UDC 331.461

O.L. Sorochynska /Ph.D in E. S./
State University of Infrastructure and Technologies (SUIT) Kyiv, Ukraine
e-mail: ellena06.84@ukr.net

O.A. Nezlina / Ph.D in E. S./
State University of Infrastructure and Technologies (SUIT) Kyiv, Ukraine
e-mail: nezlina@ukr.net

Professional Hazard Research Analysis During Welding Works

The objective of this work is to develop measures on work improvement during welding operations on enterprises. In this article the authors analyzed the major hazards, which lead to industrial injuries during electronic and gas welding of nonferrous metals and alloys. They especially emphasize that the organism can be intoxicated with foul gases, dust and evaporations, which exhale during welding. The authors considered permissible levels of noise during plasma arc cutting on plasma cutter, limit relations of the explosive mixtures components. They analyzed complex negative effect of industrial health and safety hazards on health of the welders, and also hardness and intensity of work during welding. The authors offered variety of different health precautions to prevent occupational diseases. It has been proved that comprehensive solution in labor protection sphere is important as it is objectively determined by overall low level of labor safety in Ukraine. The researchers determined a correct approach to arrangement of labor protection system at the enterprises, in which they perform welding works, analyzed practical methods and ways to improve labor protection conditions by director.

Key words: labor safety, welding works, hazard during welding works, occupational diseases analysis, working conditions improvement, health hazards.

Challenge problem. One of the main processes in manufacturing and maintenance of rolling stock are welding and other related methods, fraught by industrial health and safety hazards, which lead to typical occupational diseases of the welder workers.

Despite the fact that welding methods and welding materials are continuously improved, there are still many hygiene issues in welding production, which are not solved completely at this moment. As a consequence the working conditions of the welders are still inadequate, which adversely affect their health and working ability. Due to the fact that adverse affect of industrial health and safety hazards on health of the welders is complex, and that this work is hard and stressful, it is necessary to carry out different health precautions.

Research objective is to determine correct approach to arrangement of the labor protection system at the enterprises, in which welding is performed and practical methods and ways to improve labor protection conditions by director.

Statement of basic materials. Comprehensive solution in labor protection sphere is important as it is objectively determined by overall low level of labor safety in Ukraine. The necessary solution of these issues will be to manage labor protection and industrial safety in efficient and complex manner [1].

Safety of welding completely depends on level of workmanship, knowledge and skill of the welder to perform it.

Main hazards, which lead to occupational diseases during welding:

• Electroconvulsive shock during arc welding operations;

• Ocular damage and open skin surface by electric arc radiation;

• Poisoning of organism by foul gases, dust and evaporations, emitted during welding;

• Fire hazard and та burns;

• Blasts of the acetylene generators due to backfires, when the hydraulic back-pressure valve malfunctions;

• Explosions of oxygen containers at the moment of their opening, is there is oil on the connecting branch of the container or on the reducing gear valve;

• Emergency in case of the burner is used carelessly;

• Mechanical injuries during blanking and assembly welding works [2].

Besides industrial injuries during welding the workers who perform such type of works are exposed to hazards effect, which causes occupational diseases. The disease caused by affect of harmful working conditions on the worker, is classified as occupational disease. Occupational intoxication also belongs to occupational diseases. Level of occupational morbidity in welding production is much higher than in other branches of industry.

Each industrial environment possesses one common characteristic – several hazards can affect the human organism at the same time, which either cancel out, or superimpose on one another, having a harmful influence the human health. Over the last years we can see that level of brain and nervous system morbidity due to using monotonous, often repeated movements and physical activity. These diseases are registered on sections, where production process is partially automated and mechanical, where they use only hand work [3].

As industrial health and safety hazards available in table 1, it means that they are inherent consequences of welding process, among them the Welding Aerosol is the biggest threat to the welder's health, due to the fact that till no the welder is hardly protected against Welding Aerosol. Affect of the welding aerosol on organism causes bronchopulmonary diseases, such as pneumoconiosis (or dust disease), which contracts when the welders worked for more than 15 years in welding departments, and chronic bronchitis, which appears after 5 years of work. During welding in places inaccessible for ventilation in the enclosed spaces at the time of pneumoconiosis progression shortens to 5 years. For another thing there are data, saying that impact of cancer-producing substances, such as hexavalent chromium and nickel being parts of Welding Aerosol on respiratory system tend to increase risk of cancer development [4].

Table 1 – Hazardous substance maximum allowable concentration in air during metal welding

Welded metals, alloys and gas compounds	Substances	Maximum allowable concentration, mg/m^3
Aluminum and aluminum-based alloys	Aluminum	2
Beryllium bronze	Beryllium and its compounds	0,01
Lead	Lead and its inorganic compounds	0,01
Hydrogen compounds	Hydrogen fluoride	0,05
Copper and copper-based alloys	Copper (metal and its oxides)	1
	Manganese oxide	0,3
	Silicon oxide	1
	Nickel oxide	0,5
	Zink oxide	5
	Nitrogen oxide	5
	Ozone	0,1

Content and amount of foul gases, dust and evaporations depend on which type of welding is used, composition of protective means (coatings, fluxing agents, gases), welding and electrode materials. Amount of welding dust (aerosols) and simple compounds in welding comprises 10 to 150 mg on kg of molten electrode metal.

The principal constituents of it are as follows: iron oxide (to 70 %), manganese, silicon, chrome and other compounds. The quickest of them are chrome, manganese and fluoride compounds. Besides by virtues of aerosols the air is polluted by different foul gases, such as nitrogen oxides, carbon ones, hydrogen fluoride and so on in the workstations during welding.

Most frequently the workers are being affected by hazardous substances during welding and cutting of non-ferrous metals. Their maximum allowable concentrations are often much more exceeded in practical terms. In table 2 we listed maximum allowable concentrations of hazardous substances in air during welding of some non-ferrous metals and alloys [5].

If we compare the data of the tables, we can see that content of almost all the substances near respiratory system of the welders is much bigger than allowable standards. Peculiarities of following safety instructions during welding of copper and copper alloys lay in the fact copper and alloying elements in its alloys extensively vaporize, and their pair is toxic. The given data concerning maximum allowable concentrations of hazardous substances are taken in air on lever of respiratory system.

Table 2

No з/п	Name of hazards	Maximum allowable concentration, mg/m³
1.	Manganese in welding aerosols in concentration:	
	To 20 %	0,2
	from 20 to 30 %	0,1
2.	Chrome oxide (on Silica gel Sg (Cr)³*)	1,0
3.	Chromates, biochromates (calculated as SgO_3 CrO_3)	0,01
4.	Nickel, nickel oxide (by No)	0,05
5.	Ferrum, ferrous oxide (by Pe)	6,0
6.	Silicon dioxide noncrystalline in mix with manganese oxide aerosolised in condensation, when content of each of them is no more than 10 %	1*
7.	Copper	1/0,5**
8.	Titanium, titanium dioxide (by Ti)	10,0
9.	Zink oxide	0,5
10.	Fluorides (by P):	
	a) sodium fluoride, potassium fluoride...	1/0,2**
	б) aluminum fluoride, magnesium fluoride, calcium fluoride, strontium fluoride, Copper fluoride, chrome fluoride...	2,5/0,5**

*MAC for gross weight of aerosol.

**Maximum in nominator, time-weighted average – in denominator.

The occupational diseases of the welders also include: intoxication (poisoning) manganese, which is typical for central nervous system injury. High concentration of carbon monoxide in the air may be the reasons of both acute and chronic poisoning. Impact of nitrogen oxides in the closed rooms may occur as pulmonary edematization. Heightened content of solid and gaseous compounds of fluorine in Welding Aerosols causes upper airway mucous tunic injury, bronchi injury, development of bronchopneumonia. Small amounts of ozone irritate upper airway, and big ones devastate it. The unspecific diseases, cause by welding aerosol, are parts of functional illness of central nervous system and cardiovascular one, allergic diseases and so on.

Welding process is one of the powerful production infrared sources. Not only welders, but also workers of other specialties, who are nearby, are exposed to its impact. Infrared radiation during welding of heated products, especially big components parts, is a factor that makes conditions for microclimate in manufacturing facilities. Depending on power of arc-welding current, temperature of arc and welding bath, degree of heating and other conditions, radiation has different spectral distribution and covers the area 0,76...10 mkm and more. Radiation intensity of worksites ranges within 100...2450 W/m². Intensity of infrared radiation depends on welding regime, power of arc and increases from 350...400 W/m² during welding by covered electrodes on regimes from 150...200 A to 1200...1500 W/m², during welding of nonferrous metals in reactionless gases, and also preliminarily heated constructions.

All the types of welding metals by open arc, except for welding under fluxing agent is a source of visible radiation, ultraviolet rays, sparks and splashes of molten metals and stag. As there are different ways of welding, ultraviolet rays of spectrum is within 1...40% of radiant flux integrated intensity. As power of arc-welding current and arc voltage increases, intensity of ultraviolet component of radiation in optical spectrum increases as well. Radiation spectrum changes position to short waves. Composition of the electrode coating and material of admixtures also impact on intensity and ultraviolet radiation spectrum. The biggest impact on range of ultraviolet radiation reveals composition of protective gas. As content of argon increases in protective gas mixture, intensity of ultraviolet radiation increases too. As distance from the arc increases, intensity of ultraviolet radiation decreases. Exposure of welder's body to radiation depends on beating and passing-through properties of working clothes. Impact of ultraviolet radiation on unprotected eyes may cause electric ophthalmology, reduction in vision, conjunctivitis and other diseases [6].

Level of noise, created by the arc, depends on welding regime. Indeed, during mechanized welding in carbon dioxide when the current force changes from 200 to 450 A level of noise increases from 86 to 97 dBA, and during welding in argon increase of the current from 150 to 500 A causes increase of noise intensity from 90 to 150 dBA, in other words, on some separate regimes standard is exceeded. At the same time, besides noise, created by the arc and welding equipment, the workers may be exposed to impact of other sources of noise, created during work of processing equipment.

Physiological impact on the welder manifests as physical and neuro-psychic loads. Physical loads cause static and dynamic stresses, which depend on mass of the welding tool, flexibility of hoses and wires, duration of continuous work, maintenance of working stance. As a result static excessive stress may cause neuromuscular disease of thoracic girdle. Neuro-psychic loads cause excessive stress of visual analyzers and occurrence neuro-psychic tension of the welders. These loads depend of tension of vision, cause by continuous surveillance over unsatisfactory contrasting elements of the welding area

of small size (welding bath, interface gap, crater depth, the seam is hardened and so on), responsibility for high quality of weld seals and complexity of work. Excessive stress of visual analyzers may cause fatigue and as a result it breaches contractile eye muscle function. Neuro-psychic tension may violate functional status of cardiovascular and central nervous system (increase in arterial blood pressure, change of ecliptic period of motional-powered reaction).

Statistics of welders' occupational diseases (%):

– intoxication by Manganese (40-45%);

– pneumoconiosis (35%);

– musculoscepetal system disorders of upper limbs (9%);

– neuritis of osteophone (7%);

– intoxication by welding aerosols (besides Manganese) (4%);

– intoxication by gases (2%);

– functional illness of nervous system (46%);

– change of upper airways (pharyngitis) (30%);

– bronchitis, pulmonary emphysema (10%);

– gastrointestinal problems (gastritis, ulcer) (14%).

For this reason labor protection in welding is of vital importance. In order to reduce number of occupational diseases the director of the enterprise must dramatically review the old ways and develop new ways to improve working conditions for the welders. First he must determine correct approach to arrangement of the workplace and means to improve the working conditions. Unfortunately, means concerning improvement of the working conditions for the welders, which were used in previous years, did not show significant positive results, the problem of creating healthy and safe working conditions for the welders remains to be currently central and vital problem of modern times. There must be more radical approach for its solution, in particular, according to global and national experience, they need to combine engineering and sanitary measures on elimination of the welding aerosols hazard, and also to use respiratory protective devices for the welders. First course is engineering, which provides reduction of the welding aerosols exhalation into the air by virtue of improvement of the welding process, choosing the technology and ways of welding, type and brand of the welding material, protective gas and welding regime. The second course is sanitary, which provides localization and neutralization of the welding aerosols of the modern efficient means of local ventilation. The third course is using respiratory protective devices of new generation, which allows to protect the respiratory system of the welders in different production conditions. Depending on the working conditions, and also the requirements to quality of the welding seals, they need to use the complex of these means, or some of them [7].

They need to put more focus on the substances, which affect the workers during welding and cutting of the nonferrous metals. Their maximum allowable concentrations are oftentimes higher in reality. They need to follow the safety rules during welding of copper and copper alloys, as copper and alloying elements in its alloys are extensively evaporate, and vapors are very toxic. Special focus must be on manganese concentration, its availability in the air more than 0,3 mg/m^3 may cause severe diseases of nervous system. During preliminary or additional heating of nonferrous metals during welding of the mixture with oxygen при may be inflammable.

The principal means of eliminating hazard of the welding materials on body is using ventilation. But there is the other means of air environment improvement, which is no less important and is of particular interest – engineering one, which is in improvement of welding engineering and materials, and also in choosing the appropriate welding regimes.

During welding the worker also may be exposed to electric shock. Electric shock occurs when a person touches conducting parts of electric circuit wiring and welding equipment, which are used for arc, interface and beam types of welding. The currents, which go through human body, which are more than 0,05 A (in frequency 50 Hz), may cause severe consequences and even death (> 0,1 A). Resistance of human body, depending on state (fatigue, skin moisture, health state), changes between 1 000 to 20 000 Ohm. No-load voltage of the normal arc electric power supply reaches 90 V, and during plasma arc cutting the person must take into account larger value of welding arc voltage and free movement of electric power supply (180 V during manual and to 500 V during machine cutting). For this reason if the welder feel ill, he may get electric shock close to maximum – 0,09 A.

Electrical safety must be provided by performing the electrical safety requirements of the electric welding equipment, reliable isolation, using shelter belts, automatic blocking, earthing of electric facilities and its elements, limitation of free movement of electric power supply (generator of direct current to 90 V, transformers to 75 V). Length of wires between the power line and displaceable welding outfit should not exceed 15 m. During work in complicated conditions either in enclosed vessels the welding unit must have blocking device for automatic release of arc-welding circuit or brownout of voltage during arc break to 12 V. Casing of the welding units, framing of distribution boards and cabinets it is necessary to earth by the copper conductor cutting no less than 6 mm² or steel cut no less than 12 mm². Temperature of heating of some parts of welding unit should not exceed 75°C; protective devices

(work in dry and strong working clothes and gloves, in shoes without metal prickers and nails); following working conditions (termination of work during rain and heavy snowfall, when there is no shed; using the rubber carpet, rubber helmet and overshoes during work inside container, also by portable lamp of voltage no more than 12 V; repair of electric welding equipment and facilities by electrical engineer).

Protection of vision and skin of face during arc welding is provided by using boards, masks or helmets from heat-proof dielectric materials (ready-mixed paints, soaked with special solution, veneer and so on) with shielding glass – light filters (size 52Í102 mm),which hold and absorb radiation of arc. Depending on arc power, they use different light filters. In order to protect from arc radiation in steady-state conditions they establish safety cabins, and in construction and installation works they use portable shields and covers. In order to protect body they use working clothes from retentive canvas or woolen cloth, which is sometimes from asbestos fabric.

During welding of copper and some of its alloys they use nitrogen and argon, which have bigger relative density, so they may expel oxygen from the room. This factor is especially hazardous during work in closed spaces, which should be considered during installation of suction guns of local and general ventilation. In such spaces air intake to control content of nitrogen and argon must be conducted constantly by virtue of continuous automatic gas analyzer.

Conclusions: Problem of protection for the workers, improvement of labor protection arrangement at the enterprise, at the institution, at the organization is currently central for today. Assessment of labor protection state and efficiency of its improvement is one of the main tasks for managing the labor protection. All the business profiles in one way or other effect the level of provision by labor protection by promoting or reducing it.

According to expert evaluation during next 10 years almost 2/3 the basic production funds of the country will be worn out. Namely both funds functioning for 15-20 years and those for 10-14 years as well, will be critically worn out. At the same time potentiality of Ukraine will not allow Ukraine along with foreign investors to perform their complete renewal, so in the nearest years we have to wait increase of number of industrial disasters, catastrophes, industrial accidents. So in such conditions first we need to speed up processes of restructuring and modernization of the enterprises. In this process labor protection is essential as system, which should focus all its efforts on provision of proper safety for labor and production environment.

The principal measures on reduction of accident rate and occupational diseases are the ones considered in light of safety of works, namely engineering of work material, assembly and welding, correct equipping of workplaces and following main safety engineering rules by the staff.

REFERENCES

1. Sorochynska O.L. (2014) Stan Okhorony Pratsi V Ukraini Ta Zakhody Dlia Yii Polipshennia [State of labor protection in Ukraine and means to improve it]// Zbirnyk Naukovykh Prats Derzhavnoho Ekonomiko-tekhnolohichnoho Universytetu Transportu Seriia «Transportni Systemy I Tekhnolohii» [Collection of research papers of State Economic and Technology Transport University]. – Ed. 24. – P. 240-248.
2. Bykovskyi O.G., Lazutkin M.I. (2012) Okhorona Pratsi Pry Vyrobnytstvi Konstruktsii Z Kolorovykh Metaliv I Splaviv [Labor protection in manufacturing constructions of non-ferrous metals and alloys]// Visnyk Natsionalnoho Tekhnichnoho Universytetu «Kharkivskyi Politekhnichnyi Instytut» [Bulletin of National Engineering university "Kharkiv Polytechnic Institute"]. – Ed. 1.,– P. 128-136.
3. Sorochynska O. L. (2016) Analiz sposobiv pokrashhennya umov oxorony` praci na pidpry`yemstvi [Analysis of ways of improving the conditions of labor protection at the enterprise]// Metalurgijna ta girny`cha promy`slovist` [Metallurgical and Mining Industry]. – No.12. – P.12-16.
4. Levchenko O.G. (2004) Gigiyena praci ta vy`robny`cha sanitariya u zvaryuval`nomu vy`ro¬bny`cztvi. Navchal`ny`j posibny`k dlya studentiv zvaryuval`ny`x special`nostej. [Labor health and industrial sanitation in welding production. Training manual for students of welding specialties.]– 98 p.
5. Edited by L. M. Lobanov. (2003) Svarnye stroitel'nye konstrukcii: Sprav, izd. 3-h t. [Welding building constructions, edition in 3 volumes]/ – V. 3, 378 p. – O. G. Lebchenko, V. A. Metlickij. Glava 6: Ohrana truda pri svarke [Chapter 6: labor protection in welding]/ – P. 293-319.
6. DSTU 2456-94. Zvaryuvannya dugove i elektroshlakove. Vy`mogy` bezpeky`. – K.: Derzhstandart Ukrayiny`, (1994). [Arc and electroslug welding. Safety requirements. Kyiv. State Standards of Ukraine]– 18 p.
7. Levchenko O. G., Metlickij V. A. (2001) Sovremennye sredstva zashhity svarshhikov. – [Modern protection devices of the welders] Kyiv; – 84 p.

Photographer Miroslav Orshak©