedules for Bronzes

Name of bronze	Designation	Hardening: Heating temperature, °C	Hardening: Cooling medium	Tempering: Heating temperature, °C	Brinell hardness number
Aluminium-iron bronze	Бр.АЖ9-4	850	Water	350	—
Aluminium-manganese bronze	Бр.АМц9-2	800	Ditto	400	150-187
Aluminium-iron-manganese bronze	Бр.АЖМц 10-3-1.5	830-860	Ditto	300-350	207-285
Aluminium-iron-nickel bronze	Бр.АЖН10-4-4	980	Ditto	400	400 max
Chromium bronze	Бр.Х0.5	950-1000	Ditto	400	—
Cunial	Бр.НА14-3 Бр.НА6-1.5	900	Water or air	500	260 210
Beryllium bronze	Бр.Б2 ВНТ1.7 БНТ1.9	760-780	Water	310-330 *	300 min
Silicon-nickel bronze	Бр.КН1-3	850	Ditto	450	150-200

* Bronzes used for diaphragms are tempered at 290-310° C.

Examples:

Nickel alloys:

1. Alumel НМцАК2-2-1, averaging 2% manganese, 2% aluminium, 1% silicon, the balance (95%) being nickel and cobalt.

2. Chromel HX9.5, averaging 9.5% chromium, the balance being nickel and cobalt.

Copper-nickel alloys:

1. Copel MHMц43-0.5, averaging 43% nickel, 0.5% manganese, the balance being copper.

2. Cunial MHA13-3, averaging 13% nickel, 3% aluminium, the balance being copper.

Bright annealing of nickel and copper-nickel alloys is similar to that of nickel (Table 96).

Copper-nickel alloys Cunial "A" MHA13-3 and Cunial "Б" MHA 6-0.5 are toughened by means of heat-treatment according to the following schedule: hardening from 900°C in water and tempering at 500°C for two hours. Mechanical properties following this treatment are:

	MHA13-3	MHA6-0.5
Tensile strength in kg/mm²	90-95	65-75
Elongation in %	5	7
Brinell hardness number	260	210

Low-temperature annealing of nickel and its alloys, aimed at removing internal stresses, is carried out in the 250-300° C range.

Magnesium alloys. Cast as well as wrought magnesium alloys (Table 97) are subjected to a variety of heat-treatments, the set purpose of which is indicated in Table 98.

The work is heat-treated in furnaces of the following types: shaft, vacuum, chamber and bath-type furnaces (containing a mixture of potassium and sodium bichromates).

It is recommended, in order to prevent oxidation, to heat the work in a controlled gas atmosphere composed of a mixture of air with 0.7-1% of sulphurous anhydride. When sulphurous anhydride is not available, the protective or controlled atmosphere is obtained by charging 3-4 kg of pyrites per 0.7-1 ton of the weight of the work.

The furnace temperature should be adjusted to within ±5° C with the aid of an automatic regulator.

To avoid possible fusion, the heating of large articles should be a two-stage procedure: first, up to 330-340° C or 360-370° C, depending on hardening temperature, then, after a 2-4 hour holding, to the final required temperature Prolonged holdings on heating are necessary because of very slow consummation of the diffusion processes (Table 99).

To prevent cracking on hardening, it is not recommended to use cold water.

Strict temperature control is to be ensured when heat-treating magnesium alloys, as the latter inflame readily. At no time should the requisite temperatures be surpassed. Articles to be heat-treated should be clean from magnesium dust, chips, burrs, grease and oil.

Defects possible in the heat-treatment of magnesium alloys are described in Table 100.

Aluminium and its alloys. Heat-treatment of aluminium involves annealing at 370-400° C with subsequent air-cooling. After annealing

20482

Table 96

Annealing Schedules and Approximate Mechanical Properties of Nickel and Copper-nickel Alloys

Name of alloy	Designation of alloys	Annealing temperature, °C	Mechanical properties		
			Tensile strength, kg/mm^2	Elongation, %	Brinell hardness number
Manganese-bearing nickel	НМц2.5	900	50	40	
Ditto	НМц5	800-850	75 max	18 min	147
Monel	НМЖМц28-2.5-1.5	800-850	45-50	35 min	120-130
Chromel	НХ9.5 and НХ9	850-900	60-70	35-40	150-200
Alumel	НМцАК2-2-1	900-950	56	36	130
Nickel silver	МНЖМц30-0.8-1	780-810	38-40	23-28	60-70
Ditto	МН19	600-780	40	35	70
German silver	МНЦ15-20	700-750	38-45	35-45	70
Leaded German silver	МНЦС17-18-1.8	750	40	40	82
Copper-nickel alloy	МН5	650			38
"ТП" alloy	МН0.6	500	25-30	50 max	50-60
"ТБ" alloy	МН16	750-760	39	26	70
Copel	МНМц43-0.5	800-850	40	35	85-90
Constantan	МНМц40-1.5	800-850	40-50	30	75-90
Manganin	МНМц3-12	700-750	40-55	30	120
Nichrome	Х20Н80	850-900	40	50	
Ferronichrome	Х15Н60	750-850	64	28-30	160

Table 97

Chemical Composition of Commercial Magnesium Alloys

Grade	Chemical composition, %				
	Aluminium	Zinc	Manganese	Silicon	Magnesium
		Foundry Alloys			
МЛ1	—	—	—	1-1.5	The balance
МЛ2	—	—	1-2	—	
МЛ3	2.5-3.5	0.5-1.5	0.15-0.5	—	
МЛ4	5-7	2-3	0.15-0.5	—	
МЛ5	7.5-9.3	0.2-0.8	0.15-0.5	—	
МЛ6	9-11	Up to 2.0	0.1-0.5	—	
		Wrought Alloys			
MA1	—	—	1.3-2.5	—	
MA2	3-4	0.2-0.8	0.15-0.5	—	
MA3	5.5-7	0.5-1.5	0.15-0.5	—	
MA4	6.5-8	2.5-3.5	0.15-0.5	—	
MA5	7.8-9.2	0.2-0.8	0.15-0.5	—	
MA8	—	—	1.5-2.5	Cerium 0.15-0.5	

Table 98

Conventional Designations, Uses and Varieties of Heat-treatment Processes Applied to Magnesium Alloys

Designation	Purpose	Heat-treatment applied
T2	Removal of internal stresses, removal of strain-hardening and increase of ductility	Annealing
T4	Improvement of mechanical properties	Hardening
T6	Increase in yield point	Hardening and ageing

the mechanical properties are: tensile strength σ_b—8-10 kg/mm², relative elongation δ—40-45%, Brinell hardness number H_B=20.

When only internal stresses are to be removed, aluminium is annealed at 150° C.

Two types of aluminium alloys are distinguished: the wrought alloys and the cast alloys.

The wrought aluminium alloys are divided into two groups: (1) alloys which are not toughened by heat-treatment; (2) heat-treatable alloys (Table 101).

Aluminium alloys acquire good ductility as a result of annealing in saltpetre baths for 20-30 min or in electric furnaces in air atmosphere for 1-2 hours. The duration of heating is indicated in Table 102, while the temperatures for heat-treatment schedules are presented in Table 103.

Best ductility and minimum hardness of aluminium alloys are obtained after a 30-min annealing at 420° C with subsequent cooling, first, within the furnace at a rate of 30° C down to 280° C, and then in the air.

Heating for the toughening of aluminium alloys is carried out in the furnaces mentioned above. Temperatures in excess of the upper range of hardening temperatures may cause burning revealed by sharp darkening of the surface, and by the presence of blisters and cracks.

Water temperature for hardening should not fall below 30° C. As machine parts grow both in size and complexity, it is recommended to increase the temperature of water, bringing it up to 70-80° C. An increasein temperature reduces the formation of cracks as well as warping.

The time interval between the removal of parts from the furnace and their immersion in water should not exceed 20-30 seconds.

Parts heated in saltpetre baths should be thoroughly flushed and wiped with rags after hardening. Following hardening aluminium alloys toughen to a certain extent but are still as ductile as to permit distortion of the article.

After a certain lapse of time the alloy ages. The time interval between the hardening and the beginning of ageing is given in Table 105. Ageing is speeded up through tempering at 150-170° C for 6-12 hours.

"Fresh"-hardened condition of the articles can be retained by holding them at a temperature ranging from 0 to —20° C after hardening.

Hardnened and aged duralumin can be restored to "fresh"-hardened condition through short-term heating (0.5-1 min) at 240-260° C. After the necessary working (stamping, etc.), the alloy is aged again.

Cast aluminium alloys. Cast aluminium alloys (Table 104), depending on requirements, are heat-treated; the conventional designations of the processes and their objectives are presented in Table 106.

Prolonged heatings are essential for the heat-treatment of cast alloys, because of their very coarse structure. Fancy-shaped parts are preheated in electric furnaces to 300-350° C (Table 107) prior to heating on hardening in salt baths.

When treating aluminium as well as magnesium alloys in furnaces with air atmosphere, furnaces with positive mixing of atmosphere should be used to provide uniform heating (type ПН-31, etc.).

Table 99

Recommended Heat-treatment Schedule for Magnesium Alloys in Electric Furnaces with Air Atmosphere and Approximate Mechanical Properties (Undervalued for the Most)

Alloy grade	Conventional designation of heat-treatment	Annealing and hardening			Ageing			Mechanical properties		
		Heating temperature, °C	Holding, hrs	Cooling medium	Heating temperature, °C	Holding, hrs	Cooling medium	Tensile strength, kg/mm²	Elongation, %, minimum	Brinell hardness number
A. Foundry Alloys										
МЛ1	T2	200-250	3-5	Within the furnace	—	—	—	9	2	40
МЛ2	T2	200-250	3-5	Ditto	—	—	—	9	3	30
М3	T2	170-250	3-5	Ditto	—	—	—	16	6	40
МЛ4	T2	170-250	3-5	Ditto	—	—	—	16	3	50
	T4	375-385	8-16	Air	—	—	—	21	4	55
	T6	375-385	8-16	Ditto	170-180	16	Air	22	2	60
МЛ5	T2	170-250	2-3	Ditto	—	—	—	15	2	50
	T4	410-420	8-16	Ditto	—	—	—	21	4	50
	T6	410-420	8-16	Ditto	170-180 or 195-205	16 8	Air Ditto	22	2	60
МЛ6	T2	170-250	3-5	Within the furnace	—	—	—	15	1	50
	T4	405-415	24-32	Air	—	—	—	21	3	60
	T6	405-415	24-32	Ditto	185-195	4-8	Air	21	1	65

Alloy grade	Conventional designation of heat-treatment	Annealing and hardening			Ageing			Mechanical properties		
		Heating temperature, °C	Holding, hrs	Cooling medium	Heating temperature, °C	Holding, hrs	Cooling medium	Tensile strength, kg/mm²	Elongation, %, minimum	Brinell hardness number
B. Wrought Alloys										
MA1	T2	340-400	3-5	Air	—	—	—	—	—	—
MA2	T2	Up to 400	3-5	Ditto	—	—	—	24	5	45
MA3	T2	320-380	4-8	Ditto	—	—	—	26	8	50
MA4	T2	320-350	4-6	Ditto	—	—	—	34	7	70
	T4	Step Treatment								
		330-340	2-3							
		375-385	4-10	Hot water	—	—	—	35	7	80
MA5	T2	350-380	3-6	Air	—	—	—	—	—	—
	T4	410-420	4-12	Hot water	—	—	—	34	15	64
	T6	410-420	4	Ditto	170-180	16-24	Air			
MA8	T2	280-320	2-3	Air	—	—	—	25	12	55

Notes. 1. For castings from МЛ5 alloy, with the side thickness above 12 mm, the hardening temperature is 415 to 425° C, the holding time being 16-24 hours.

2. Holding time is taken without the time interval necessary for the heating.

3. Holding time varies within the limits indicated, depending upon the mass of the article.

Table 100

Defects in Heat-treatment of Magnesium Alloys and Their Prevention

Defect	Symptom	Detection	Cause	Prevention
Low mechanical properties		1. Testing for mechanical properties 2. Microstructure inspection	Low heating temperature on hardening or insufficient holding time	Control of furnace run. Correction by repeated heat-treatment with strict compliance to schedule
Local fusing	1. Strongly oxidised metallic prills on the surface	Visual inspection	1. Coarse cast structure	1. Heating with preliminary preheating
	2. Minute surface gas cavities and internal microcavities	Microstructure inspection	2. Rapid heating on hardening 3. Non-uniform furnace temperature	2. Checking of furnace pyrometers 3. Lowering of heat-treatment temperature by 5-10° C
Oxidation on heating	Surface of the metal covered with powder from grey to black in colour. Minute cavities uncovered after sand-blasting	Visual inspection	1. Overheating or non-uniform furnace temperature 2. Air leakage 3. Water vapour present in the furnace	Similar to those on fusing plus protective atmosphere
Grain growth in cast alloys during heat-treatment	Bright spots on machined surface before and after oxidising	Visual inspection	During the casting process	Heating (prior to hardening) to 300° C for 1-2 hrs to remove internal stresses

Table 101

Chemical Composition of Aluminium Wrought Alloys

Grade	Chemical composition, %					
	Copper	Magnesium	Manganese	Silicon	Other elements	Aluminium
АМц	—	—	1.0-1.6	—	—	The balance
АМг	—	2.0-2.8	0.15-0.35	—	—	
АМг5п	—	4.7-5.7	0.2-0.6	—	—	
Д1	3.8-4.8	0.4-0.8	0.4-0.8	—	—	
Д6	4.6-5.2	0.65-1.0	0.5-1.0	—	—	
Д7	3.0-4.0	0.25-0.5	0.25-0.5	—	—	
Д16	3.8-4.9	1.2-1.8	0.3-0.9	—	—	
Д1П	3.8-4.5	0.4-0.8	0.4-0.8	—	—	
Д3П	2.6-3.5	0.3-0.7	0.3-0.7	—	—	
Д16П	3.8-4.5	1.2-1.6	0.3-0.7	—	—	
Д18П	2.2-3.0	0.2-0.5	—	—	—	
АВ	0.2-0.6	0.45-0.9	0.15-0.35	0.5-1.2	—	
АК	—	—	—	4.5-6.0	—	
АК2	3.5-4.5	0.4-0.8	—	0.5-1.0	Nickel 1.8-2.3 Iron 0.5-1.0	
АК4	1.9-2.5	1.4-1.8	—	0.5-1.2	Nickel 1.0-1.5 Iron 1.1-1.6	
АК4-1	1.9-2.5	1.4-1.8	—	—	Nickel 1-1.5 Iron 1.1-1.6	
АК6	1.8-2.6	0.4-0.8	0.4-0.8	0.7-1.2	—	
АК8	3.9-4.8	0.4-0.8	0.4-1.0	0.6-1.2	—	
АЛД	—	0.5-0.9	—	0.8-1.0	Iron 0.2-0.5	
Д12	—	0.8-1.3	0.9-1.4	—	—	
В95	1.4-2.0	1.8-2.8	0.2-0.6	—	Zinc 6.0 Chromium 0.2	

Note. Chromium may be substituted for manganese in the same amounts as the latter in alloy grades АМг and АВ.

Cast aluminium alloys with high magnesium content (АЛ8) are to be heated, on hardening, in air furnaces instead of saltpetre baths, because of inflammation hazard. The interval between the discharge from the furnaces and the cooling should be reduced to a minimum. The more complex the shape of the article the higher should be the temperature of the cooling medium.

Titanium and its alloys. While being low in specific gravity (4.5) titanium has great tensile strength and ductility, i.e., σ_b=45-60 kg/mm², elongation δ=25% (Tables 108, 109).

Commercial grade BT1 titanium and its alloys take on considerable cold working when rolled without heating (stamping, etc.), and they should be annealed in air atmosphere or vacuum to restore ductility.

Table 102

Approximate Heating Time On Hardening of Aluminium Wrought Alloys (Minutes)

Heating equipment	Thickness or diameter of work, mm									
	Up to 0.8	0.8-2.5	2.5-5.0	5-12	12-20	20-50	60	70	80	90
Saltpetre bath	8	10	12	15	30	40-60	60	70	80	90
Air electric furnace	12	20-30	40	80	90	110	130	130	180	180

Notes. 1. Holding time is counted off from the moment the furnace reaches requisite temperature after charging.

2. Holding time is reckoned bearing in mind the greatest cross-sectional dimension of the part.

3. Excessive holding of plated alloys impairs the properties of the plated layer.

4. In case of repeated hardening, the time of heating should be cut down by half.

Annealing temperature for plain titanium is 510-570° C, while that for titanium alloys is 650-750° C.

Finished articles and sheet stock are annealed at lower temperatures and reduced holding time as compared to half-finished products and bulky articles. Prolonged holding, especially at high temperatures, causes scaling and brittleness.

Zinc is annealed at 50-100° C whenever its softening is required. After annealing, the mechanical properties of zinc are: tensile strength σb=7-10 kg/mm²; elongation δ=10-20%.

Silver and silver-platinum alloys are annealed at 650-700° C with cooling being effected in water, preferably acidulated.

Table 103

Heat-treatment Schedules and Typical Mechanical Properties of Wrought Aluminium Alloys

Grade	Annealing		Hardening		Ageing		Mechanical properties		
	Heating temperature, °C	Cooling medium	Heating temperature, °C	Cooling medium	Heating temperature, °C	Holding time	Tensile strength, kg/mm²	Elongation, %	Brinell hardness number
АМц	350-410	Air or water	Not applied				13	20	30
АМг	350-410	Ditto	Ditto				20	23	45
АМг5п	340-370	Air	Ditto				27	23	70
Д1	340-370	Ditto	—	—	—		21	18	45
	—	—	495-510	Water	15-20	4 days	42	18	100
Д6	340-370	Air	—	—	—	—	22	15	50
	—	—	497-503	Water	15-20	4 days	46	15	105
Д16	340-370	Air	—	—	—	—	21	18	42
	—	—	495-505	Water	15-20	4 days	47	17	105
Д3П	340-370	Air	—	—	—	—	17	20	45
	—	—	490-500	Water	15-20	4 days	34	20	80
Д18П	340-370	Air	—	—	—	—	16	24	38
	—	—	490-505	Water	15-20	4 days	30	24	70

Table 103 continued

Grade	Annealing		Hardening		Ageing		Mechanical properties		
	Heating temperature, °C	Cooling medium	Heating temperature, °C	Cooling medium	Heating temperature, °C	Holding time	Tensile strength, kg/mm²	Elongation, %	Brinell hardness number
AB ("avial")	340-370	Air	—	—	—	—	13	24	30
	—	—	515-530	Water	150-160	6 hrs	33	12	95
AK	Not subject to above treatments								
AK2	350-460	Air	—	—	—	—	—	—	—
	—	—	510-520	Water	165-175	15-18 hrs	42	13	100
AK4	350-460	Air	—	—	—	—	—	—	—
	—	—	525-540	Water	165-175	15-18 hrs	44	10	110
AK6	350-460	Air	—	—	—	—	—	—	—
	—	—	505-515	Water	150-160	12-15 hrs	42	13	105
AK8	350-460	Air	—	—	—	—	—	—	—
	—	—	495-505	Water	175-185	5-8 hrs	49	13	130
AK9			520-535	Water	130-160	5 hrs	39	10	115
B95	420-440	Air	—	—	—	—	26	13	—
	—	—	465-475	Water	120-125	24 hrs	55	16	150

Table 104

Chemical Composition of Aluminium Foundry Alloys

Grade of alloy	Chemical composition, %					
	Silicon	Copper	Magnesium	Manganese	Other elements	Aluminium
АЛ1	—	3.75-4.5	1.25-1.75	—	Nickel 1.75-2.25	The balance
АЛ2	10.0-13.0	—	—	—	—	
АЛ3	4.0-6.0	1.5-3.5	0.2-0.8	0.2-0.8	—	
АЛ4	8.0-10.5	—	0.17-0.30	0.25-0.5	—	
АЛ5	4.5-5.5	1.0-1.5	0.35-0.6	—	—	
АЛ6	4.6-6.0	2.0-3.0	—	—	—	
АЛ7	—	4.0-5.0	—	—	—	
АЛ8	—	—	9.5-11.5	—	—	
АЛ9	6.0-8.0	—	0.2-0.4	—	—	
АЛ10В	4.0-6.0	5.0-8.0	0.2-0.5	—	—	
АЛ11	6.0-8.0	—	0.1-0.3	—	Zinc 10.0-14.0	
АЛ12	—	9.0-11.0	—	—	—	
АЛ13	0.8-1.3	—	4.5-5.5	0.1-0.4	—	
АЛ14В	6.0-8.0	1.5-3.0	0.2-0.6	0.2-0.6	—	
АЛ15В	3.0-5.0	3.5-5.0	—	0.2-0.6	—	
АЛ16В	3.0-5.0	2.0-4.0	—	0.2-0.5	Zinc 2.0-4.0	
АЛ17В	3.0-5.0	1.5-3.5	—	0.2-0.6	Zinc 4.0-7.0	
АЛ18В	1.5-2.5	7.5-9.5	—	0.3-0.8	Iron 1.0-1.8	
ВИ-11-3	0.8-1.5	—	10.5-13.0	—	Beryllium 0.07 Titanium 0.07	

Note. The letter B at the end of the alloy grade designation indicates that the castings are manufactured from pig aluminium foundry alloys.

Table 105

Time Interval During Which Ductility of Aluminium Wrought Alloys Is Preserved After Hardening

Grade of alloy	Time, hrs	Grade of alloy	Time, hrs
Д1	2-3	AB	2-3
Д6	1.5	AK6	2-3
Д16	1.5	AK8	2-3
AK4	2-3	B95	6
AK4-1	2-3		

Table 106

Conventional Designations, Varieties and Uses of Heat-treatments of Aluminium Foundry Alloys

Designation	Heat-treatment	Use
T1	Ageing at temperatures up to 200° C	For light-duty parts rapidly cooled when cast
T2	Annealing at temperatures up to 300° C	Dimensional stabilisation of parts and removal of stresses
T4	Hardening	Increase in ductility
T5	Hardening and partial ageing	Increase in strength and yield point
T6	Hardening and full ageing to maximum hardness	Attainment of both maximum strength and yield point
T7	Hardening and stabilising annealing at temperatures above 200° C	For parts working at elevated temperatures
T8	Hardening and softening annealing at temperatures above 300° C	For small parts requiring increased ductility with high magnesium content in the alloy

Table 107

Recommended Heat-treatment Schedules for Aluminium Foundry Alloys Treated in Air Atmosphere Furnaces

Grade of alloy	Conventional designation of heat-treatment	Hardening			Annealing, tempering and ageing			Mechanical properties		
		Heating tempera-ture, °C	Holding time, hrs	Cooling medium	Heating tempera-ture, °C	Holding time, hrs	Cooling medium	Tensile strength, kg/mm²	Elonga-tion, %	Brinell hardness number
АЛ1	T5	510-520	2-4	Water 50-100° C or air	210-230	2-4	Air	20	0.5	95
АЛ2	T2	—	—	—	280-300	2-4	Furnace to 50-80° C, then air	16	4	50
АЛ3	T1	—	—	—	175-185	5	Air	17	1	70
	T2	—	—	—	280-300	2-4	Ditto	12	—	65
	T6	510-520	5-12	Water 50-100° C	170-180	5	Ditto	21	—	75
	T7	510-520	4-6	Water 50-100° C	225-235	5	Ditto	20	1	70
	T8	510-520	4-6	Water 50-100° C	325-335	3-5	Ditto	18	2	65
АЛ4	T1	—	—	—	170-180	5-15	Ditto	20	1.5	70
	T6	530-540	5-8	Water 50-100° C	170-180	15	Ditto	23	3	70
АЛ5	T1	—	—	—	175-185	5-10	Ditto	16	—	65
	T6	520-530	5-8	Water 50-100° C	175-185	5	Ditto	20	0.5	70
	T7	520-530	5-8	Water 50-100° C	225-235	5	Ditto	18	1	65

Table 107 continued

Grade of alloy	Conventional designation of heat-treatment	Hardening			Annealing, tempering and ageing			Mechanical properties		
		Heating tempera- ture, C°	Holding time, hrs	Cooling medium	Heating tempera- ture, °C	Holding time, hrs	Cooling medium	Tensile strength, kg/mm²	Elonga- tion, %	Brinell hardness number
АЛ6	T2	—	—	—	280-300	3	Air	15	1	45
АЛ7	T4	520-530	10-15	Water 50-100° C	—	—	—	20	6	60
	T5	520-530	10-15	Water 50-100° C	145-155	2-4	Air	22	3	70
АЛ8	T4	430-440	10-12	Water or oil 50-100° C	—	—	—	28	9	60
АЛ9	T4	530-540	5-12	Water 50-100° C	—	—	—	18	4	50
	T5	530-540	5-12	Water 50-100° C	145-155	3-6	Air	20	2	60
АЛ10В	T1	—	—	—	175-185	—	—	17	—	90
	T6	530-545	2-6	Water 50-100° C	170-180	15	Air	13	—	80
АЛ11	T2	—	—	—	280-300	3		20	2	80
АЛ12	T6	530-545	2-6	Water 50-100° C	—	—	—	17	—	100
АЛ13	—	Not applied								
АЛ14В	T5	—	—	—	—	—	—	20	0.5	85
АЛ15В	T5	—	—	—	—	—	—	20	—	80
АЛ16В	T5	—	—	—	—	—	—	20	—	70
АЛ17В	T5	—	—	—	—	—	—	20	—	75
АЛ18В	—	Not applied								
ВИ-11-3	T4	420-430	10-24	Water 20-100° C	—	—	—	25	4	75

Note. The mechanical properties of heat-treated alloys, with the exception of АЛ3 and АЛ12, refer to sand castings. Strength characteristics of chill mould castings are superior to those above.

Table 108

Chemical Composition of Titanium Alloys

Grade of alloy	Basic components, %						Additions, % (max)					
	Al	Cr	Mo	Mn	V	Ti	Fe	Si	C	N	O	H
BT3	4-6.2	2-3	—	—	—	The balance	0.8	0.4	0.1	0.05	0.2	0.015
BT3-1	4-6.2	1.5-2.5	1-2.8	—	—		0.8	0.4	0.1	0.05	0.2	0.015
BT4	4-5	—	—	1-2	—		0.3	0.15	0.05	0.05	0.15	0.015
OT4	2-3.5	—	—	1-2	—		0.4	0.15	0.1	0.05	0.15	0.015
OT4-1	1-2.5	—	—	0.8-2.0	—		0.4	0.15	0.1	0.05	0.15	0.015
BT5	4-5.5	—	—	—	—		0.3	0.15	0.05	0.04	0.15	0.015
BT5-1	4-5.5	—	—	2-3	—		0.3	0.1	0.1	0.05	0.2	0.01
BT6	5-6.5	—	—	—	3.5-4.5		0.3	0.15	0.05	0.04	0.15	0.015
BT8	5.8-6.8	—	2.8-3.8	—	—		0.4	0.35	0.1	0.05	0.2	0.01

Table 109

Mechanical and Physical Properties of Titanium Alloys

Properties	Units	BT3	BT3-1	BT4	OT4	BT5	BT6	BT8
Tensile strength	kg/mm²	95-115	95-120	80-90	70-85	80-95	90-100	105-118
Yield point	kg/mm²	85-105	85-110	70-80	55-65	70-85	80-90	95-110
Limit of proportionality	kg/mm²	70-80	70-85	50-60	—	65-80	70-80	75-85
Relative elongation	%	10-16	10-16	15-22	15-40	12-25	8-13	9-15
Relative reduction of area	%	25-40	25-40	20-30	25-55	30-45	30-45	30-55
Resilience	kgm/cm²	3-6	3-6	—	3.5-6.5	3-6	4-8	3-6
Hardness		27-36*	27-36*	—	60-70**	—	320-360***	310-350***
Modulus of elasticity	kg/mm²	11,000	11,500	11,000-12,000	11,000-12,000	10,400	11,300	11,000
Modulus of shear	kg/mm²	4,250	4,300	4,200	4,000	4,250	—	4,250
Poisson's ratio		0.3	0.3	0.31	—	0.3	—	0.3
Shearing strength	kg/mm²	65-70	⩾65	—	—	65	—	65-70
Specific gravity		4.46	4.5	4.6	4.55	4.5	4.43	4.47
Electric resistance	ohm·mm²/m	1.58	1.36	—	—	1.08	1.6	1.61
Coefficient of linear expansion ($\times 10^6$)		8.4	8.6	8.5	—	8.0	8.41	8.4
Heat conductivity	cal/cm·sec·°C	0.017	0.019	0.02-0.03	0.02	0.018	0.018	0.017

* Rockwell scale C; ** Rockwell scale B; *** Brinell hardness number.

Chapter IX

FORGING OF FERROUS AND NON-FERROUS METALS

The present chapter considers heating, forging and cooling of blanks from ferrous and non-ferrous rolled stock.

1. FORGING OF STEEL

Heating rate. The heating of blanks prior to forging is carried out, as a rule, at a maximum rate (induction heating included). Rapid heating increases furnace throughput and reduces scaling. Slow preforging heating is employed for steels with low heat conductivity, namely:

1. For medium- and high-alloy steels greater than 50 mm in cross-section. Steels with total content of alloying elements exceeding 2.5% are regarded as medium-alloy steels, while high-alloy steels are those which contain over 10% of alloying elements.

2 For alloy steels with increased carbon content and high-carbon steels over 160 mm in cross-section.

3. For steels in stressed condition. Slow heating is generally ensured by charging the blanks in the lowest temperature zone, usually near the furnace door, and then by pushing it gradually towards the high temperature zone. Under all conditions heating should be uniform, excluding pronounced local overheating of the blanks. Charging in bulk is to be avoided and uniform distribution of the charge throughout the furnace ensured.

Forging temperature ranges and cooling conditions applicable to blanks are presented in Table 110. Steels attain best ductility in the temperature ranges indicated.

Too high temperatures at the beginning of forging cause overheating and burning. Completion of forging at temperatures considerably in excess of those mentioned in the table provokes grain growth and formation of cementite lattice and embrittles the steel. When forging is concluded at temperatures below those indicated in the table, steel becomes strain-hardened and cracks are possible.

Cooling rates indicated in the table ensure the best structure of the forgings. The formation of cementite lattice may take place even when high-carbon steel is very slowly cooled from normal temperatures. Therefore, these steels are cooled in the air down to 700° C, heating colour being as a guide, and then at a slower rate. Practically, this method is employed for forgings with thin sides, as well as with abrupt changes in section in which air-cooling from beginning to end may result in cracking.

Table 110

Approximate Temperatures for the Beginning and Completion of Forging and Cooling Schedules for Steel Blanks

Grade of steel	Temperature, °C		Cooling schedules for the below-mentioned dimensions			
	Beginning of forging	Completion of forging	Up to 50 mm	51-100 mm	101-200 mm	201-300 mm
Carbon Structural Steels						
Ст.0, Ст.1, Ст.2, Ст.3, 10, 15	1300	700	In the air			
Ст.4, Ст.5, 20, 25, 30, 35	1250	750	Ditto			
Ст.6, Ст.7, 40, 45, 50, 55, 60	1200	750	Ditto			
15Г	1250	800	Ditto			
20Г, 30Г, 10Г2	1230	800	Ditto			
40Г, 50Г, 60Г, 65Г	1200	800	In the air		In the pile	In the pit
30Г, 35Г2, 40Г2	1200	800	Ditto			
45Г2, 50Г2	1180	800	Ditto			
Alloy Structural Steels						
15X, 20X	1220	800	In the air			
30X	1220	800	In the air		In the pile	In the pit
35X, 38XA, 40X, 45X, 50X, 20X3	1200	800	Ditto			
15XФ, 20XФ	1250	800	In the air		In the pile	In the pit
40XФ, 50XФ	1230	800	In the air	In the pile	In the pit	In the furnace

12M, 15M, 20M	1260	800	In the air			
30M, 30XMA	1180	800	In the air		In the pile	In the pit
12XM, 15XM, 20XM	1200	800	In the air		In the pile	In the pit
35XM, 35X2M	1180	800	In the air	In the pile	In the pit	In the furnace
33XC, 37XC, 40XC	1200	850	In the air		In the pile	In the furnace
15XΓ, 20XΓ	1200	800	Ditto			
40XΓ, 50XΓ	1150	850	In the air	In the pile	In the pit	In the furnace
35XΓ2	1170	800	Ditto			
18XΓT, 18XΓM	1180	800	In the air		In the pile	In the pit
40XΓM, 55C2, 60C2	1200	825	In the air	In the pile	In the pit	In the furnace
27CΓ	1240	800	In the air		In the pile	In the pit
35CΓ	1200	800	Ditto			
20XΓC, 25XΓC	1220	800	Ditto			
30XΓC, 35XΓC	1180	800	In the air	In the pile	In the pit	In the furnace
30XΓCHA	1180	850	In the pile	In the pit		In the furnace
25H	1220	750	In the air		In the pile	In the pit
30H	1200	750	Ditto			
20XH	1200	800	In the air		In the pile	In the pit
40XH, 45XH, 50XH	1180	850	In the air	In the pile	In the pit	In the furnace
12XH2, 12XH3	1180	800	In the air		In the pile	In the pit
20XH3, 30XH3A	1170	850	Ditto			
37XH3A	1160	800	In the air	In the pile	In the pit	In the furnace
12X2H4	1160	800	In the air	In the air	In the pile	In the pit
20X2H4	1160	850	Ditto			
35XЮA, 38XMЮA	1100	800-850	In the air	In the pile	In the pit	In the furnace
35XMΦA	1160	850	Ditto			
25X2MΦA	1180	850	Ditto			
13XHBA	1200	820	In the pit		In the furnace	
18XHBA, 18XHMA	1180	820	Ditto			
25XHBA	1180	850	In the pit		In the furnace	
12X2H3MA, 18X2H4MA	1180	850	Ditto			

Table 110 continued

Grade of steel	Temperature, °C		Cooling schedules for the below-mentioned dimensions			
	Beginning of forging	Completion of forging	Up to 50 mm	51-100 mm	101-200 mm	201-300 mm
33XH3MA	1180	850	In the pit		In the furnace	
40XHM	1150	850	In the air	In the pile	In the pit	In the furnace
30XH2MΦA, 45XHMΦA	1180	850	In the pit		In the furnace	
13H2A, 13H5A, 21H5A	1160	800	In the air	In the pile	In the pit	In the furnace
Ball-bearing Steel						
ШX6, ШX9, ШX12, ШX15	1110	850	Cooling in the air			
ШX15CГ	1080	850	to 700° C, then in the pit			
Wear-resistant Steels						
Г13	1150	900	In the air			
Heat-resisting Stainless Steels						
1X13	1150	850	In the furnace			
2X13	1150	900	Ditto			
3X13, 4X13	1120	900	Ditto			

X17, X25, X28	1050	820	In the air
9X18	1050	950	In the furnace
0X18H10, 1X18H9, 2X18H9	1200	850	In the air
X23H13	1200	850	Ditto
X23H18	1180	850	Ditto
4X9C2	1200	900	In the furnace
X5M	1180	850	Ditto
3X13H7C2	1100	850	Ditto
4X18H25C2	1150	900	In the air
1X18H9T	1150	900	Ditto
X18H11Б	1150	900	Ditto
1X17H2	1150	900	In the furnace
X6CM, X7CM, 4X10C2M	1180	800	Ditto
4X14H14B2M	1160	850	In the air
X14H14CB2M	1100	850	Ditto

Carbon Tool Steel

У7, У7А	1130	800	In the air | In the pile | In the pit
У8, У8А	1120	800	Ditto
У9, У9А	1100	800	Cooling in the air to 700° C, then in the pit
У10, У10А	1100	820	Ditto
У11, У11А, У12, У12А	1080	820	Ditto
У13, У13А	1080	820	Ditto

Table 110 continued

Grade of steel	Temperature, °C		Cooling schedules for the below-mentioned dimensions			
	Beginning of forging	Completion of forging	Up to 50 mm	51-100 mm	101-200 mm	201-300 mm
Alloy Tool Steel						
7Х3	1150	820	Cooling in the air to 700° C, then in the pit			
8Х3	1110	820	Ditto			
9Х, Х, ХО9	1120	800	Ditto			
ХО5	1120	830	Ditto			
Х12, Х12М	1100	860	In the pits or in the furnace			
Х12Ф1	1120	860	Ditto			
Ф	1120	840	Cooling in the air to 700° C, then in the pit			
В1	1120	800	Ditto			
ХГ	1100	830	Ditto			
ХГС	1080	830	Ditto			
4ХС	1160	800	In the piles	In the pits		In the furnace
6ХС	1160	820	Ditto			
9ХС	1120	840	Cooling in the air to 700° C, then in the pit			
8ХФ	1100	860	Ditto			

85XΦ	1100	860		Ditto	
4XB2C, 5XB2C	1140	800	In the piles	In the pits	In the furnace
6XB2C	1150	820		Ditto	
5XBΓ	1160	800		Ditto	
9XBΓ	1120	820		Cooling in the air to 700° C, then in the pit	
XBΓ	1100	830		Ditto	
3X2B8	1160	850		Ditto	
4X8B2	1160	850		Ditto	
XB5	1100	850		Ditto	
5XHM	1200	850	In the piles	In the pits	In the furnace
5XΓM	1180	800		Ditto	
5XHT, 5XHB	1180	850		Ditto	
5XHCB, 5XHC	1180	870		Ditto	

High-speed Steels

P18, P9, P9Φ5, P10K5Φ5, P9K10, P14Φ4	1180	900-950	In the pits or in the furnace
P18K5, P18K0, P18Φ2, P18K5Φ2	1200	900	Ditto

Large and simple-shaped forgings from the steels mentioned above can be air-cooled to room temperature. To avoid cracks, no water is to be splashed on the hot forgings and, furthermore, the latter should never be thrown on a moist floor or metallic plates, or cooled in the draught. The higher the content of carbon and alloying elements in the steel, the greater care should be taken in dealing with the cooling schedule. Cooling pits should be filled with sand, ash or cinder. It is recommended to cool high-alloy steel forgings in pits with warmed-up sand or cinder; furthermore, each forging should be covered up separately.

Distinctive forging features of tool and high-alloy structural steels. To obtain most favourable structural characteristics and best mechanical properties, the steel should be forged from all sides, this being of great importance for high-alloy and high-speed steels larger than 50 mm in section, in order to disintegrate the carbides and to distribute them evenly over the entire forging.

The forging procedure should be started with rapid light strokes. As the work cools, the force of the strokes should be increased, the frequency remaining unchanged. Light strokes at the end of forging may cause cracks; at the same time, care should be taken to avoid overheating the steel which may result from too heavy blows. A correct forging schedule will ensure a through deformation of the forging and its slow cooling during the hot-working. Excessive feed of blanks per blow of hammer should be avoided to prevent internal cracks. No sharp angles should be allowed to appear in forging manipulations; if these angles appear they should immediately be hammered in because subsequent hammering may cause cracks at the cooled angles.

Table 111 lists forging defects of steel and their correction.

2. FORGING OF NON-FERROUS METALS

Table 112 presents the temperatures of hot working of copper and copper alloys.

Table 113 lists temperature ranges for forging aluminium alloys liable to plastic working. Alloys of grades Д6 and Д16 are not subject to forging. The alloys mentioned are forged only in exceptional cases, the utmost attention being given to the forging schedule.

All tools used for the forging of aluminium alloys, namely: strikers, dies, etc., should be preheated to 250-300°C. Forgings are to be cooled in a heated pit. It is not recommended to throw them on a cold floor. To avoid sticking of the alloys to the die, the surface of the latter is oiled with a lubricant consisting of 15-20% graphite and 85-80% oil (or fuel oil).

Table 114 presents temperatures ranges for the hot working of nickel and its alloys.

Table 115 presents temperature ranges for the forging of magnesium alloys subject to plastic working.

All tools used for the forging and stamping of magnesium alloys should be heated to 250-320° C. Forging and stamping should be effected by means of hydraulic and steam hydraulic presses, ensuring low deformation rates.

Table 111

Steel Forging Defects

Defect	Cause	Correction and prevention
Oxidation	Oxygen contained in furnace gases combines with iron	Furnace atmosphere control. Rapid heating of the metal and normal forging temperature range. In calculations the loss of metal through oxidation and waste is assumed to equal 2%
Decarburisation	Furnace gas oxygen combines with carbon. Decarburisation is promoted by silicon, tungsten, vanadium, molybdenum, contained in steel	Ditto
Surface cracks	Rapid cooling of the metal during and after forging	Local rapid cooling of forgings is to be avoided. Hammer in sharp angles, preheat the forging in time, avoid cooling in draughts, on damp floors, etc. Fine cracks should immediately be cut out
Internal cracks (forging cracks)	Poor-qualify metal, insufficient ductility of the blank core. Weak forging, excessive feed per hammer blow	Heat the blank through. Forge the piece quickly and vigorously. Feeding rate should average 3/4 of the diameter or side of the cross-section of the forged blank
Carbide lattice	Forging completed at too high a temperature. Slow cooling of hypereutectoid steels from forging temperatures	Strict compliance to forging temperature range. Correction: normalising from $Ac_m + 20$—$30°C$, then annealing according to schedules usual for the steels concerned

Table 111 continued

Defect	Cause	Correction and prevention
Flaky fracture characteristic of high-speed steels	Forging of high-speed steel completed at too high a temperature	Strict compliance to forging temperature schedule
Cracking of the blank	Burning of the metal	Control of forging temperature and holding time

Table 112

Temperature Ranges for the Hot Working of Copper and Copper Alloys

Grade	Temperature range, °C	Grade	Temperature range, °C
Copper	900-800	ЛС 60-1	820-780
Brasses		ЛС 59-1	780-640
Л96	850-775	*Bronzes*	
Л90	900-850	Бр.ОФ6.5-0.4	770-750
Л80	870-820	Бр.ОФ4-0.25	780-750
Л68	850-750	Бр.ОЦ4-3	750
Л62	850-750	Бр.А5	880-830
ЛС59	820-730	Бр.А7	880-830
ЛА77-2	770-720	Бр.АЖ9-4	850-750
ЛАН 59-3-2	750-700	Бр.АЖМц10-3-1.5	825-775
ЛЖМц 59-1-1	730-680		
ЛК 80-3	850-750	Бр.АЖН10-4-4	900-850
ЛМц 58-2	730-680		
ЛН 65-5	850-750	Бр.АМц9-2	850-800
ЛО 90-1	900-850	Бр.КМц3-1	850-800
ЛО 70-1	750-650	Бр.КН-1-3	910-890
ЛО 62-1	750-700	Бр.Мц5	850-800

Forging temperatures for titanium and its alloys are in the 800-900°C range. Heating prior to forging should be carried out in two stages to reduce scaling and prevent grain growth, first up to 700-750° C, and then to 900° C. Holding time for blanks at high temperatures should be as short as possible, averaging 30 sec at the most per 1 mm of the maximum thickness of the blank.

Table 113

Forging Temperatures for Aluminium Alloys

Grade	Temperature, °C	
	Beginning of forging	End of forging
АК2	470	380
АК4	470	380
АК6	470	380
АК8	460	400
В95	440	380
Д1	460	400
Д6	450	400
Д16	450	400

Table 114

Hot Working Temperatures for Nickel and Some of Its Alloys

Grade	Description	Temperature range, °C
НТ	Commercial nickel	1250-1140
НМц2.5	Manganese-bearing nickel	1250-1150
НМц5	Ditto	1150-1100
НМЖМц2.8-2.5-1.5	Monel metal	1150-975
МНЖМц30-0.8-1	Nickel silver	960-900
МН19	Ditto	1030-980
МН5	Copper-nickel alloy	1000-950
МНА13-3	Cunial А	980-750
МНА6-1.5	Cunial Б	980-750

Table 115

Forging Temperatures for Magnesium Alloys

Grade	Temperature, °C	
	Beginning of forging	End of forging
МА1	410	260
МА2	410	230
МА3	400	230
МА4	350	300
МА5	385	300
МА8	420	280

Chapter X

MANUFACTURE OF BUILT-UP CUTTING TOOLS

Built-up cutting tools are manufactured by means of butt welding of high-speed and structural steels for the shank tools, as well as by welding or brazing of cutting tips to the holders of single- or multi-point tools. Steels of grades 40, 45, 40X, 45X are usually used when manufacturing holders and shanks. Steel of grade У7 is also used for the holders of fine cutting-off tools.

Butt welding. It is effected in a butt-welding machine. The blanks should be descaled, cleaned from dirt and other deposits which prevent a perfect contact with the grips of the welding machine. Table 116 lists an approximate projection length for blanks, the melting allowance for the welding process included. Difference in the cross sections of welded blanks should not exceed 1 mm. If this difference surpasses 1 mm, then the larger blank should be machined to the diameter of the smaller one, on a length equal to approximately 3 or 4 welding allowances. The transition from the larger size to the neck should be filleted with a radius not less than 1-2 mm.

Table 116

Approximate Data on Projection Lengths and Allowances for Butt Welding

Blank diameter	Projection length, mm		Welding allowance, mm	
	High-speed steel	Structural steel	High-speed steel	Structural steel
Up to 10	6-8	10-12	3	2
10-20	8-10	12-15	4	2
21-25	10-12	15-18	4	2
26-30	12-14	18-22	4	2
31-35	14-16	22-24	4	3
36-40	16-18	24-28	4	3
41-46	18-20	28-32	5	3
46-50	20-22	32-38	5	3

Whenever it is necessary to weld blanks larger than those specified by the welding machine rating, the articles are recessed in the butts (Fig. 31) so as to reduce the cross-section, and then welded. An opening

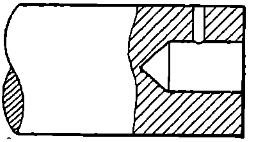


Fig. 31. Large-section blank machined in order to be welded on a machine of insufficient rating

3-5 mm in diameter should be provided in the recessed part to ensure the evacuation of gases.

Table 117

Dimensions of Shank Tools with Section Recessed for Butt Welding

Tool	Diameter of blanks, mm	Diameter of recessed section, mm
End milling cutter	30-35	14-16
	35-45	16-20
	45-55	20-25
	55-65	25-30
	65-75	30-35
	75-85	35-40
Drills, reamers, counterbores	30-35	14-20
	35-45	20-28
	45-55	28-35
	55-65	35-42
	65-75	42-50
	75-85	50-56

Table 117 presents recess diameters for various types and sizes of shank tools. In order to avoid cracks, the welded blanks are charged to a furnace at 730-760° C. Following charging the blanks are held over till the blanks charged last are heated through; after this, the blanks are removed to the air or cooled together with the furnace.

For structural steel, the quality of the welding is checked after annealing by knocking the blank twice, at a distance 5-8 mm from the welding seam, against the angle of a massive metallic plate, turning the blank 90° after the first blow. For high-speed steels, annealing is checked by means of the Rockwell hardness test at 2-4 mm from the seam. The hardness number should not exceed $R_C=25$.

Tips from high-speed steel are welded by the use of welding compounds, the composition of which is presented in Table 118. Welding compounds are prepared by grinding ferromanganese and other components to fine powder, sieved through a 0.2-0.3 mm mesh. The welded faces of the holder and tip should be machined but not ground to ensure the strength of the joint. The size of the tips should approximate that of the holder seat. If the tips are well trimmed, the work can be hardened immediately following welding, use being made of the welding heat. If the size of the tip does not fit the seat (particularly, when the tip is larger than the seat), burning of the tool may occur, and, therefore, the tools concerned should be hardened after sharpening.

Table 118

Composition of Welding Compounds for Welding High-speed Steel Tips

Application of compound	Ferromanganese, Mn 1	Borax or glass	Copper
1. For tools subject to sharpening only	67-80	33-20	—
2. For tools in which the welding seam is subject to various methods of machining	60-65	15-20	15-20

Brazing of carbide tips. The brazing of carbide tips is effected by the use of hard solders. Table 119 presents the composition of solders, recommended by a research institute VNII, as well as their applications. In shop practice, whenever the manufacture of complex solders meets with difficulties, brass is used for brazing multi-point tools while copper is employed for various other tools. The solder is used in the form of foil, thin wire, fragments cut from sheet or band, chips or filings. Fluxes, the composition of which is given in Table 120, are employed to prevent oxidising of the welded surfaces.

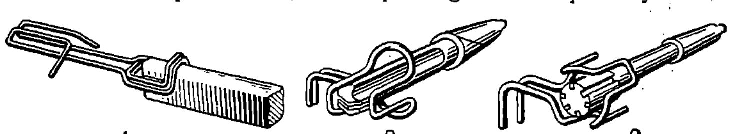
Commercial borax is generally employed when being calcined at 800° C prior to use and ground to fine powder. Calcined borax is to be kept in a well-plugged recipient so as to avoid air moisture absorption. Apart from powders, aqueous water solutions of fluxes are also used. They are prepared by dissolving 1 kg of the flux in 3-5 litres of water. The tools (chiefly with the slots for the tips being coated) are boiled for several minutes in such a solution prior to brazing.

The welded faces of the holder and tip should fit one another snugly. The clearance between the holder and the tip should not exceed 0.05 mm, while that between the sides of the slots in a multi-point tool and the tip should not exceed 0.15 mm. The tool tips are brazed in forges, furnaces, baths, resistance-welding machines and induced-heat installations. Brazing in an induced-heat installation is a highly productive operation, which is, moreover, noted for its up-to-date technical level.

Soldering Compounds Recommended for the Manufacture of Carbide Tip Tools and Their Applications

Soldering compound	Grade	Chemical composition, % (average content): Copper	Nickel	Manganese	Other elements	Zinc	Melting point, °C	Recommended application
Copper	M1	99.9	—	—	—	The balance	1083	Furnace brazing
Brass	Л62	61.5	—	—	—		905	Electrical brazing of light-duty tools of the BK group
Nickel brass	ЛН 58-5	58.5	5.0	—	—		850	Brazing of heavy-duty tools of the BK group
Manganese brass	ЛМц 58-5	58.5	—	4.25	Iron 0.75		850	Brazing of light-duty tools of the TK group
Nickel-manganese brass	ЛНМц 56-5-5	56.5	4.5	4.5	Ditto		900	Brazing of heavy-duty tools of the TK group
Aluminium-nickel-manganese bronze	Бр. АНМц 5-3-2	90.5	3.0	1.5	Aluminium 5.0		1100	

Fig. 32 shows inductors used for the brazing of cutting tools, as well as for the multi-point tools, each tip being brazed separately. This



A B C

Fig. 32. Inductors for heating by induced heat:
a — for brazing and welding of tips on to cutter holders; *b* — for brazing of drills; *c* — for brazing of reamers

method cannot be employed for gang milling cutters with negligible clearance between the tips, as tips, next to those soldered, will heat to a high temperature, thus causing spoilage of the work. A method for simultaneous brazing of carbide tip gang milling cutters in induced-heat installations is described below.

Table 120

Fluxing Compounds Recommended for Brazing Carbide Tools and Their Applications

Flux composition		Melting point, °C	Recommended application
Component	Amount in % by weight		
Commercial borax	100	741	Copper brazing of group BK tips
Commercial borax Boric acid	90 10	600-650	Brazing of group BK tips with low-melting solders
Commercial borax Potassium fluoride	70 30	800-850	Brazing of group TK tips with all solders, as well as brazing of carbide alloys onto chromium steels

A groove is made in a refractory brick, to the dimensions of the bottom inductor, with the aid of a cape chisel (Fig. 33). The brick 4, with the inductor 1 inserted in the groove, is placed on the table, fixed in a tapered bushing of the bottom part of the hydro-hoist of the Г3-46 apparatus (or on any other similar table mounted on any other type of apparatus).

The brick is covered with sheet asbestos 3, the milling cutter (which is "boiled" in a flux solution prior to the operation) is placed atop and the inductor is seated over the latter; after this the two inductors are clamped in the holder.

While clamping the upper inductor 2 should be slightly lifted, so as to avoid contact with the cutter. The bottom coil of the inductor 2 should clear the cutter by 2-3 mm. It is intended to heat the body of the milling cutter directly at the cutting tips. At the same time the latter are also heated through heat conduction.

The upper coil of the inductor 2 is situated 8-12 mm above the tips. Its destination is to ensure, in conjunction with the inductor 1, the initial heating of the body of the milling cutter and the tips and to melt the solder.

The rate of heating can be controlled by varying the spacing between the cutter and the inductor coils. For the bottom inductor, the said distance is adjusted by varying the thickness of the asbestos pad.

The brazing technique for multi-point cutter is simple enough:

1. The cutter is placed between the clamped inductors on the asbestos pad. To facilitate the operation, the upper inductor is forced slightly upwards.

2. The flux is spread additionally around the tips with the aid of a spatula.

3. Current is switched on and the cutter is heated through to approximately 800-900° C, after which heating is cut out and solder is added by means of tweezers. The hard solder is in the form of two half-rings fashioned to the diameter of the cutter (Fig. 33).

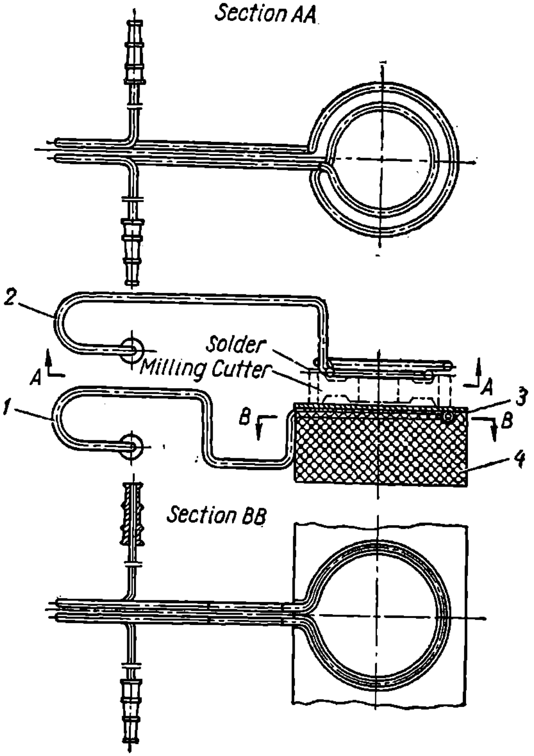


Fig. 33. Device for simultaneous brazing of multi-blade milling cutters with carbide tips on induced heat apparatus

4. Heating is switched on again and the cutter is brazed. The brazing of a 150 mm dia and 15-mm thick milling cutter with 16 tips takes 2-2.5 minutes. The solder fills the gaps entirely. Table 121 describes tool brazing defects and measures which should be taken to prevent them.

Table 121

Defects in the Brazing of Built-up Tools and Their Prevention

Defects	Cause	Prevention
	Manufacture of Brazed and Welded Tools	
The solder does not flow in the gaps	1. The gap between the sides of the groove and the tips is too large or too small 2. Insufficient heating	1. When assembling the tools the gaps should be limited to 0.05-0.15 mm. No continuity of calking is necessary 2. Normal heating temperatures and sufficient holding time should be ensured
The solder forms balls on melting	1. Presence of oxides on the brazed surfaces 2. Soldered surfaces have been ground or lapped	1. Sufficient amounts of flux should be fed 2. The soldered faces should not be ground or lapped
Voids under the tips	1. Maladjustment of tips and holders 2. Switching on and off of current after the melting of solder 3. Premature pressing of the tip	1. Clearances and curvatures should be up to the recommended values 2. After the hard solder has started melting, the current should not be switched off till the termination of brazing 3. The tip should be pressed after full melting of the hard solder
Blackening of the seam	1. Insufficient feed of flux 2. Insufficient heating	1. Sufficient amounts of flux should be fed 2. Normal heating temperatures and sufficient holding time should be ensured

Defect	Cause	Prevention
Burning of the holder at the point of contact with the electrode	1. Contact surface is too small 2. Weak contact 3. High degree of heating and prolonged holding	1. Contact area should be equal to the product of the holder width at the point of contact by the thickness of the tip 2. Contact pressure on the holder should be increased 3. Heating temperature and holding time should be decreased
Cracks in carbide tips	1. Rapid cooling after brazing 2. Contact between the electrode and the tip 3. Non-uniform heating of tip because of great thickness	1. Slow cooling after brazing should be ensured 2. Electrode should be lowered to prevent contact with the tip 3. Reduce the thickness of the tip
Manufacture of Butt-welded Tools		
Incomplete penetration	1. Too low heating temperature 2. Insufficient upsetting strength	1. The work should be heated till the butts melt 2. Sharp upsetting is required
Voids	Insufficient upsetting because of too low machine power rating	The work is to be welded in a machine of adequate rating or the blanks should be recessed according to Table 115
Annular cracks in high-speed blanks at 1-3 mm from the welded seam	Local welding stresses are caused by too rapid cooling of the welded blank	After welding the blank should be immediately charged to a furnace and then, after holding, cooled with the furnace

Table 121 continued

Defect	Cause	Prevention
Overheating	Excessive heating of the blanks	1. Keep strictly to the projection lengths recommended in Table 114 2. Follow strictly the heating schedule

Chapter XI

EQUIPMENT, FUEL AND ACCESSORY MATERIALS FOR HEAT-TREATMENT SHOPS

1. FURNACES

According to the fuel used, furnaces can be of the solid-fired, liquid-fired, gas-fired or electrically heated type.

Solid-fuel furnaces are used only when other types of furnaces are not available.

Table 122 presents technical data on electric furnaces.

Metallic resistors (Table 123) are used for furnaces with working temperatures up to 1100° C, while carborundum resistors (Table 124) are used for those with higher temperatures.

In three-electrode СП-2 and СП-3 bath-type, salt furnaces, the electrodes are set on the walls of the working space at approximately 120° to each other. On heating, the current passes through the heated work and, as the resistance of the metal is lower than that of the salt, overheating of the article can occur, especially if the latter is nearer than 25-30 mm to the electrodes.

Bath-type C-20, C-25 and C-45 furnaces with submerged electrodes are provided with one pair of electrodes each, the latter being situated near the wall at 12 to 25 mm from each other. With this arrangement of electrodes, the current does not flow through the work and there is no danger that the latter would be overheated. The fact that the electrodes are spaced at a short distance from each other gives rise to powerful electromagnetic fluxes, which mix the salt and equalise its temperature. Large C-50 and C-100 bath-type furnaces are provided with three pairs of electrodes each situated near the back wall.

Another advantage of the bath-type furnaces with submerged electrodes is the possibility of changing the electrodes during the run of the furnace (hot reconditioning). After relining, bath-type furnaces can best be dried with the aid of electric heaters. The working space, where the heater is placed, should be covered with asbestos. Drying is continued till the furnace shell heats to approximately 50-60°C; drying time for the СП-2 furnace averages 30-40 hours. When drying by wood or coal, air should be fed to the bottom part of the working space to ensure adequate combustion; otherwise, the fuel will smoulder with ensuing poor drying of the furnace and possible eruption of the salt on its initial melting. Steels of the heat-resisting grade X23H13.

Table 122

RATINGS OF ELECTRIC FURNACES USED FOR HEAT-TREATMENT OF METALS

Furnace type	Power rating, kW	Working space dimensions, mm			Overall dimensions, mm			Total weight, metric tons	Maximum working temperature, °C	Maximum throughput, kg/hr	Comments
		Width or diameter	Length	Height	Width	Length	Height				
Chamber Furnaces with Metallic Heating Elements											
a) For Operation in Air Atmosphere											
H15	15	300	650	250	1,100	1,600	1,440	1.2	950	50	
H30	30	450	950	450	1,400	1.790	2,020	2.2	950	125	
H45	45	600	1,200	500	2,050	2,250	2,000	3.8	950	200	
H60	60	750	1,500	550	2,200	2,560	2,450	5.0	950	275	
H75	75	900	1,800	600	2,360	2,860	2,500	6.2	950	350	
НШ-100A	100	970	1,820	600	2,280	5,030	2,440	9.5	860	300	Furnace with spherical hearth and carriage
b) For Operation in Controlled Atmosphere											
H20X40	8	200	400	140	710	1,105	660	0.29	950	15	Heating elements situated on roof, sidewalls and hearth
H25X50	12	250	500	170	820	1,245	760	0.4	950	30	

H30X65	18	300	650	200	870	1,395	790	0.5	950	50	Heating elements situated on roof, sidewalls and hearth
H30X45	12	300	450	200	870	1,195	790	0.4	1000	25-35	
H40X80A	30	400	800	260	1,550	1,860	1,960	1.6	1000	80	
H40X55	18	400	550	260	1,550	1,610	1,960	1.4	1000	50-70	
H50X100	45	500	1,000	320	1,650	2,240	2,135	2.35	1000	150	Heating elements situated on roof, sidewalls, hearth, doors
H50X65	24	500	650	320	1,650	1,890	2,135	2.1	1000	90-120	
H65X130	70	650	1,300	400	1,800	2,460	2,135	3.3	1000	220	
H65X90	36	650	900	400	1,800	2,060	2,135	3.0	1000	130-170	
H85X170	170	850	1,700	500	1,900	2,800	2,280	5.3	950	400-450	
H85X110	110	850	1,100	500	1,900	2,200	2,280	4.8	1000	230-280	
НШ-100В	100	910	1,825	615	2,185	5,400	2,483	9.5	860	300	Furnace with spherical hearth and push-type carriage

Chamber Furnaces with Carborundum Heating Elements

ОКБ-333С	15	250	360	200	1,200	1,140	1,400	0.75	1300		
Г30	30	300	400	250	1,500	1,600	1,770	2.1	1300	50	
ОКБ-210	50	520	945	400	1,450	2,100	2,000	3.6	1300	120	
ОКБ-194А	19	$\frac{325}{250}$	$\frac{410}{360}$	$\frac{180}{175}$	1,350	1,325	1,800	1.5	$\frac{850}{1300}$	25	A two-chamber furnace. Data in the numerators refer to the bottom chamber, those in the denominators—to the upper chamber

Table 122 continued

Furnace type	Power rating, kW	Working space dimensions, mm			Overall dimensions, mm			Total weight, metric tons	Maximum working temperature, °C	Maximum throughput, kg/hr	Comments
		Width or diameter	Length	Height	Width	Length	Height				
Shaft-type Hardening Furnaces											
Ш30	30	450	—	800	1,690	1,670	1,900	2.1	950	140	
Ш35	35	300	300	1,200	1,550	1,500	2,290	3.0	950	125	
Ш55	55	300	300	2,000	1,550	1,550	3,000	4.2	950	230	
Ш70	70	600	—	2,500	2,320	2,780	4,120	6.4	950	330	
Г65	65	300	300	1,470	1,500	1,500	2,820	4.7	1300	225	
Г95	95	300	300	2,210	1,500	1,500	3,550	5.8	1300	265	
Shaft-type Tempering Furnaces											
ПН-31 (ПН-31Б)	24	400	—	500	1,460	1,430	1,900	1.5	650	100	
ПН-32	36	500	—	650	1,540	1,540	2,090	1.8	650	280	
ПН-34	75	950	—	1,220	2,530	3,260	3,040	5.6	650	550	
Shaft-and Muffle-type Carburising Furnaces											
Ц25	25	300	—	450	1,420	1,790	1,980	2.3	950	50	Single charges in kg
Ц35	35	300	—	600	1,420	1,790	2,320	2.5	950	100	
Ц60	60	450	—	600	1,590	1,970	2,390	3.6	950	150	
Ц75	75	450	—	900	1,590	1,970	2,760	5.0	950	220	
Ц90	90	600	—	900	1,770	2,170	2,880	6.7	950	400	
Ц105	105	600	—	1,200	1,770	2,170	3,220	7.7	950	500	

				Shaft-type Muffleless Gas-carburising Furnaces							
ШЦН20	20	300	—	450	1,370	1,865	2,295	1.8	1050	50	Single charges in kg
ШЦН45А	45	450	—	600	2,010	2,120	3,115	3.7	1050	150	
ШЦН65А	65	450	—	900	2,010	2,120	3,325	4.0	1050	220	
ШЦН95А	110	600	—	1,200	2,160	2,270	3,870	5.2	1050	500	
				Shaft-type Nitriding and Cyaniding Furnaces							
ОКБ-3016	10	200	—	300	900	900	1,000	—	650	80	
ОКБ-3017	24	320	—	480	1,100	1,300	1,635	—	650	150	
ОКБ-3018	60	500	—	750	1,620	1,900	2,220	—	650	400	
ОКБ-3019	120	800	—	1,200	1,970	2,200	3,000	—	650	1200	
ОКБ-3020	100	750	2,300	950	1,970	8,600	3,795	—	650	1250	
				Bath-type Furnaces with Metallic Heating Elements							
В-10	10	200	—	350	1,160	—	1,800	0.9	850	30	
В-20	20	300	—	535	1,380	—	2,000	1.3	850	80	
В-30	30	400	—	555	1,450	—	2,260	1.6	850	130	
				Bath-type Electrode Furnaces							
С-20	20	220	—	460	905	—	1,820	1.0	1300	90	
С-25	25	380	—	475	1,100	—	2,190	1.3	850	90	
С-45	45	340	—	600	1,100	—	2,100	1.3	1300	200	
С-50	50	600	900	450	1,750	2,020	1,310	2.6	600	100	
С-100	100	600	900	450	1,650	1,650	1,320	3.0	850	160	
СП-2-35	35	220	—	420	1,000	—	1,820	0.9	1300	30	
СП-3-75	75	340	—	580	1,100	—	2,090	1.6	1300	55	
				Conveyor-type Hardening Furnaces							
К-90	90	375	3,220	200	2,650	6,325	2,075	12.48	875	180	
К-130	130	375	4,180	200	2,650	7,285	2,090	14.43	875	270	
К-170	170	575	5,140	200	2,850	8,245	2,990	17.23	875	380	

Table 122 continued

Furnace type	Power rating, kW	Working space dimensions, mm			Overall dimensions, mm			Total weight, metric tons	Maximum working temperature, °C	Maximum throughput, kg/hr	Comments
		Width or diameter	Length	Height	Width	Length	Height				
Conveyor-type High-tempering Furnaces											
K-65	65	375	4,200	415	2,240	6,350	2,780	14.5	700	200	
K-95	95	600	4,200	415	2,440	6,350	2,975	16.05	700	270	
K-135	135	575	6,120	415	2,440	8,910	2,975	20.3	700	380	
Conveyor-type Low-tempering Furnaces											
KO-35	40	400	4,690	400	1,990	6,680	2,220	9.0	250	130	
KO-55A	55	575	7,460	415	2,355	9,415	2,700	16.0	350	270	
KO-75A	75	775	7,460	415	—	—	—	18.0	350	380	
Pusher-type Hardening and Annealing Furnaces											
T-100Б	100	600	3,070	400	1,960	9,355	2,300	15.43	950	250	
T-140M	155	600	4,550	400	3,400	9,880	2,300	15.5	950	350	
T-240B	240	1,400	5,440	400	—	—	—	38.0	950	650	
T-300	300	1,200	7,900	400	2,610	12,300	2,300	30.0	780	500	Annealing furnace
Pusher-type High-tempering Furnaces											
T-65	65	600	3,070	400				13.8	650	250	
T-85	85	600	4,550	400	3,235	9,715	2.295	17.0	650	350	
T-165Б	165	1,400	6,515	400	2,738	10,125	3,000	31.0	700	650	
Pusher-type Low-tempering Furnaces											
TO-45	45	600	4,625	400	3,230	8,190	2,570	9.3	250	350	

					Barrel-type Hardening and Annealing Furnaces						
ОКБ-130С	19	400	—	2,750	1,330	4,850	1,750	2.1	180	30	
ОКБ-128С	30	200	—	1,200	2,300	4,785	3,040	5.2	830	30	
Б-70	70	310	—	2,000	1,350	5,700	3,735	9.0	920	160	
					Pusher-type Furnaces for Heating Work in Hydrogen Atmosphere						
ЦЭП-214	25	250	1,000	98	1,390	5,800	1,920	2.7	1500	—	
ЦЭП-219А	12	58	—	620	1,000	2,540	1,800	0.9	1750	—	
ЦЭП-220А	20	100	—	750	1,250	3,370	1,800	1.6	1400	—	
					Vacuum Furnaces						
ОКБ-704	15	300	—	350	1,700	2,250	2,500	2.0	1200	—	
ЦЭП-245	35	220	—	450	1,050	1,675	1,290	0.8	1100	—	
ЦЭП-301	50	250	—	370	1,750	2,260	1,900	2.14	1300	—	
ОКБ-744	100	800	1,090	—	4,500	3,740	5,940	4.14	1000	—	
ОКБ-745	190	1,100	1,780	—	4,670	4,070	6,100	7.5	1000	—	
					Oil Baths						
МВ-21	6/3	350	300	280	580	380	620	0.1	300	—	Capacity 21 litres
МВ-40	8/4	450	350	350	680	430	690	0.1	300	—	Capacity 40 litres
					Laboratory-type Furnaces Used in Heat-treatment Shops						
МП-0	1.75	137	210	85	445	430	485	0.042	1000	—	Temperature control through a rheostat
МП-1	1.75	137	210	85	445	492	485	0.04	1000	—	Automatic temperature control
МП-2	2.6	175	263	95	525	603	566	0.06	1000	—	Automatic temperature control
Ш-0.05	1.1	410	390	—	585	570	700	0.55	250	—	Automatic temperature control

Notes. 1. Furnaces equipped with metallic heating elements are fed directly from the 220 or 380 V mains. Electrode-equipped furnaces, as well as those with carborundum heating elements, necessitate step-down transformers.

2. Pusher-type T-240B and T-165Б furnaces admit two pans each on the width of the working space.

3. Crucibles for alkali baths as well as mixers should be manufactured rather from carbon than stainless steel.

etc., as well as of low-carbon grade 10, 15, 20, Ст.2, etc., are used for the manufacture of the electrodes of bath-type furnaces.

Table 125 shows comparative data presented by the "Frezer" Works and relating to electrode durability in three- and two-electrode bath-type furnaces. The author considers these data as somewhat undervalued. Thus, a C-20 furnace in the plant, the author is connected with, has shown a run of 16 days (a total of 106 hours) at 1220-1260°C between replacements of electrodes.

Of great importance, when consumption of electrodes in two-electrode furnaces is considered, is the furnace start-up method. The elec-

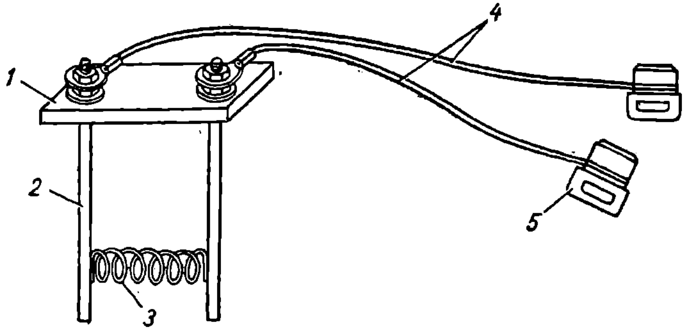


Fig. 34. Coil for melting of salt in salt baths:
1—asbestos-cement; 2—pin; 3—coil from Ø 4 mm, 1-1.6 m wire; 4—ПРГ wire; 5—contact blade

trodes crumble generally during the start-up of the furnace, the trouble spot being the line of contact of graphite powder with the electrodes. The furnace is heated up at the highest voltage, and if contact between the graphite powder and the electrode is lost, an arc strikes up and destroys the electrode. To reduce electrode wear, the heating-up operation should be carried out at the highest voltage only to the moment when the salt melts between the electrodes, after which graphite should be immediately removed and the voltage lowered. The most efficient method for initial, as well as repeated starting up of a submerged-electrode furnace is with an electric heating coil. After the melting of the salt, the coil is removed and subsequent heating is effected through electrodes. At the end of operation, after the furnace has been switched off, the coil is immersed in the molten salt to a 10-30 mm depth, and the salt solidifies. Repeated starting of the furnace necessitates only the switching-on of the coil current.

Motor generators as well as vacuum-tube oscillators are used to heat up articles by means of high-frequency current.

Tables 126 and 127 present technical data on motor generators and vacuum-tube oscillators manufactured in the Soviet Union.

Motor generators are used for heating up articles larger than 16 mm in diameter, the depth of the hardened layer being not less than 2 mm. Vacuum-tube oscillators are generally employed for heating up minute

Table 123

Properties of Metallic Resistors

Grade of alloy	Maximum working temperature, °C	Specific resistance in ohm·mm²/m
Х15Н60	1000	1.10
Х20Н80	1100	1.15
Х20Н80Т3	1150	1.27
Х13Ю4	1000	1.26
0Х23Ю5А	1200	1.35
0Х23Ю5	1200	1.35
0Х25Ю5	1200	1.40

Table 124

Chemical Composition and Properties of Carborundum Resistors

Type	Chemical composition, %							Maximum temperature, °C	Specific resistance in ohm·mm²/m at 20°C
	SiC	SiO	C	Al	Fe	Si	CaO + MgO		
Silit	94.4	3.6	0.3	0.2	0.6	0.3	0.6	1500	1,000-2,000
Globar	96.0	1.5	0.6	0.3	0.7	0.3	0.6	1500	930-1,950

Table 125

Comparative Data on Durability of Electrodes in Bath-type Furnaces

Working temperature, °C	Electrode durability in days	
	Three-electrode furnaces	Furnaces with submerged electrodes
Up to 600	—	40-50
From 600 to 1000	90-110	18-24
From 1000 to 1300	10-13	1.5-2

and odd-shaped parts, the depth of the hardened skin averaging from a fraction of a millimetre to 2-3 mm.

Tubular-type ТЭН heaters are most efficient for the heating of saltpetre, alkalis, oil and other materials used in heat-treatment technology.

Tubular-type electric heaters are curved tubes from carbon or stainless steels, which house insulated electric heating coils. The length and the power rating of the heating unit, as well as the tube material are selected in accordance with the bath volume, heating temperature and the composition of the material to be heated. Table 128 lists approximate data which may be used as a guide for the choice of tubular-type heaters.

The feeding of protective atmosphere to furnaces can be effected by an endothermic gas generator, type ОКБ-724, having the following rating:

Output	30 m^3/hr
Power rating	30 kW
Voltage	220/380 volts
Phases	3/1
Connection of resistors	Star/Series
Working temperature	1050-1100°C
Composition of protective atmosphere:	
hydrogen	36-40%
carbon dioxide	18-20%
nitrogen	The balance
Raw materials	Natural gas, town gas, reduced propane-butane compounds
Raw gas consumption	6 m^3/hr
Overall dimensions:	
width	1,440 mm
length	2,350 mm
height	2,500 mm
Weight	2,750 kg

The dimensions of bath-type furnaces working on liquid or gas fuels are standardised (Table 129).

Tables 130 and 131 indicate types of burners which have found widest industrial use.

Approximate furnace throughput rates are presented in Table 132.

2. REFRACTORIES

Firebrick is chiefly used for the building and re-lining of heat-treatment furnaces.

Electric furnace lining is patched with special-shaped refractory brick or with plain firebrick shaped to the configuration desired.

Lutes composed of 25% fireclay and 75% crushed firebrick are used for overhauls.

Data on thermal insulating materials and refractories are given in tables 133 and 134.

3. FUELS

Fuel oil with approximate calorific power of 9,600 kcal/kg is used as liquid fuel.

Various gases are used as gas fuels, the composition and calorific power of which are presented in Table 135.

Table 126

Technical Data on МГЗ-type High-frequency Hardening Installations

Type of installation	Installation equipment: Name	Installation equipment: Designation	Power rating, kW	Frequency, cps	Overall dimensions, mm: Width	Overall dimensions, mm: Length	Overall dimensions, mm: Height	Weight, tons	Cooling water consumption, m³/hr
МГЗ-52	1. High-frequency generator:	ГС-50Х1/2.5							
	a) High-frequency converter	ПВ-50/2500	50	2500	1040	1120	1040	2.1	—
	b) Driving motor starter	БН5121-35А2							
	2. Induced-heat hardening installation	ЗС-50/2.5	50	2500	1325	2280	2135	2.0	4.5
МГЗ-102	1. High-frequency generator:	ГС-100Х1/2.5							
	a) High-frequency converter	ПВС-100/2500	100	2500	1040	1495	1040	2.5	
	b) Auto-transformer starter	ОКБ-442-2							
	2. Induced-heat hardening installation	ЗС-100/2.5	100	2500	1325	2280	2135	2.0	4.5
МГЗ-108	1. High-frequency generator:	ГС-100Х1/8							
	a) High-frequency converter	ПВВ-100/8000	100	8000	1150	1685	1110	16.5	1
	b) Auto-transformer starter	ОКБ-442-2							
	2. Induced-heat hardening installation	ЗС-100/8	100	8000	1325	2280	2135	2.0	4.5

Notes. 1. Type ЗС induced-heat installation is composed of the following units: hardening, hardening control and pouring and high-frequency contactor.

2. Type ГС generator comprises (save the converter and the starter): measuring instruments desk, control unit and contactor board.

3. All three installations are supplied either as a complete unit (МГЗ-52АК, etc.) or in separate racks (МГЗ-52АБ, etc.). The latter differs from the complete installation in that the high-frequency transformer ТВД-2 and the condenser battery are situated in separate racks, which widens the possibility of incorporating the installation in hardening machines and automated productio lines.

Table 127

Technical Data on Vacuum-tube Oscillator

Type of oscillator	Power rating, kW	Frequency, cps	Overall dimensions, mm			Weight, tons	Cooling water consumption, m^3/hr
			Width	Length	Height		
ЛГЗ-10А	8	300-450	1,000	1,170	2,150	0.75	0.54
ЛЗ-13	10	300-450	1,020	1,120	2,050	0.85	1.2
ЛЗ-37	30	60-74	4,020	2,200	2,250	2.7	1.75
ЛПЗ-37	30	60-74	4,020	8,550	2,250	3.2	2.0
ЛЗ-67	60	60-74	4,020	2,200	2,250	3.1	2.25
ЛПЗ-67	60	60-74	4,020	3,400	2,250	3.4	2.5
ЛЗ-107	100	60-74	4,120	2,200	2,250	3.8	2.25
ЛЗ-207	200	60-74	4,620	2,800	2,500	6.0	7.0

Table 128

Technical Data on Tubular-type Electric Heater

Designation	Overall length of the tube, metres	Power rating, kW	Tube material	Application
НММ, НВ, НП	From 0.5 through 6 m, (11 sizes with gradations every 0.5 m)	From 0.5 to 7	Carbon steel	Heating of air, water and oil
НВГ	From 2 through 6 m (8 sizes with gradations every 0.5 m)	From 2 to 7	Carbon steel	Heating of alkalis and salt solution
НСЖ, НМЖ, НВЖ	From 2 through 6 m (8 sizes with gradations every 0.5 m)	From 2 to 7	Stainless steel	Heating of saltpetre and salt

4. TEMPERATURE CONTROL INSTRUMENTS

Manometric thermometers are used to measure, record and control temperatures in low-annealing bath-type furnaces and isothermal hardening tanks.

A manometric thermometer comprises essentially a thermal bulb, a capillary, a tubular spring and indicating or recording devices.

Table 129

Technical Data on Fuel-oil and Gas Bath-type Furnaces

Designation of bath-type furnaces		Crucible dimensions, mm		Crucible weight, kg	Average throughput, kg/hr
Gas-fired	Fuel-oil-fired	Diameter	Depth		
ПТВГ-1	ПТВМ-1	200	350	49	20
		200	535	73	35
ПТВГ-2	ПТВМ-2	250	350	62	35
		250	535	86	50
		250	610	95	60
ПТВГ-3	ПТВМ-3	300	535	130	70
		300	610	146	80
ПТВГ-4	ПТВМ-4	400	535	160	100
		400	610	210	125

Manometric thermometers are classified as gas thermometers (filled with nitrogen), liquid thermometers (filled with xylene, mercury or methyl alcohol) or steam thermometers (filled with a liquid turning to steam at a definite temperature).

Table 138 lists data on manometric thermometers used in heat-treatment departments.

Temperatures from —200° to +500°C are also measured with resistance thermometers known for their very accurate readings. These thermometers are manufactured either from platinum resistance wire, the ЭТП type, with 11-a and 12-a scales and measurement range from —200° to +500°C, or from copper resistance wire, the ЭТМ type, with 2-a scale and measurement range from —50° to +15°C. The many types of resistance thermometers available are classified according to design, application and temperature ranges. Thermometers are manufactured with protective sheaths from low-carbon or heat-resistant steels, from 0.5 to 2 m in length. Indications provided by resistance thermometers are read with the aid of measuring instruments (Table 137).

Thermocouples are the most widely used means for measuring temperatures (Table 138). Table 139 lists and describes briefly pyrometer millivoltmeters (galvanometers) operating in conjunction with thermocouples and telescope of radiation pyrometers. Care should be taken that the graduation of thermocouples and galvanometers be similar. Thermocouples are to be connected to measuring instruments by means of compensating leads, or, when the latter are not available, with plain insulated copper conductors.

Compensating leads are manufactured in impregnated cotton sheath—the КПО brand, in lead sheath—the КПС brand, in steel wire

Table 130

Technical Data on Burners

Type of burners		Nozzle diameter, mm	Capacity in kg/hr at air pressure of, mm water gauge							Diameter of air main, mm
			150	300	400	450	500	600	700	
One-stage, large-capacity	ФОБ-1	16	2	3	4	—	4.2	—	—	38
		20	3	3.7	6	—	7	—	—	
	ФОБ-2	20	4	5.5	7	—	8	—	—	50
		26	5	8	10	—	12	—	—	
	ФОБ-3	45	14	21	25	—	27	—	—	75
		50	17	25	30	—	33	—	—	
	ФОБ-4	70	25	25	41	—	45	—	—	100
		80	32	45	51	—	56	—	—	
Two-stage, large-capacity	ФДБ-1	50	—	—	—	20	22	24	25	50
	ФДБ-2	64	—	—	—	30	34	37	40	75
	ФДБ-3	70	—	—	—	48	52	56	60	100
	ФДБ-4	90	—	—	—	76	82	89	95	125
Low-pressure	А-40	40	—	16	18	—	20	22	24	—
	А-30	30	—	11	13	—	14.5	16	17	65
	А-60	60	—	38	44	—	50	55	58	100
	А-52	52	—	32	36	—	41	46	49	—
	А-75	75	—	54	62	—	69	76	81	125
	А-95	95	—	80	95	—	105	115	120	150
	А-125	125	—	135	148	—	170	185	205	200

Table 131

Thermal Characteristics of Low-pressure Long Flame Gas Burners

Type of burner		Capacity, m^3/hr	Diameter of gas and air mains, mm		Pressure in mm water gauge and velocity in m/sec		Size of gas-air mixture nozzle, mm
			gas main	air main	gas	air	
With separate gas and air feeds	ГЩ-1	5-15	25	25			22.5×50
	ГЩ-1½	10-30	37	37	50-100	100-200	21×75
	ГЩ-2	20-60	50	50	10-15	15-20	24.5×118
	ГЩ-2½	40-100	63	63			24.5×118
Slot type	ГЩ-3	60-140	75	75			53×120
	ГЩ-4	100-200	100	100	50-100	100-200	58×150
	ГЩ-5	150-300	125	125	10-15	15-20	68×183
Tangential with turbulent flame	ГТН-1	50-100	50	65	Not less than	Not less than	ø70
	ГТН-2	100-200	65	80			ø90
	ГТН-3	150-300	85	100	80-100	100-150	ø115
	ГТН-4	200-400	100	125	10-15	15-20	ø140
	ГТН-5	300-600	125	150	Mixture velocity		ø170
	ГТН-6	500-1000	150	170	10-12 m/sec		ø200
With turbulent flame	ГТ-1	100	67	80	Not less than	Not less than	ø80
	ГТ-2	160	85	100	80-100	100-150	ø100
	ГТ-3	250	106	125	10-15	15-20	ø125
	ГТ-4	400	132	160	Mixture velocity		ø160
	ГТ-5	630	170	200	10-12 m/sec		ø200
	ГТ-6	1000	212	250			ø250

Table 132

Approximate Furnace Throughput Rates (in kg/m²hr) for Various Heat-treatment Operations

Heat-treatment operation	Heat-treatment furnaces				
	Chamber	Car-type	Pusher-type, continuous	Conveyor, electric	Rotary-hearth
Normalising	120-150	60-100	150-200	120-220	160-200
Annealing	40-60	35-50	50-70	—	—
Hardening	120-160	60-80	150-200	180-220	150-200
Carburising:					
solid carburiser	8-12	8-12	15-20	—	15-18
gas carburiser	—	—	40-50	—	—
Gas cyaniding	—	—	80-100	—	—
Tempering	90-110	60-80	100-150	100-150	—

Table 133

Data on Thermal Insulating Materials

Material	Maximum temperature of use, °C	Volume weight, kg/dm³
Unburnt diatomite in lumps	800	0.68
Unburnt diatomite powder	900	0.3
Burnt diatomite powder	1000	0.55
Diatomite brick	950	0.55-0.75
Foamy diatomite brick	900	0.40-0.55
Fluffed asbestos	500	0.8
Asbestos millboard	500	0.90-1.2
Asbestos cord	300	0.80
Glass wool	600	0.25-0.30
Glass fibre	600	0.10-0.20
Foam concrete	300	0.40-0.50
Boiler cinder	800-950	0.7-1.0

sheathing—the КПП brand, in flexible sheaths—the КПГО type, and also in special-purpose sheaths.

When choosing thermal control instruments, it is recommended to bear in mind the following points. Type ЭПП, ЭПД and СП potentiometers are the most precise instruments, with permissible error not exceeding ±0.5% of the upper temperature range; for the type МПП-054 potentiometer the error does not exceed ±1%, while for the rest of the instruments described in Table 138 the accuracy of measurement is within ±1.5%. The upshot of this is that preference should be given

Table 134

Refractoriness and Allowable Working Temperatures of Refractories

Refractory	Refractoriness, °C	Allowable temperature range, °C
Firebrick, grade A	1730	1300-1400
" " Б	1670	1250-1300
" " В	1580	1200-1250
Silica brick, grade I	1710	1600-1650
" " grade II	1690	1600-1650
Corundum (alundum) articles	1900-1950	1600-1700
Carborundum articles (carbofrax)	1850-2000	1400-1500
Graphite articles	2000	2000
Red brick	—	700-750

Table 135

Mean Chemical Composition and Calorific Power of Gases

Gas	Chemical composition, per cent						Calorific power, kcal/m³
	Carbon dioxide	Carbon monoxide	Methane	Heavy hydrocarbons	Hydrogen	Nitrogen	
Blast-furnace gas	11	27	Up to 1	—	3	58	900
Coke gas	2	7	23	2	58	8	3900
Lighting gas	6	16	20	10	25	23	4500
Generator gas (from coal)	4.5	25	2	0.2	13	55.3	1350
Generator gas (from shale, Estonia)	18	11	24	6	39	2	4760
Natural gases:							
Saratov	—	0.7	94.3	2.7	1.8	1.2	8800
Dashava	—	0.2	97.8	0.5	0.2	1.3	8500
Kuibyshev	0.8	—	75-80	8-10	—	11-13	8500
Ukhta	0.2	—	93	1.2	—	1.2	8150

to potentiometers when treating aluminium and magnesium alloys, beryllium bronze, as well as when tempering steel or performing various other heat-treating operations within narrow temperature ranges; in heat-treatments requiring wider temperature ranges, indicating, controlling or recording millivoltmeters (which are considerably cheaper than the potentiometers, yet are as reliable) are to be preferred. The same considerations apply to ratiometers and balanced bridges operating with errors up to ±1.5% and ±0.5% respectively.

Table 136

List of Manometric Thermometers and Their Brief Characteristics

Instrument	Type	Purpose	Measuring range, °C	Length of capillary, mm
Manometric remote control thermometer, gas-filled . .	ТГ-270	Indicating	0-300	20.40 and 60
Ditto	ТГ-278	Indicating, with signalling device	0-300	20.40 and 60
	ТГ-410	Recording, with clock drive	0-300	20.40 and 60
Ditto	ТГ-610	Recording, with synchronous motor	0-300	20.40 and 60
Ditto	ТГ-618	Recording, with synchronous drive and signalling device . .	0-300	20.40 and 60
Regulating and recording thermometer.	04-ТГ-410	Regulating and recording, with clock drive	0-200	—
	04-ТГ-610	Regulating and recording, with synchronous drive	0-200	—

Note. Specifications indicate extreme ranges of temperatures measured. Practical ranges are: 0-120, 0-160, 0-200 and 0-300°C.

High temperatures can be measured with optical or radiation pyrometers, data on which are listed in Tables 140 and 141.

The radiation pyrometer of type РАПИР designed to measure surface temperature of heated bodies, 35 to 200 mm in diameter, consists of: (1) type ТЕРА-50 focussing telescope; (2) type ПУЭС-54 resistance panel (not required for the 400-1000°C and 600-1200°C temperature ranges); (3) type ЗАРТ-53 protective fixtures, as well as auxiliary instruments (millivoltmeter МПЩР-53, МСЩР-54, electronic potentiometers ЭПП16 and ЭПД02).

The telescope should be spaced at approximately 350-1500 mm from the radiation source.

The surface temperature of a body can also be measured with thermocolours, made from substances which change their colour when subjected to temperature variations.

Table 137

Brief Characteristics of Instruments Coupled to Resistance Thermometers

Name	Type	Brief characteristics
Indicating ratiometer with profile scale	ЛПр-53	For measuring temperatures
Electromechanical balanced bridge with automatic recording on a tape chart .	АУМ	For measuring temperatures in one, three or six points
Same with electric regulating device	АУМР	For measuring and regulating temperatures in one or three points
Same with pneumatic regulating device	АУМРП	Same for liquid- or gas-fuel furnaces
Self-recording alternating-current automatic electronic bridge with disk chart	ЭМД-202	For measuring temperatures in one point without regulation
Same with electric three-position regulating device	ЭМД-212	For measuring and regulating temperatures in one point
Same with pneumatic isodromic regulating device	ЭМД-232	For measuring and regulating temperatures in liquid- and gas-fuel furnaces
Electronic automatic balanced bridge with positional regulating device and tape chart	ЭМП-209	For measuring, recording and regulating temperatures in one, three, six or 12 points
Same with pneumatic isodromic regulator	ЭМП-209	For measuring, recording and regulating temperatures in liquid- or gas-fuel furnaces

Note. It is not recommended to use alternating-current instruments ЭМД type wherever there is a possibility of inducing stray currents in the measuring circuits. Direct-current bridges, marked ЭМД-102, ЭМД-112 and ЭМД-132, should be preferred.

Table 138

Thermocouple Characteristics

Type	Material		Temperature range, °C			Wire diameter mostly used, mm	Compensating leads		
				Upper			Material and colouring		Designation
	Positive	Negative	Lower	Prolonged use	Short-turn use		Electropositive	Electronegative	
ПП	Platinum-rhodium	Platinum	0	1300	1600	0.5	Copper (red)	Alloy "ТП" (green)	П
ХА	Chromel	Alumel	0	1000	1300	3.2	Copper (red), chromel (violet)	Constantan (brown), alumel (black)	М
ХК	Chromel	Copel	0	600	800	3.2	Chromel (violet)	Copel (yellow)	ХК
НК-СА	НК	СА	300	1000	—		Plain electric cord		
ЖК	Iron	Copel	0	600	800	3.2	Iron (white)	Copel (yellow)	ЖК
МК	Copper	Copel	0	350	500	3.2	Copper (red)	Copel (yellow)	МК

Note. Thermocouples of the НК-СА type are operated without correction for the cold junction.

Table 139

Brief Characteristics of Temperature Control Instruments Coupled to Thermocouples or Radiation Pyrometer Telescope

Instrument	Type	Brief characteristics	Substituted for types
Indicating portable millivoltmeter	МПП-054	For measuring temperatures	ГНКП, МП-08
Indicating panel-mounted millivoltmeter with flat scale	МПЩпл-54	For measuring temperatures. Not to be coupled to thermocouples type ПП and telescope type РП	ГНЗС, МС-08
Indicating panel-mounted millivoltmeter with profile scale	МПЩпр-54	For measuring temperatures	ПГУ, МПБ-46
Self-recording panel-mounted millivoltmeter with profile scale	МСЩпр-154	For measuring and recording temperatures in one point	СГ-1
	МСЩпр-354	Same in three points	СГ-3
	МСЩпр-654	Same in six points	СГ-6
Controlling panel-mounted millivoltmeter with profile scale	МРЩпр-54	For measuring and regulating temperatures	КГ, ЭРМ-47
Electromechanical potentiometer with recording on a tape chart	СП-1 СП-3 СП-6	For measuring and recording temperatures in one, three and six points	
Same with electric controlling device	СПР	For measuring and recording temperatures in one or three points	
Same with pneumatic controlling device	СПРП	For measuring and recording temperatures in liquid- or gas-fuel furnaces	
Electronic automatic potentiometer with recording on a disk chart	ЭПД-02	For measuring temperatures in one point	ЭПД-07
Same with electric positional controlling device	ЭПД-12	For measuring, recording and regulating temperature in one point	ЭПД-17

Table 139 continued

Instrument	Type	Brief characteristics	Substituted for types
Same with pneumatic isodromic controlling device	ЭПД-32	For measuring, recording and regulating temperatures in liquid- or gas-fuel furnaces	ЭПД-37
Electronic potentiometer with rotating scale and stationary temperature indicator	ЭПВ-01	For measuring temperatures	ЭПУ-18 and ЭПУ-28
Automatic electronic potentiometer with electric positional controlling device and recording on a tape chart	ЭПП-09	For measuring, recording and regulating temperatures in one or three, six and twelve points	
Same with pneumatic isodromic controlling device	ЭПП-09	For measuring, recording and regulating temperatures in liquid- or gas-fuel furnaces	

Table 140

Radiation Pyrometer Characteristics

Conventional designation	Name	Scale, °C	Tolerated error
ОППИР-09	Optical pyrometer	1. 800-1400 2. 1200-2000	
ОППИР-20-55	Ditto	1. 800-1400 2. 1200-2000	±21 ±30
ОППИР-30-55	Ditto	1. 1200-2000 2. 2001-3000	±30 ±50

Note: The pyrometers are to be spaced at 0.7 m and over from the heat source to be measured.

Table 141

Main Data on TEPA-50 Telescopes

Telescope optics	Measurement ranges, °C	Tolerated error		Graduation
		Temperature range	Error	
Quartz glass	400-1000 *	400-699	±12	Гр.Р1
	600-1200	700-899	±14	Гр.Р1
	700-1400	900-1099	±18	
		1100-1400	±22	Гр.Р2
Glass K-8	900-1800	900-1099	±18	Гр.Р3
	1100-2000	1100-2000	±22	
Same	1200-2200	1200-2000	±22	
	1400-2550	2001-2200	±24	Гр.Р4
		2201-2500	±28	

* Temperature ranges not specified by Soviet Standards.

Each thermocolour changes its colour at a definite temperature which is a function of its chemical composition. Thermocolours are intended to measure surface temperatures from 40° to 580°C on open heating.

As practice shows, temperatures can also be determined by heat colours. It should be borne in mind that a change in shop lighting may be the cause of considerable errors when this method is applied (Table 142).

Table 142

Approximate Measurement of Temperatures by Heat Colours

Heat colour	Approximate temperature, °C
Dark brown	530-580
Brown-red	580-650
Dark red	650-730
Dark cherry-red	730-770
Cherry red	770-800
Light cherry-red	800-830
Light red	830-900
Orange	900-1050
Dark yellow	1050-1150
Light yellow	1150-1250
Bright white	1250-1300

Table 143

Ink Composition for Recording Instruments

Material	Quantity, %
Pure glycerine (spec. gr. from 1.21 to 1.26)	22.9
Pure alcohol (spec. gr. from 0.79 to 0.81)	7.15
Distilled water	68.70
Dye	0.1
Joiner's glue	1.15

Note. The following chemicals are used as dyes: methyl violet, methylene blue or light blue, eosin, orcein, etc.

Method of preparation: the colouring agent is dissolved in alcohol with gradual addition of water by portions. Glycerine and glue are heated till they mix perfectly. The cooled mixture is added by portions to the dissolved colouring agent while mixing continuously. After complete mixing of glycerine, glue and colouring agent, the mixture is allowed to stand for 4-5 hours, after which it is filtrated.

Accessory materials, used in heat-treatment, are given in Table 144.

Table 144

Approximate Consumption of Some Auxiliary Materials Used in Heat-treatment

Material	Consumption in grams per 1 kg of treated articles	Remarks
Hardening		
Common salt, etc.	10	Heating in the 800-1000° C range
Barium chloride	20	Same for temperatures above 1000° C
Spindle oil	20-30	Cooling medium
Caustic soda	1	Cooling medium
Tempering		
Potassium or sodium nitrate	30-40	For heating
"Vapour" oil	10	For heating
"Viscosin" oil	20	For heating
Lead	10	For heating

Table 144 continued

Material	Consumption in grams per 1 kg of treated articles	Remarks
Carburising		
Solid carburiser	60-100	
Kerosene	20-30	For shaft furnace
Pyrobenzene	20-30	Same
Kerosene	20-30	Production of pyrolisis gas
Solar oil	8	Purification of pyrolisis gas
Nitriding		
Ammonia	5-50	The smaller the size of articles treated, the greater the consumption
Cyaniding		
Cyanide compound "ГИПХ"	20	
Sodium cyanide	20	
Calcium chloride	50	
Sodium chloride (common salt)	30	
Iron vitriol	20	Neutralising
Cleaning		
Sand, size of particles from 1 to 1.5 mm	50-80	
Shot ø 0.8-1.0 mm	Up to 1	
Pickling		
Sulphuric or hydrochloric acid	30-40	
Crack checking		
Crocus	20	

Chapter XII

SAFETY ENGINEERING

SAFETY REGULATIONS FOR FUEL-OIL FURNACES

The following procedure is to be adhered to when starting up a fuel oil furnace: (1) scavenge the furnace with air to evacuate accumulated explosive gases; (2) introduce an electric-ignition device or a lighted torch on a long, slim rod into the firing chamber, then open, first, the air valve, then the fuel valve; (3) after the stable flame has been obtained, remove the device and increase gradually fuel and air feed.

The lid of the charging door should be kept open during the lighting operation.

Do not peer into the firing chamber. Avoid drips and pools of fuel oil underneath the burner and keep the latter in perfect condition.

In case of an abrupt cut in fuel oil or air feed, as well as after the termination of operations, first shut off the fuel valve, then the air valve.

SAFETY REGULATIONS FOR GAS FURNACES

Industrial gases are dangerous because of toxicity. When mixed with air they present explosion hazards.

Methane content in the mixture	*Behaviour of the mixture on ignition*
Up to 4%	Neither burns nor explodes
From 4 to 15%	Does not burn, but explodes
Above 15%	Burns but does not explode

Explosive range of an air-gas mixture may vary depending on composition, moisture and temperature. Leaks should not be searched for with the aid of a torch. An aqueous solution of soap should be employed for this purpose.

The following procedure is to be performed when firing a gas furnace:

1 Open the slide valve and the lid of the charging door, switch on air supply, and scavenge the furnace with air for 5 minutes, after which cut the air supply off.

2. Open the main gas valve, and scavenge the gas main for 5 minutes, discharging the gas through a riser.

3. Ignite the gas primer and gradually switch on the gas supply.

4. Adjust the combustion of the fuel in the gas burner by varying air supply.

5. When igniting one should stand on one side of the burner; glass goggles are to be on to protect the eyes. When laying off a furnace, cut the air supply, first, then turn off the gas.

It should be borne in mind that 0.1% of hydrogen sulphide and over 0.002% of carbon dioxide cause serious poisoning.

FIRST AID IN GAS POISONING

When a person has been gas-poisoned it is imperative to take the injured person out of premises to the fresh air, unbutton his clothes and not let him sleep until medical personnel arrives. If the person does not breathe, artificial respiration should immediately be applied.

RULES FOR SAFE OPERATION OF SALT BATHS

Operation of salt baths using melted salts, alkalis or lead requires strict keeping to all safety regulations.

1. Ventilation systems should be inspected prior to starting-up operation.

2. Goggles and gloves are obligatory when operating the salt baths.

3. It is strictly forbidden to put one's head under the draught hood.

4. Lead or salt should be added to the bath in small portions; the added salt should be well dried, while lead should be thoroughly preheated.

5. Parts and hardening devices should be dipped into crucibles filled with salt or lead only after being completely dried and preheated to 100-150°C. Cold parts may cause eruptions of salt or lead from crucibles, which may burn the operator.

6. Spilled salt or lead should be covered with dry sand. Flooding with water is prohibited.

7. Saltpetre ignites on heating above 550°C. A combination of saltpetre, charcoal, soot and grease leads to explosions. The use of saltpetre should be avoided. When the use of above components is unavoidable, controlling apparatus with sonic signalling devices are imperative.

8. Special attention should be given to the drying of a salt electrode furnace after relining. Inadequately dried furnace may explode after a few hours' operation, splashing all salt out.

RULES FOR SAFE OPERATION OF CYANIDE BATHS

Cyanide salts are most violent poisons. The combination of cyanide salts with acids produces a very poisonous gas—the prussic acid. Only well-trained operators should be permitted to operate cyanide baths.

One should adhere strictly to the following safety rules when working with the cyanide bath-type furnaces:

1. Check the ventilation prior to operation. The operator should not start working if ventilation defects are detected.
2. Furnace shell doors should be opened only when charging or discharging parts and adding salts.
3. It is forbidden to handle cyanide salts with bare hands.
4. Salt should be added to the melted bath by small portions, with the furnace doors closed, and only when well dried. Goggles, gloves and respirators should be used.
5. Hardened parts should be thoroughly water-flushed to remove traces of cyanide salts.
6. All tools stained with cyanide salts should be stored under draught.
7. No saltpetre or potassium bichromate should be admitted to the melted bath, as this unavoidably causes explosions.
8. It is strictly forbidden to smoke or eat in the shop, as this presents mortal danger.
9. Prior to eating and smoking it is necessary to thoroughly wash hands and rinse the mouth.
10. It is forbidden to wash hands in hardening and washing tanks.
11. In case the ventilation fails, shut the furnace off immediately, leave the shop and inform the managing personnel.
12. All scratches or wounds, however small, should be bandaged prior to work.
13. If one is suffering from a cold or some other indisposition, medical care should be sought immediately.

RULES FOR DECONTAMINATING WATER FROM CYANIDE HARDENING AND WASHING SHOPS

Decontamination of 1 litre of water necessitates 3 grams of iron vitriol and 1 gram of soda ash (assuming sodium cyanide content averages up to 0.1%).

The operation should be carried out as follows:

1. Prepare the necessary amount of iron vitriol and soda, in conformity with the tank capacity.
2. Dissolve iron vitriol in water and add soda.
3. Pour the prepared mixture into the hardening or washing tank and mix it thoroughly.
4. Drain decontaminated water, simultaneously opening the water tap to bring the concentration still further down.

SAFETY RULES FOR OPERATION OF EQUIPMENT

1. Fuel oil or grease spilled on the floor should be covered with generous amounts of sand and swept away.
2. Prior to work sleeve cuffs should be tied up and dangling bits tucked away.

3. No moist blanks should be charged as this may cause violent flame eruptions.

4. When quenching slim articles with through holes, orient the latter away from shop personnel to avoid burns from vapour or oil.

5. Do not switch on bath-heating appliances when aqueous solutions are thick or frozen (blueing solution, etc.), as eruptions of solutions and burns would be unavoidable.

6. When quenching articles with compressed air the operator should put the goggles on and interpose a wire screen protecting him from the rebounding scale.

7. Water should be poured first into sulphuric acid pickling tanks; sulphuric acid is added then in a thin jet.

8. Undried parts, tongs, hooks should not be dipped into a tempering oil bath while the latter is hot.

SAFETY REGULATIONS FOR HANDLING ELECTRICAL EQUIPMENT

1. Moist clothes or foot-wear, damp floor or mats, etc. increase electric shock hazard.

2. Only well-grounded electrical equipment is authorised for operation.

3. Switches and starting buttons should not be switched on by means of pokers, tongs and similar metallic objects.

4. Rubber mats are imperative when operating electric furnaces.

FIRE PROTECTION

1. Pans with sand should be available underneath the burners when liquid fuel is being used.

2. Sand and spade from the fire-extinguishing box should never be used for operation needs.

3. Fuel-oil storage tanks should be situated far from fire.

4. It is strictly forbidden to heat up the fuel-oil mains with a torch or a blow torch, or to heat fuel oil, stocked in storage tanks, by dipping hot pieces of metal.

5. All quenching and tempering oil baths should be provided with lids to prevent air access, if the oil ignites.

6. On hardening it is forbidden to heat kerosene above 38°C.

INDEX

I

J

K

L

M

N

O

P

Q

R

S

T

TO THE READER

Peace Publishers would be glad to have your opinion of the translation and the design of this book.

Please send all your suggestions to 2, Pervy Rizhsky Pereulok, Moscow, U.S.S.R.

И. КАМЕНИЧНЫЙ

КРАТКИЙ СПРАВОЧНИК ТЕРМИСТА

На английском языке

Printed in the Union of Soviet Socialist Republics