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Evaluation of the radiation situation in utilization of metal contaminated with radioactivity using the effect of self-decontamination

Victor Mashinistov

PhD in Technical Sciences
The National Metallurgical Academy of Ukraine, Dnipropetrovsk

Oleg Galkin

The National Metallurgical Academy of Ukraine, Dnipropetrovsk

Abstract
In presented paper the evaluation of the radiation situation had been carried out. It is meant the situation, which is formed while performing the technological operations with metal contaminated with radioactivity, which is used in steel-smelting production as charge.
It is shown that the necessary level of radiation safety is ensured, while stocking the scrap of metal contaminated with radioactivity, transportation and melting this scrap.
Key words: METAL CONTAMINATED WITH RADIOACTIVITY, EVALUATION OF THE RADIATION SITUATION, SELF-DECONTAMINATION, UTILIZATION OF THE METAL

The gradual (progressive) accumulation of a high quantity of radioactive waste takes place in the process of economic activity at industrial enterprises of different purpose. The major part of this waste accounts for metal contaminated with radioactivity. Potential threat of radiation danger for people and natural environment is directly proportional to the scale and quality composition of such accumulations and it shows tendency to rise. The negative character of this technogenous phenomenon is also connected with serious expenses for servicing the objects of storage and the actual withdrawal of a big quantity of metal from the economic turn-over. In practice, the radioactively contaminated metal (RCM) is used repeatedly after its decontamination employing for this purpose different means- chemical (liquid), mechanical, hydraulic, thermal and others. While doing this one does not always succeed in ensuring the necessary degree (level) of clearing metal surface of radioactive substances, and, beside that, the new radioactive waste (radioactive slag, scale, slime or sludge and dust, big volumes of the waste decontaminating solutions) are formed. The economic aspect of decontamination technologies to be used is also of no small importance: for example, for one ton of the RCM the value of utilization presents from 2,000 to 8,000 Euros [1].

The big volume of metal with surface contaminated with radioactive substances is formed as a result of large-scale emergencies on the installations of nuclear energetics with emission of radionuclides into environment. A big quantity of radioactive waste is accumulated on installations of nuclear energetics while running and dismounting the equipment, which had working out its service life. In non-nuclear sector of industry there is also the possibility of the surface contamination of the metal articles with natural radionuclides (radium, thorium, potassium), for example, at oil production and exploitation of artesian wells. As to the degree of radioactive contamination, the most of this waste (90-95%) are low-active, level of emission of this waste exceeds admissible by units and tens times. In [2] the approach is proposed consisting in charging RCM into the smelting furnace with the type technological process omitting the stage of preliminary decontamination. The maximum quantity of this metal is determined by the value of admissible level of radioactive emanation of the smelted metal. While using this method, the process of melting metal leads to absorbing the important part of emanation of radionuclides, which were brought into the furnace, in the volume of melted metal. It means that under such conditions the effect of the self-decontamination takes place. It is also necessary to take into account the fact that in the process of melting RCM the radioactive substances, which have the temperature of boiling lower than the temperature in the smelting furnace, are evaporating, clearing additionally the finished products from the sources of ionizing radiation (IR).

The process of utilization of the RCM according to technology under consideration includes a number of operations connected with putting the metal scrap in storage, its transportation and metallurgical processing. In this case the whole package of measures aimed to ensuring the radiation safety and prevention of additional radioactive contamination of environment should be planned and carried out.

While performing operations with RCM, it is necessary in each particular case to apply one's judgement to the radiation situation in purpose of determining the degree of potential action of the latter on the personnel performing the work for utilization of the RCM. Evaluation of the RS includes determination of the scale and degree of the radioactive contamination of metal scrap, analysis of the influence of these factors on people, the choice of the most expedient variants of acting excluding any unjustified irradiation of the production personnel by the level of radiation exceeding the standard ones.

The production personnel carrying out the applicable operations is (or can be) under the action of radiation levels, which serve as initial data for evaluating the RS on each stage of RCM utilization.

Intensity of the radioactive emanation can be predicted on the basis of the known laws, dependences, assumptions. But in this situation it is practically impossible to take into account all the factors influencing this parameter. That is why on the stages of putting into storage, transportation and charging the radioactively contaminated metal scrap into the furnace the necessary data are obtained by the way of carrying out measurements by means of dosimetric devices (by means of devices serving to monitoring the radiation level). As in the course of these operations it is necessary to handle immediately the metal (to have contact with metal), which is the source of ionizing radiation, in accordance with established norms of radiation safety [3], they (these operations) are to be done by production personnel of the category A (appertaining to the category A).

The general (common) radiation-sanitary and organization and technical requirements and procedure of carrying out of all kinds of radiation control for metal scrap are presented in [4].

According to these requirements, only specialists, who have right to carry out the radiation control of facilities in the process of their utiulization, as well as dismantling of details and units of the sets, which include sources of ionizing radiation (IR), are allowed to perform these operations (this kind of work).

One of the stages of this control is revealing and removing the local sources of IR got into the scrap or metal articles with the level of IR exceeding largely allowable one. Fulfillment of above-mentioned requirements ensures radiation safety of the process of RCM utilization on the stages of putting it in storage, transportation and charging into the melting furnace.

The radioactive substances, which are introduced into the furnace, lie on the surface of metal scrap used as charge. The process of melting leads to transition of radionuclides got into the furnace to the volume of the melted metal and are distributed evenly there. Such distribution remains the same in the articles of the smelted metal. As a result, each article represents the source of IR, formed by assemblage (aggregation) of radionuclides, which are distributed evenly in the volume of metal. Each of them can be presented as an elementary isotrope radiating element.

Metal is the solid substance with the great density and high electric conduction, which imposes certain particularities on interaction of metal with different kinds of IR. So, the charged α-particles and β-particles have extraordinary short length of the run, and that is why they do not practically leave the limits of metal. γ-radiation, which is of electromagnetic nature, and neutrons, which have no electrical charge, are able to overcome a few centimeters inside the metal and because of this they can escape into environment and affect the biologic objects staying there. Since the contribution of neutrons into radiation background is insignificant, articles of metal are usually considered only as the source of γ-radiation [6].

Radionuclides, which are present in the volume of metal, are fixed fast in it and that is why they can't leave the boundaries of an article. Therefore these articles are the closed sources of IR and radioactive substances can't get the environment. So, the biologic objects are subject only to external action of radiation created by above-mentioned articles, and all the protective measures are to be carried out taking into account this circumstance.

Only γ-radiation of radionuclides located in the layer situated near the surface of an article of the melted metal can leave its boundaries. The level of the surface radioactivity in finished products is subject to the maximum admissible activity put into the melting furnace [2]. RS in the volume of metal emitting radiation, which is totally absorbed in it, do not present any potential danger (threat) for biologic objects and do not contaminate the environment. In that way metal obtained of the radioactively contaminated charge becomes safe, reliable and long-term depository of RS withdrawn from the sphere of the human vital activity. Under such conditions the intensity of γ-radiation off the surface of metal does not exceed the value permissible by norms (standards).

Thus, in the process of melting metal containing the RS in admissible quantity, the radiation safety of production personnel is maintained as well as while tapping the finished product from the furnace.

As it was shown in [2], in the process of melting, at the same time with the effect of self-decontamination, we have the process of evaporation of radionuclides, which have the temperature of boiling lower than temperature in the furnace (for example, caesium-137, strontium-90). In the example presented in above-mentioned paper, it is shown that is permissible to charge into the furnace the RCM with average level of expositional dose power 216 mcR/hour, and the admissible value of activity put into the furnace is $A = 5{,}6 \cdot 10^{10} B_k$.

Assuming that caesium-137 has such activity, let us calculate its mass according to expression taken from [6]:

$$m = 0{,}24 \cdot 10^{-23} \cdot M_a \cdot T_{0,5}.$$

There M_a is the atomic mass of a radionuclide, g; $T_{0,5}$ is the period of the half-disintegration of the radionuclide.

For caesium-137, M_a=137, $T_{0,5}$=30,2 years. Then the mass of the radionuclide will be: $m = 0{,}24 \cdot 10^{-23} \cdot 137 \cdot 30{,}2 \cdot 365 \cdot 24 \cdot 60 \cdot 60 = 3 \cdot 10^{-23}$, g.

It is obvious that in the time of melting the whole of caesium-137 will be evaporated, and it can get the atmosphere with subsequent deposition on the surface of the ground. As a result, the RS can penetrate through the skin integument into the human organism with air, water and feed leading to his internal irradiation. For preventing ejection of RS into atmosphere in the process of metal melting, the furnace should have a reliable system for purification of emissions to be released into atmosphere.

The process of disintegration of radionuclides, which are present in the volume of metal causes continuous in the time decrease of the level of IR off the metal surface. Insignificant content of radionuclides in composition of metal can't lead to the change of physical and chemical properties of the latter.

The use of proposed technology for utilization of RCM allows to get radiation safe metal, which can be used later on without any restrictions. The known facts quoted in [5] telling, for example, about detecting radioactive cobalt-60 in the finished metallurgical products have, in our opinion, the following explanation. The metallic ampules with radioactive cobalt-60, which are used in powerful industrial IR sources, got into the furnace with metal scrap. The level of radioactivity of such ampules exceeds by several orders of magnitude the value of maximum radioactivity, which can be brought into the furnace with RCM to ensure the necessary radiation purity of finished products. Since in the process of melting metal cobalt-60, which has the temperature of boiling higher than the temperature in the furnace, does not evaporate, it remains, correspondingly, in the finished products, increasing the level of γ-radiation off their surface to the values inacceptable in terms of safety.

Caesium-137, strontium-90 and other radionuclides, which have the temperature of boiling lower than the temperature in the furnace, are widely used in industrial sources of IR side by side with cobalt-60. Ampules with these radionuclides can also be found in the furnace. However, data about detecting these radionucledes in the finished products, are unknown to the authors of the present paper, what is indicative of the total evaporation of these radionuclides in the process of metal melting.

Thus, the evaluation of the radiation situation, which took place while performing operations in utilisation of RCM, showed that the irradiation of production personnel with levels of radiation exceeding the norms (standards) is to be excluded at the choice of intelligent variants of working. All the operations with RCM are to be performed by the personnel belonging to the category A – persons who work with sources of IR.

The necessary radiation purity of finished products of the melted metal contaminated with RS is reached at the expense of the effect of self-decontamination as well as at the cost of evaporation of the radionuclides, which have the temperature of boiling lower than the working temperature in the melting furnace.

Such result can be reached using the existing melting furnaces, which do not demand additional equipment and change of technological heat. In that way the high technological (engineering) and economical indices are ensured for the process of manufacturing products using the RCM, as well as for solving the ecologic problems connected with contamination of environment with metallic radioactive waste.

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