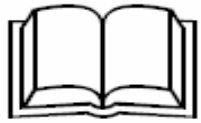

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Welding Electrodes Market Research in Russia

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Preliminary comments

This report is devoted to the investigation of current standing of market of welding electrodes in Russia and medium-term forecast of the market development. The Report is made up of seven sections, contains 90 pages including 27 tables and 11 illustrations. This work is a desk study. The authors used the following sources of information: data of the Federal Agency of the State Statistics, RF Federal Customs Service, official railage statistic, annual and quarterly reports of companies, as well as data from web sites of market players. Since trucking of freight is not liable to obligatory statistic in Russia, the report provides only railway transportation data.

The first Section of the report presents review of technology of production and technical requirements, imposed on quality of welding electrodes, as well as data on consumables for their production, including some data on supplies of the resources to enterprise-producers of welding electrodes.

The second Section is devoted to analysis of production statistics for the decade from 1997 until 2006, including data on the welding electrodes output over the same period both in Russia as a whole and broken by enterprises. The dynamics of production has been also reviewed. Besides, the Section describes the current state of certain producers, primarily the biggest of them – The Orel plant OAO "Severstal-Metiz", OAO "Losinoostrovskyi Electrode Plant", ZAO "Welding Electodes Plant SIBES". Data on range and quality of produced welding "electrodes, volumes of the production, plans on development of the enterprises are presented, as well as data on volumes and destinations of supplies of the products in 2004-2006 both to domestic and world market.

The third Section deals with analysis of Russian foreign trade in welding electrodes in 1999-2006. In latest years, a tendency for increasing imports of welding electrodes and decreasing the exports is in force. In 2006, the volume of imports of welding electrodes increased almost 3 times as compared with 2002, whereas volumes of the exports for the period decreased 2.8 times.

The fourth Section is devoted to analysis of prices on welding electrodes. The Section presents dynamics of average monthly release prices of producers of welding electrodes from 2001 to 2006, the prices of some producers in May 2007, dynamics of average annual export and import prices in 1999-2006, and export and import prices of some suppliers and buyers in December 2007.

The fifth Section presents analysis of consumption of welding electrodes in Russia. The Section presents supply-demand balance of the product and data on volumes of the consumption of large consumers in 2004-200. The consumption of welding electrodes for 1999-2006 grew by 40 % and amounted to 175,6 thousand tons in 2006.

The sixth, final Section of the report focuses on the prospects of Russian of market of welding electrodes (medium-term forecast), based on analysis of development of end-uses. The analysis allows to expect increasing consumption of welding electrodes in nearest years, at even higher rates than in latest years.

The appendix contains contact information on enterprises-producers and some traders.

Introduction

One of the most popular ways of welding is hand arc welding by means of metal electrodes with coating. It is widely used for joining of small and middle (up to 30 mm) thickness work-pieces by short seams.

Welding Electrodes are metal rods with coating applied on them. Coating is applied on rods by submersion or molding.

The coating consists of slag-forming and gas-forming minerals, for which such materials as manganese and iron ore, marble, quartz – various natural minerals as well as organic substances (starch, cellulose and others) are used. Electrode coating functions and provides the following: 1) stable burning of the arc since it contains easy-ionizing chemical elements with low potential of ionization, such as potassium, sodium, calcium; 2) protection of the weldpool metal achieved by creation of a gas atmosphere, which presses back the air and by creation of slag on the surface of weldpool and metal blobs; 3) disoxidation of the weldpool metal since it contains chemical elements more active than iron (with closer affinity with oxygen) in the coating; the most active disoxidators are silicon and manganese; 4) alloying of the metal seams thorough adding into coating ferroalloys (Fe-Cr, Fe-Mo and others) and pure metals that when welding turn into seams' metal altering its chemical compound.

Length of the electrodes according to the GOST 9466-75 could be 250-450 mm, depending on the diameter of the rod.

Electrodes for hand welding vary in types in marks. Type of electrodes is indicated by the letter «E» and numbers, which show the guaranteed ultimate strength of welded metal. The letter «A» after number shows increased plastic properties of welded metal.

One type could include several marks of electrodes, which define the compound of coating, and technological attributes of electrodes (type and polarity of the current, possibility of welding in different spatial positions and other)

Specifications for electrodes welding carbon steel and alloy steel are defined in the GOST 9467-75, and for welding of high-alloy steel – GOST 10052-75.

Hand welding is started by lighting the arc by touching the welding item with the end of the electrode and quick withdrawal on the distance of several millimeters. On an arch, there is a voltage of 20-25 V depending on length of an arch and electrode mark.

Process of hand arc welding is carried out as follows. The electric arc burns between a metal rod of an electrode and welded article. The electrode rod melts, and the molten metal in the form of separate blobs is transferred to the weldpool formed as a result of melting of the edges of the articles. The rod melts along with the electrode coating, forming protective gas atmosphere around the arc and the liquid slag covering the surface of the metal weldpool and blobs of liquid metal. In process of arc movement there is a hardening of a weldpool and formation of a welding seam. Hardening slag forms a firm slag crust on the seam surface.

Welding can be carried out in various spatial positions – flat, vertical, horizontal, overhead. It is most convenient to carry out welding in the flat position. Seams on a vertical plane (vertical and horizontal) are more difficult to carry out, since an outflow liquid metal from a welding bath is possible under influence of gravity effect. It is even more difficult to carry out welding of overhead seams. In overhead position, liquid metal is kept in the weldpool by forces of a surface tension, and metal transferring happens because of so called «arc blasting», which represents a set of the several processes defining directed movement of metal blobs from an electrode.

At correctly chosen parity between the diameter of an electrode and a welding current, fusion of an electrode rod outruns coating fusion. As a result, the coating forms a cone-shaped peak that creates directed (cumulative) movement of gases towards the blank. Skilled welders apply the peak to the surface of the blank to maintain constant length of an arc.

The longer the arc is, the less stable it might be. The arc deviation can be caused by air movement and magnetic fields created by the current passing through blanks that have random character. Therefore welding is usually performed with a short arc. The length of the arc should not be larger than 1,4 diameters of an electrode. Welding with a short arc allows achieving narrow equal seams with deep penetration and minimal metal sputtering. While using a short arc metal protection is carried out better.

In the process of welding, there occurs burning-off of an electrode. For maintenance of the constant length of the arc an electrode is pushed towards weldpool. Simultaneously the welding arc is moved along welding edges in the direction of welding. Sometimes cross-section fluctuations with the electrode end are made for a wider seam.

Welding conditions are defined by set of controllable parameters of process that make up a welding mode.

Diameter of the electrode, strength, type and polarity of the current, pressure on the arc, speed of welding are the main parameters of the mode. Diameter of the electrode “d” is chosen depending on thickness of metal, sizes of seams and its spatial position.

Welding current could be chosen roughly under the empirical formula I = k*d, where “k” – the factor depending on the mark of the electrode and spatial welding position. For electrodes with coating k = 30-60 A/mm. The current strength should not be excessive as the current that goes through the electrode and heats it up quickly which leads to increased metal sputtering. With insufficient current strength, the arc is unstable, and the seam comes out with skin welds. While welding the seams in vertical and overhead position electrodes in diameter not more than 4 mm are chosen, and a current strength 10-20 % lower, than for welding in the flat position.

Arch voltage is defined according the background materials or the certificates enclosed to the packing of electrodes.

One of the important characteristics of an electrode is its weld deposition factor, which has dimension ща g/A-hour and is given in the technical data for each mark of an electrode.

When sizes of the welded item, length of welding seams and the sectional area of the seam are known, it is possible to count up in advance the required number of electrodes, labour input of welding, the electric power consumption. So it could be assumed that the weight of electrodes together with the weight of the coating, and also metal losses on sputtering and charcoal fumes 1,6-1,8 times exceeds the weight of the built up metal.

Important value for reduction of residual deformations after welding and tension has a rate of performance of welding seams on a product. Residual deformations and residual tension are a consequence of non-uniform heating of a product at welding. Because of unequal temperature of expansion of metal at heating sections of a product are separated and exposed to plastic deformations. Therefore after product cooling in a weldpool there is residual pressure of a stretching, and in the next sections there are the residual pressure of compression causing deformation of a product.

For reduction of residual deformations it is recommended to use seams of average length (300-1000 mm) to weld from the middle to the edges, longer seams – by backstepping method in sections of 150-200 mm or randomly. Welding of multilayered seams is recommended to be carried out cascadely.

1. Production: technology, materials, requirements, imposed on quality of the products

1.1. Technology of production of welding electrodes

One of initial operations is the washing of lump materials and silicate-block for their clearing of pollution and barren rock. This operation is carried out in the jet washer. Material is loaded into the machine bunker, and it continuously directed by the feeder to rotating washing barrel where water is supplied. The washed clean material is unloaded into the container.

Crushing of materials is carried out in breaking machines to form fractions not bigger than 70 mm. The material supplied for crushing, should have the fragment size of no more than 350 mm. Crushing of ferrotitanium is performed with the addition of inert material (marble) in the ratio of 100 kg of marble per 1000 kg of ferrotitanium.

Crushed materials are filled into containers and undergo drying for removal of moisture which has a negative effect on welding-technological characteristics of electrodes. The crushed and granular materials are poured from containers into a receiving bin, from where feeders advance it into rotating inclined barrels of continuous action with heating by natural gas. The drying of materials is carried out at different temperatures, for example, marble, fluorspar – at temperature of 500°C, lumpy ferroalloys – at temperature of 150-170°C. Duration of drying depends on initial humidity.

Then the materials follow through receiving device into containers forwarded for ***grinding***. Grinding of mineral materials is performed in ball mill of continuous action of type CM-6008 and CM-6004 with the use of metal spheres. After that the material is sifted through a sieve, established on drum sides. The resulted powder arrives on separation where large and small fractions are separated. The basic fraction goes to the bunker. From the bunker the powder is presented by pneumatic transport on the bunker-discharger of proportioning division. The air is used while transporting inert materials and while transporting fire and burst-off dangerous materials – inert gas. The operational control is carried out on granulometric structure of the grinded components at materials grinding. Grinding rate is defined on Sheite's remainder (grain size). During the ferroalloys grinding inert gas is submitted to the mill for the purpose of explosion avoidance.

An operation of ***passaging*** is performed in order to give passiveness to the active ferroalloys powder (ferrosilicon, ferromanganese) against the course of reactions with liquid glass which leads to lute structure disturbance and surface bulging of electrodes owing to gas emission. Operation consists of addition of bichromate to the autoclave int the process of liquid glass melting up to 0,5 % to the weight of the silicate-block and water or potassium permanganate – 3-4 %.

Liquid glass is used as binding agent at preparation of coating mixture. ***Melting and dissolution of silicate-block*** is carried out by an autoclave in hot water where steam under pressure of 0,4-0,7 MPascals is presented at the temperature of

140-200º C. For proper dissolution of a silicate-block pure or softened water is used. After finishing of melting-dissolution, liquid glass is pumped into receiver tank where it is conditioned at temperatures of 75-80ºC. liquid glass is filtered for clearing from impurity. After the filtration, melted glass is pumped in to receiver tanks where it is killed at temperature not less than 15º C. In case of cooling of the glass down, it is streamed through the thermostats where it is warmed up. Liquid glass that is prepared for batching, should possess parameters (viscosity, density, module) matching the requirements of particular type of electrodes. From receiver tanks melted glass is moved to dispensers of mixing machines, thus it should be pumped permanently by pumps to looped thermostat.

Preparation of charge and coating mixture is carried out in the following sequence:

- Proportioning of the components according to the recipe;
- Mixing of dry components;
- Preparation of the coating mixture (wet mixture);
- Preparation of briquettes.

Proportioning of components is performed with automatic dispensing installation which is equipped by automatic scales for plumbing of small doses. Reservoirs and weight devices are filled with inert gas during dispensing of fire hazardous and explosive materials.

Compounding is carried out in the mixing machines that provide uniform variable mixing of the entire batch bulk.

Preparation of coating mixture consists in mixing of dry charge with liquid glass until it turns into plastic, suitable for embedding electrodes. Coating mixture production is carried out in counterflow mixers within 3-5 minutes or in muller mixers. Ready mixture is transported by driven trolley to a briquetting press or electrode-producing press. Bricks are prepared on briquetting presses, and then they are also transported to the electrode-producing press.

Electrode rods are made of a wire matching requirements of The GOST 2246-70. ***Flattening and cutting of wires into rods*** are performed by straightening-cutting machine equipped with untwisting devices. Cutting and storing of rods is carried out separately according to the types and diameters. The following requirements are advanced for finished cores after cutting:

a) There should be a straight cut on the end of the rod;
b) Waviness of the rod is not allowed;
c) Bending deflection should not exceed 0,5 mm;
d) Length tolerance for a rod should not exceed 2 mm;
e) Presence of the impurity on the surface of the rod is not allowed.

Rods from the straightening-cutting machine are advanced towards electrode-producing presses.

Pressing of electrodes (covering rods with coating) is carried out on an electrode-producing press on which the following operations are performed:

- Pumping of coating mixture to press cylinder under pressure;
- Carrying-in of rods in the head of the press and embedding them with coating;

- Transfer of electrodes to cleaning machine and clearing of the front and back ends of rods;
- Transfer of electrodes through the conveyor into the drying-burning furnace.

The basic tool at rod pressing is gage plug with rod diameter for coating. The gage plug is a regulator of uniform applying of the coating mixture that is one of the electrodes' quality indicators. The lesser is the indicator of eccentricity of the electrodes, the higher is their quality.

1.2. Requirements, imposed on quality of welding electrodes

The quality requirements for coated metal welding electrodes produced by method of embedding for hand arc welding of steels and welding of surface layers of steels and alloys are defined in GOST 9466-75.

Depending on their functions, electrodes are subdivided into:

1) For carbon and low-alloy structural steels with point of maximum load up to 60 kgs/mm ² (U);
2) For welding of alloyed structural steels with point of maximum load up to 60 kgs/mm ² (L);
3) For welding of alloyed thermally stable steels (T);
4) For welding of high-alloy steels with special characteristics (V);
5) For welding of surface layers with special characteristics (N).

Types of electrodes are defined by GOST 9467-75, GOST 10051-75 and GOST 10052-75. Division of electrodes by types is defined by standards or specifications. Each type of electrode is marked with one or several indices.

Depending on thickness of coating according to ratio D/d (D – diameter of coating, d – diameter of the electrode determined by diameter of rod) electrodes are subdivided: with the thin coating – $D/d \leq 1{,}20$ (M); with the average coating – $1{,}20 < D/d \leq 1{,}45$ (C); with the thick coating – $1{,}45 < D/d \leq 1{,}80$ (D); with the extra thick coating $D/d > 1{,}80$ (G).

By species, the coatings are subdivided: with acid coating – A; with basic coating– B; with cellulose coating – TS; with rutile coating – R; with mixed coating– a corresponding double symbol; with other kinds of coatings – P. With presence of iron powder in the coating in proportion of more than 20 % to a designation of the electrode type is added the letter ZH.

According to admissible spatial positions of welding or welding deposition electrodes are subdivided: for all positions – 1; for all positions, except vertical from top to bottom – 2; for down, horizontal on a vertical plane and vertical from bottom to top – 3; for down and bottom 'in boat' (gravity position welding) – 4.

The division of electrodes by nature and polarity of the current used at welding or welding deposition, and also by rated voltage of idling of used welding arc power supply of the alternate current of 50 Hz frequency is given in table 1 below.

Electrodes used for welding and welding deposition only on direct current of reversed polarity are marked with 0.

Table 1. Breakage of electrodes by electrical parameters of welding.

Recommended polarity of direct current	Rated voltage of idling of the used supply of alternate current, V		Description
	Rated	Deviation limit	
Reversed			0
Any	50	±5	1
Direct			2
Reversed			3
Any	70	±10	4
Direct			5
Reversed			6
Any	90	±5	7
Direct			8
Reversed			9

Source: GOST 9466-75

Standard sizes of electrodes are presented in table 2.

Table 2. Sizes of electrodes.

Nominal diameter of the electrode, specified by the rod diameter d	Nominal length of electrodes L (limit deviation ±3) with rods made of welding wires		Length of the trimmed end *l* (limit deviation ±5)
	Low-carbon or alloyed	High-alloy	
1,6	200	150	20
	250	200	
		(250)	
2,0	250	200	20
	(300)	250	
		(300)	
2,5	250	250	
	300	(300)	
	(350)		
3,0	300	300	25
	350	350	
	(450)		
4,0	350	350	
	450	(450)	
5,0	450	350 450	
6,0			
8,0			
10,0			30
12,0			

Source: GOST 9466-75

The sizes given in brackets are not recommended to apply. It is allowed to produce electrodes in nominal diameter 3,15; 3,25; 6,3 and 12,5 mm.

Other length of electrodes can be established upon agreement between the manufacturer and the consumer.

As per agreement between the manufacturer and the consumer the coating of the electrode end at length ***l*** is allowed not to be trimmed. Thus, both ends face of electrode should be trimmed as contact.

Separate electrodes, total number of which should not exceed 10 % of the total number of controlled electrodes, it is allowed to increase limit deviation of electrode length up to ±4 mm.

The form of coating trimming from the side of the contact end of the electrode should be conic, rounded or transitive between conic and rounded. In addition, the cone angle and radius of curvature are not regulated; however in any case the contact end of the electrode should be free from coating.

Separate electrodes, total number of which should not exceed 10 % of total number of the controlled electrodes, it is allowed to perform flat coating trimming at the electrode contact end on the entire perimeter or on separate sites but there should be no coating on the surface of the contact end.

Contact end of electrode could have a layer of ionising substance that boosts excitation of welding arc compound of which should correspond to standard or specifications for electrodes of a concrete mark.

The reference designation of electrodes includes the following information: 1 – type; 2 – mark; 3 – diameter, mm; 4 – description of electrode function; 5 – an indication of coating thickness; 6 – group of the indexes specifying characteristics of deposited metal and seam metal in line with GOST 9467-75, GOST 10051-75 or GOST 10052-75; 7 – indication of type of coating; 8 – designation of allowed spatial positions of welding or welding deposition; 9 – a designation of current type applied at welding or welding deposition, polarity of direct current and rated idle voltage of welding arc of alternate current power supply at frequency of 50 Hz; 10 – designation of GOST 9466-75 standard; 11 – standards designation on types of electrodes.

For electrodes of the marks, which do not belong to the types in line with GOST 9467-75, GOST 10051-75 or GOST 10052-75, in reference designation of electrodes types is not indicated, and instead a designation of standard or specifications for the electrodes of specific mark is specified.

In the reference designation of electrodes for welding of carbon and low-alloy steels with tensile strength up to 60 kgs/mm2 there is no dash typed after the letter E.

Reference designation should be specified on labels or on boxes' marking, on packs and boxes of the electrodes. In all kinds of the documentation (except engineering information) the reference information of electrodes should consist of the mark, diameter and the standard designation (GOST 9466-75).

Example of reference designation

Electrodes of type E42A in accordance with GOST 9467-75, of the mark UONII-13/45, diameter 3,0 mm, for welding carbon and low-alloy steels U, with thick coating D, with specified by GOST 9467-75 group of the indexes specifying the characteristics of deposited metal and seam metal, 43 2 (5), with the basic coating, for welding in all spatial positions 1 with the direct current of the reversed polarity 0:

E46A-UONII-13/45-3,0-UD GOST 9466-75, GOST 9467-75
E 43 2(5) – B10

Electrode rods should be produced from welding wire appropriated for manufacturing of electrodes, in accordance with GOST 2246-70 or with the technical requirements establishing chemical composition of wire metal and providing other requirements in accordance with GOST 2246-70.

Electrode coating should be dense, hard, without swellings, voids, rolls, cracks. On the electrode coating surface superficial axial cracks and local meshy ruptures are allowed; stretch (maximum length) which does not exceed triple nominal diameter of the electrode, if the minimum distance between the nearest ends of cracks or (and) edges of sites local meshy ruptures more than triple length of the more extensive crack or a site of rupture.

On a surface of the electrode coating local dents of the depth not more than 50 % of the coating thickness at quantity of no more than four are allowed at total length up to 25 mm on one electrode. Two local dents located on two sides of the electrode in one cross-section, can be counted as one if their total depth does not exceed 50 % of the coating thickness.

On the electrode part that abuts to the freed of coating contact end of the electrodes it is allowed to keep bare rod spots of length not more than half of rod diameter, but not more than 1,6 mm for the electrodes with basic coating and not more than 2/3 of the rod diameter, but not more than 2,4 mm for electrodes with sour, cellulose and rutile coating.

On the surface of the coating it is allowed to keep local tearings with length that does not exceed 15 mm with depth not more than 25% of the nominal thickness of coating, but not more than one per electrode.

Difference in coating thickness ***e*** in the diametrically opposite parts of the electrode should not exceed the defined values (table 3)

Values ***e*** are given in brackets; they are allowed foe 10% of the controlled electrodes. For the electrodes with rods made of high-alloy etched wire it is allowed to rise value e by 0,02 mm with the electrode diameter more than 3,15 mm. For the electrodes with especially thick coating, assigned for welding of steels value e is defined by standards and technical requirements for the electrodes of specific mark.

Table 3. Permissible differences in coating thickness

Nominal diameter of the electrode, мм	Value *e* for the electrodes, mm	
	With thin, average and thick coating	with especially thick coating for welding deposition of upper layers with special characteristics
1,6	0,08 (0,12)	0,12 (0,16)
2,0	0,10 (0,14)	0,15 (0,20)
2,5	0,12 (0,16)	0,18 (0,24)
3,0; 3,15	0,15 (0,20)	0,23 (0,28)
4,0	0,20 (0,26)	0,28 (0,34)
5,0	0,24 (0,32)	0,32 (0,40)
6,0: 6,3	0,28 (0,36)	0,33 (0,45)
Св. 6,3	0,30 (0,40)	0,40 (0,50)

Source: GOST 9466-75

Coating should not corrupt in case of free prone fall on smooth steel plate from the height: 1 meter – for the electrodes with diameter less than 4 mm; 0,5 mm – for the electrodes with diameter 4 mm and more.

It is assumed to reduce the height of fall down to 0,3 meter for the electrodes of diameter more than 5 mm if there is an agreement between producers and consumers.

For electrodes with thick coating, compound of which contains more than 35% of metal components and for electrodes with especially thick coating height of fall should be defined by a standard of technical specifications for the electrodes of specific mark.

Slivering of coating with total length up to 5% of the coated part of the electrode is admitted during an examination.

Welding-technological features of electrodes with observance of regimes and conditions of welding, regulated by standard or technical specifications for the electrodes of specific mark, and with absence of magnetic arc blow should meet the following requirements:

- the arc should be easily excited and burn stably;
- the coating should melt uniformly, with no excessive splattering, crushing of pieces or creating of jackets or shields that obstruct normal melting of a electrode while welding in all spatial positions recommended for electrodes of this mark;
- the slag that forms during welding provide correct making of bead and be easily removed after cooling down;
- in the seam metal, and also in metal that is deposited by electrodes assigned for welding there should be no cracks, tearings and surface voids;
- Maximum size and number of inner voids and slag inclusions in the seam metal should not exceed the norms. (table 4)

Table 4. Norms of sizes and quantity inner pores and slag inclusions in joint metal

Nominal diameter of the electrode, мм	Maximum linear dimension of a void or a slag inclusion, mm	Number of inner voids and slug inclusions in the spot of their highest accumulation for 100 mm of the seam length	
		In a one-pass weld	In a multiple-pass weld
1,6	0,3	3	5
2,0	0,4		
2,5	0,6		
3,0; 3,15	0,8		
4,0	1,0		
5,0	1,2		
6,0; 6,3	1,5		
Св. 6,3	2,0		

Source: GOST 9466-75

Separate electrodes, total amount of which should not exceed 10% of the overall number of controlled electrodes it is tolerable:

- variation in length of the trimmed end *l* from the nominal value up to ±7,5;
- presence on the surface of each electrode not more than 2 transversal tears with the size not more than half of the coating circle, surface traces of electrodes adhesion, not more than three pores with outer size not more than 1,5 mm for electrodes with diameter of up to 4 mm inclusively and not more than 2,0 mm for electrodes with diameter of more than 4mm;
- extension of the surface transversal cracks length and parts of local meshy rupture on the coating surface up to the value that exceeds the norm, but not more than by 50%;
- extension of the total dent length on the coating up to 35 mm;
- Increase of the local tearings on the coating surface up to three per electrode.

Chemical compound of the deposited metal, mechanical and special features and characteristics of the metal, seam metal of the welded connection (contents of the ferrite phase, resistance towards intercrystalline corrosion and other), metal deposit factor, electrode consumption per 1 kg of deposited metal, coating mass factor, moisture content in coating, overall emission of the most harmful substances in the process of using should meet the standard requirements and technical specifications for the electrodes of the specific mark.

Useful time of electrodes is unlimited if the conditions of transportation and storing established by the standard are met. Increase of moisture content in electrode coating is eliminated through incineration before using them in the regime specified on the packing.

For a standard requirements conformance inspection of electrodes the manufacturing enterprise carries out ***acceptance tests*** for every electrodes lot.

During these tests the compliance of the electrodes with the requirements for the variability of coating thickness and norms for dimensions and number of inner voids and slag inclusions in the seam metal, and also standard requirements for the electrode of specific mark in respect of chemical compound of deposited metal, mechanical and special characteristics of deposited metal, seam metal or welding seal.

Necessity of electrodes acceptance testing for dimensions and coating quality, and also moisture content in coating is established in the standard or technical specifications for the electrodes of specific mark. However the manufacturer must maintain the compliance of electrodes with these requirements.

Every lot should be comprised of electrodes of one mark and uniform diameter. All the electrodes in the lot should be manufactured under uniform technological process, on the single-type equipment, using rods made of wires of one mark with constant coating compound of components from the same lot. Electrode lot with rods made of alloy or high-alloy steels should be manufactured with the use of wires of the same lot. Wire lot is defined by GOST 2246-70. In the cases defined by the standard or technical specifications for the electrodes of specific mark, with the consumers consent it is allowed to manufacture an electrode lot with the use of rods of alloy and high-alloy steel from two or several lots with similar chemical compound of metal. The lots should also be comprised of the wires of the same mark, diameter, function and surface type.

Weight of an electrode lot depending on their function and diameter should not exceed the specified amount (table 5). If there is an agreement between a manufacturer and a consumer it is allowed to increase the maximum weight of the lot with sour, cellulose and rutile coating, but not more than two times.

Table 5. Requirements, imposed on mass of lot of electrodes

Function of the electrode	Electrode diameter, mm	Weight of the electrode lot, tonnes
Welding of carbon and alloy structural steels	Up to 3,15	10
	over 3,15	20
Welding of alloy temperature stable steels	Up to 3,15	5
	over 3,15	10
Welding of high-alloy steels with special characteristics, welding deposition of the upper layers with special characteristics	Up to 3,15	3
	Over 3,15	5

Source: GOST 9466-75

To test for compliance the electrodes with the mentioned above from various packing spots, but not less than from ten or after the removal from heating furnace (not less than 10 samples from the conveyor at stated intervals or from different carts) 0,5 % of the electrodes are selected from every ton there is in the lot, but not

less than 10 and not more than 200 electrodes from a lot. If the results of the test are positive the selected electrodes could be used for further tests.

For the conformance testing of electrodes in respect of variations in coating dimensions not less than 5 electrodes of every ton there is in the lot, but not less than 10 and not more than 50 from a lot are selected from different packs or boxes.

For the conformance testing of electrodes in respect of requirements towards coating in case of falling, coating mass factor and moisture content in the coating for every type of test not less than three electrodes of every ton there is in the lot, but not more than 5 and not more than 25 from a lot are selected from different packs and boxes.

From every electrode lot that is tested should be selected electrodes for welding-technological characteristics tests, chemical compound of deposited metal and mechanical characteristics of seam metal and welding seal (contents of ferrite phase, resistance towards intercrystalline corrosion and other) in the number than is required for carrying out of relevant probes and samples, defined by the standards and technical specifications.

If the results on coating dimensions variations, strength and coating mass factor are unsatisfying retest on doubled number of electrodes selected from a lot is carried out. Results of retest are definitive and applied to the whole lot.

Electrodes are packed in boxes and packs according to one of the following variants:

- In encapsulated plastic boxes (cases);
- In the packs wrapped in a brown paper in accordance with GOST 8273-75 or of equivalent characteristics, with the subsequent packing of packs in encapsulated metal boxes (cases);
- In boxes from a box-like paperboard of marks А, Б or В in accordance with GOST 7933-75 with thickness not less than 0,7 mm or of equivalent characteristics with the subsequent sealed packing of each box in a polyethylene film in accordance with GOST 10354-82 with thickness of 0,1-0,2 mm or in a polyethylene thermo contracting film in accordance with GOST 25951-83;
- In the packs wrapped in a brown paper in accordance with GOST 8273-75 or of equivalent characteristics, with the subsequent packing of each pack in a sealed cover from a polyethylene film in accordance with GOST 10354-82 with thickness of 0,1-0,2 mm;
- In boxes made of box-like paperboard of the marks A, B and V in accordance with GOST 7933-75 with thickness not less than 0,8 mm;
- In the packs wrapped in two-layer packing paper of the marks B-70, B-80, V-70, V-80 or G-80 in accordance with GOST 8828-75, or in bag wet-strength paper of the marks V-70 or V-78 in accordance with GOST 2228-81, or of equivalent characteristics.

The electrodes packed according to the last 2 variants, are to be dried or tested on moisture content in coating before use and if the results are unsatisfactory are to be dried.

The weight of electrodes in a box or a pack should not exceed:

- 3 kg for electrodes of the diameter up to 2,5 mm;
- 5 kg for electrodes of the diameter of 3,0-4,0 mm;

- 8 kg for electrodes of the diameter over 4,0 mm.

The variations of electrodes weight in a box or a pack from the specified on the label or on markings should not exceed half of weight of one electrode towards reduction and estimated weight of two electrodes towards increase.

Boxes or packs with electrodes should be packed according to one of the following variants:

- In boxes made of containerboard of the marks KS or KS-1 in accordance with GOST 9421-80, or the corrugated containerboards of the marks P-1, P-2, P-3, T-0, T-1 in accordance with GOST 7376-84, or of equivalent characteristics;
- In boxes in accordance with GOST 18617-83 from wood-fiber plates with thickness of 4 mm of mark T in accordance with GOST 4598-86;
- In wooden boxes in accordance with GOST 18617-83 or GOST 15623-84 with humidity of wood not more than 22 %;
- In returnable box metal pallets of the closed type;
- In large-sized wooden boxes in accordance with GOST 10198-78.

In cases of transportation of electrodes to the regions of the Far North and remote areas the container should meet the requirements of GOST 15846-79.

The height of boxes or packs with electrodes in box metal pallets and large-sized boxes packing should not exceed 600 mm.

The gross weight of packing spots should not exceed:

- 32 kg for boxes made of paperboard;
- 50 kg for boxes made of wood-fiber plates;
- 80 kg for wooden boxes;
- 1100 kg for box metal pallets and large-sized wooden boxes.

Under the agreement of the manufacturer and the consumer packing of boxes and packs with electrodes in universal medium-weight containers under condition of their total load and installation of shelves between decks is allowed. The deck height should not exceed 600 mm.

With the consent of the consumer during transportation of electrodes within one city other kinds of packing preventing possibility of humidifying and damage of electrodes coating can be established.

On (in) each box or a pack with electrodes should be a label or the marking containing the following data:

a) the name or manufacturer trade mark;
b) design letters of electrodes;
c) Number of lot and manufacturing date;
d) Range of electrodes application;
e) Regimes of welding current depending on diameter of electrodes and position of welding or welding deposition;
f) Special conditions of welding or welding deposition;
g) Mechanical and special characteristics of seam metal, deposited metal or the welding seal, not specified in design letters of electrodes;
h) Admissible moisture content in coating before application of electrodes;
i) regime of electrodes redrying;

j) Weight of electrodes in a box or a pack.

Shipping data is drawn in accordance with GOST 14192-77. At this time such handling instructions «Fragile!» Also "Avoids damp", and on one of lateral surfaces of each box a label is applied.

Each electrodes lot should be accompanied by the certificate authenticating compliance of electrodes with the requirements of standards or technical specifications. In the certificate are specified:

- The name or the manufacturer trade mark;
- design letters of electrodes;
- Lot number and manufacturing date;
- Lot net weight in kgs;
- Weight of electrodes rods wires with the indication of the standard or technical specifications;
- Av actual chemical compound of deposited metal;
- Actual parameter values of indicators of mechanical and special characteristics of seam metal, deposited metal or welding seal, that are acceptance characteristics of electrodes of specific mark.

Electrodes are transported by any means of close-top vehicles according to the rules of transportations applied to a specific type of transport.

During railroad transportation electrodes packed in wooden boxes, are transported in covered cars carload and part-load shipments, and the electrodes packed in boxes made of paperboard and wood-fiber plates – in universal containers. Thus wooden boxes form packages in accordance with GOST 26663-85. Use of flat pallets of single application in accordance with GOST 26381-84 or backing blocks made of wooden bricks of cut not less 50x50 mm is allowed. Packages are transported according to GOST 21929-76.

Electrodes should be stored in dry heated rooms at temperature not lower than +15ºC in the conditions protecting them from pollution, humidifying and mechanical damages.

1.3. Materials and their supplies

Basis of a welding electrode is a welding wire. The welding wire is manufactured in accordance with GOST 2246-70 (2002) of the following marks: low-carbon – Sv-08, Sv-08A, Sv-08AA, Sv-08ГА, Sv-10ГА и Sv-10Г2; alloyed – Sv-08ГС, Sv-12ГС, Sv-08Г2С, Sv-10GN, Sv-08ГSMT, Sv-15GSTUTSA (EP-439), Sv-20GSTUA, Sv-18HGS, Sv-10NMA, Sv-08MH, Sv-08HM, Sv-18HMA, Sv-08HNM, Sv-08HMFA, Sv-10HMFT, Sv-08HG2S, Sv-08HGSMA, Sv-10HG2SMA, SV-08HGSMFA, Sv-04H2MA, Sv-13H2MFT, Sv-08H3G2SM, SV-08HMNFBA, Sv-08HN2M, Sv-10HN2GMT (EI-984), Sv-08HN2GMTA (EP-111), Sv-08HN2GMU, Sv-08HN2G2SMU, Sv-06N3, Sv-10H5M; high-alloy – Sv-12H11NMF, Sv-10H11NVMF, Sv-12H13, SV-20H13, Sv-06H14, Sv-08H14GNT, Sv-10H17T, Sv-13H25T, Sv-01H19N9, Sv-04H19N9, Sv-08H16N8M2 (EP-377), Sv-08H18N8G2B (EP-307), Sv-07H18N9TU, Sv-06H19N9T, Sv-04H19N9S2, Sv-

08H19N9F2S2, Sv-05H19N9F3S2, Sv-07H19N10B, Sv-08H19N10G2B (EI-898), Sv-06H19N10M3T, Sv-08H19N10M3B (EI-902), Sv-04H19N11M3, Sv-05H20N9FBS (EI-649), Sv-06H20N11M3TB (EP-89), Sv-10H20N15, Sv-07H25N12G2T (EP-75), Sv-06H25N12TU (EP-87), Sv-07H25N13, Sv-08H25N13BTU (EP-389), Sv-13H25N18, Sv-08H20N9G7T, Sv-08H21N10G6, Sv-30H25N16G7, Sv-10H16M25AM6, Sv-09H16N25M6AF (EI-981A), Sv-01H23N28M3D3T (EP-516), Sv-30H15N35V3B3T, Sv-08N50 и Sv-06H15N60M15 (EP-367).

According to functions wires are subdivided into – for welding (welding deposition) and for manufacturing of electrodes (design letter – E). According to surface type low-carbon and the alloyed wires are subdivided into non-copper-plated and copper-plated (O). The chemical compound of welding low-carbon wire is given in table 6.

Table 6. Chemical composition of low-carbon steel welding wire, %

Wire mark	C, not exceed	Si, not exceed	Mn	Cr, not exceed	Ni, not exceed	S, not exceed	P, not exceed	Al, not exceed
Sv-08	0,10	0,03	0,35-0,60	0,15	0,30	0,040	0,040	0,01
Sv-08A	0,10	0,03	0,35-0,60	0,12	0,25	0,030	0,030	0,01
Sv-08AA	0,10	0,03	0,35-0,60	0,10	0,25	0,020	0,020	0,01
Sv-08GA	0,10	0,06	0,80-1,10	0,10	0,25	0,025	0,030	-
Sv-10G4	0,12	0,06	1,10-1,40	0,20	0,30	0,025	0,030	-
Sv-10G2	0,12	0,06	1,50-1,90	0,20	0,30	0,030	0,030	-

Source: GOST 2246-70 (2002)

The wire surface should be clear and smooth, without cracks, foliations, scabs, rollings, abscess, nicks, scales, rusts, oil and other pollution. On the wire surface are tolerated grooves (including tightened), scratches, local rippling and separate. Depth of the specified defects should not exceed maximum variation on the wire diameter. At the customer's request the wire can be manufactured with the enhanced surface. In this case on a wire surface small drawing risks, scratches, polishing traces, local rippling and separate dents are tolerated at depth of each of the specified defects but not more than maximum variation for the diameter. On the surface of low-carbon and alloyed wire presence of grease lubricant, except of traces of soap grease without graphite and sulphur is not tolerated. High-alloy wires should be delivered in etched and bleached condition or after thermal processing in inert atmosphere with a clear, light-matte or grey surface, without any traces of greasing.

The main producers of welding wire are the following enterprises: Cherepovetsk and Orlovsk plants OAO “Severstal-metiz”, ZAO “Vayrtsilya metalware plant (Karelia), OAO “Magnitogorsk hardware and caliber plant”

(Chelyabinsk region), OAO "West Siberian Metallurgical Plant" (Kemerovo Region). Rods for manufacturing welding wire with diameter of from 5,5 to 8 мм are produced by Revdinck affiliate of ZAO "Nizhneserginsk hardware and caliber plant" (Sverdlovsk Region).

Alloyed welding wire is produced by the following enterprises:

Cherepovetsk and Orlovsk plants OAO "Severstal-metiz",

OOO "Volgometiz" (Volgograd), OAO "Beloretsk Metallurgical Works" (Bashkiria), OAO "Mezhgosmetiz-Mtsensk" (Orliov Region), OAO "Izhstal" (Ishevsk), OAO "West Siberia Metallurgical Plant" (Kemerovo Region), OAO Magnitogorsk hardware and caliber plant (OAO "MMK-METIZ" Chelyabinsk region), ZAO "Urals plant of precise alloys" (Sverdlovsk Region), OAO "Serp i molot" (Moscow). The volume of output of welding alloy wire in 2005 г. amounted to 53,3 thousand ton.

Table 7 shows directions of deliveries. It is based on the investigation of railroad deliveries of steel wire in 2006.

Table 7. Supplies of welding wire by railway in 2006, tons

Consumer enterprise	MSM MZ	MMK -Metiz	VMZ	Sever-stal Metiz	BMK	UZPS	ZSMK	Izh-stal
OOO "TD LEZ" (Moscow)	29173	-	-	-	-	-	-	-
Borsk Branch of OOO "OMZ-Instrument" (Nizhny Novgorod Region.)	2957	455	203	-	-	-	-	-
ZAO "VEZ Ritex" (Rostov Region)	-	513	-	254	2549	-	-	-
ZAO KOMZ-Export (Rostov Region)	1620	-	789	1338	2493	513	-	-
ZAO "SIBES" (Tumen)	509	463	-	256	5375	64	657	-
ZAO "ESAB-SVEL" (Saint-Petersb.)	5	4	-	2803	-	-	-	-
OAO "Spetselectrod" (Moscow)	-	-	127	-	191	-	-	-
OAO "Mezhgosmetiz-Mtsensk" (Orlov Region)	-	-	-	-	1215	64	-	119
OAO "Ramensk mechanical works" (Moscow Region)	-	320	-	-	255	-	131	-
OAO "Sibelectrod" (Novosibirsk)	-	-	-	-	317	-	203	-
OAO "ShEZ" (Kurgansk Region)	1207	-	-	-	893	-	-	-
OOO "Grafitel-MEZ" (Moscow)	1523	1238	-	510	318	-	193	-
OOO "Penzaelectrod"	-	125	-	-	2368	-	-	-
OOO SZSM ROTEKS (Kostroma Region)	2094	-	-	520	6	-	-	-
OOO "Sychevsk electrode plant" (Smolensk Region)	1796	127	-	958	1408	-	-	-

Source: «InfoMine» based on the analysis of the statistic data of railway transportation
Note: NSMMZ is a Revdinsk affiliate of ZAO "Nizhneserginsk hardware and caliber plant"; MMK-Metiz – OAO "MMK-Metiz", VMZ –ZAO "Vayrtsilya metalware plant, Severstal-metiz – OAO "Severstal-metiz", BMK – OAO "Belotetsk mrtallurgical works", UZPS – ZAO "Urals plant of precise alloys", ZSMK – OAO "West Siberia Metallurgical Plant", Izhstal – OAO "Izhstal"

The second component of a welding electrode is coating. The type of coating is the factor which in great degree determines the electrode characteristics. The coating may be acid, rutile, basic, cellulose and mixed.

The basis *of acid coating* is formed by ferrous, manganese and silicon oxides. The metal of the weld, made by means of electrodes with acid coating, is liable to form shrinkage cracks. In respect of seam metal or welding seam mechanical characteristics electrodes belong to types E38 and E42. Electrodes with acid coating are not liable to form voids during welding of the metal covered with scale or rust, and also during arc lengthening. Welding can be carried out by direct or alternate current.

The basis of the *rutile coating* is rutile concentrate (natural titanium dioxide). The metal of the seam carried out with electrodes with rutile coating, fits for finished of balanced steel. The resistance of the seam metal against formation of cracks on electrodes with rutile coating is higher, than for electrodes with acid coating. According to the mechanical characteristics of seam metal and weld seam the majority of rutile electrodes marks belong to electrodes of the types E42 and E46. Rutile electrodes have a number of advantages in comparison with other kinds of electrodes. They provide stable and powerful burning of an arc during welding with alternate current, small losses of metal on splattering, easy removal of slag crust, excellent seam forming. The electrodes have low sensitivity towards void formation in case of changing arc length, or welding of damp and rusty metal or on oxidised surface.

The electrodes of the considered group also include electrodes with *ilmenite coating*, which are interim between electrodes with acid and rutile coating. Ilmenite concentrate (natural compound of titanium and iron dioxide) is the basic component of these electrodes coating compound.

The main components of the *basic covering* constitute carbonates and fluoric compounds. The metal, deposited with electrodes with basic covering, is equivalent to finished steel according to the chemical composition. Due to the low contents of gas, non-metallic and harmful impurities the metal of the seam made by these electrodes, has high plasticity index and impact strength at normal and low temperatures, and also has increased endurance against formation of shrinkage cracks. According to mechanical characteristics of seam metal and weld seams electrodes with basic covering belong to the electrodes of the types E42A, E46A, E50A and E60. At the same time the technological characteristics of the electrodes with basic covering are inferior to other kinds of electrodes. They are rather sensitive to voids formation in the presence of scale, rust and oil on edges of welded parts, and also at humidifying of coating and arc lengthening. Welding, as a rule, is carried out with direct current of reversed polarity. Prior to welding the electrodes should be heated at a high temperature (250-420 ° C).

The *cellulose coating* contains considerable quantity (up to 50 %) organic components, as a rule, it is cellulose. Metal, deposited with cellulose electrodes, by chemical compound belongs to balanced or finished steel. At the same time it contains an increased quantity of hydrogen. By mechanical properties of seam metal

and welding seal electrodes with cellulose covering belong to the electrodes of the types E42, E46 and E50. It is typical for these electrodes to form a uniform backward seam roll during unsupported series welding and the possibility of the vertical seams downward welding.

In electrode coating the following materials, which have specific functional stresses are used:

1) alloying elements (ferromolybdenum, ferrovanadium, ferrosilicomarganese);
2) slag deoxidizer (ferromarganese, ferrotitanium) – they bind sulfur and withdraw it as slag;
3) slag-forming elements (quartz sand, fluoric concentrate, rutile concentrate, dolomite);
4) "plasticizer" (mica-muscovite, soda ash, sodium carboxymethylcellulose, talc, porcelain clay, electrode cellulose).

Plasticizers improve plastic characteristics of electrode paste;
5) electrode marble – is the regulator of arc burning, protects melting metal from interactions with air;
6) silicate-block is used as a binding element of electrode coating;
7) potassium dichromate – regulator of arc burning and surface-passivating additive used for exclusion of interactions of ferroalloys with melted glass alkali;
8) iron powder – electrode arc burning regulator;
9) nickel powder;
10) blacklead

Coating materials are supplied in bulk in cars or packed: in bags, canisters, metal drums and other containers and are stored in raw materials warehouse in the containers in which are delivered, and also in special containers and in separate compartments. Warehousing of materials is carried out strictly in lots and receipt time in the conditions excluding the possibility of becoming featureless, mixing of materials of different designations, marks, lots, their pollution, change of physical and chemical properties. In every place of storage there must be a table hung out that indicates: material designation, material mark, lot number, certificate number and delivery date.

The leading manufacturer of electrode cellulose (cellulose electrode powder of Э mark) is OOO "Sozim" (Kirov).