Principles and Methods of EMF Safety Maintenance by Individual Protective Means

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Abstract— According the electromagnetic safety principles one of way of this solution is protective mean use. There are 2 main kinds of protective means: collective and individual. Collective protective means in dependence of EMF frequency range decrease EMF value by means of EMF reflection or absorption. Individual protective means (protective suits) use as a rule in cases of static electric field, power frequency (50/60 Hz) electric field and radiofrequency (RF) EMF occupational exposure. The methods of these protective suits testing are developed in different countries. Great difficulties are connected with correct evaluation of RF EMF individual protective means protective characteristics. There is presented the method of RF EMF protective suit (PS) safety properties evaluation. Safety properties of modern PS are based on EMF reflection, which ensures shielding effect. PS is made of electro-conductive materials; all elements are connected to produce a "cover" around a human body, which allows reducing the EMF values to permissible levels. The testing of protective suit is carried out by special setup use. EMF is emitted by means of RF generator connected with antenna through amplifier. Special setup includes human body phantom (head, trunk and extremities) and measuring probe connected to personal computer by optic fiber. Phantom is placed in spatially homogeneous EMF for all body parts. EMF measurement is carried out in three control points (head, breast and groin) at fixed distances from RF EMF source in two phantom positions: in front and back to the RF EMF source (with and without PS). The results obtained by suggested approach allow determining PS protection level (in dB), and develop recommendations for construction upgrade. Furthermore, the obtained data of shielding effectiveness suggest that there is the relationship between protective properties and RF EMF values. Proposed method of PS shielding effectiveness evaluation can help analyze that relationship in future studies.

1. INTRODUCTION

High level electromagnetic field (EMF) human health protection is one of the major electromagnetic safety problems, occupational exposure especially. It is necessary in case of work near EMF sources like power transmission systems, cellular, satellite antennas, radars, radio and television transmitters and others. According the electromagnetic hygienic principles the worker protection is based on exposure time limits, safe distance from the EMF source and protective mean use. There are 2 main directions of protective means: collective and individual. Collective protective means in dependence of EMF frequency range decrease EMF value by means of EMF reflection or absorption.

There are some standards establishing the requirements to protective means in the Russian Federation. One of them establishes the requirements to static electric field protective means (GOST 12.4.123-83 Occupational safety standards system. "Means of static electricity protection. General technical requirements.").

Two State standards provide the requirements for collective and individual protective means from power frequency (50 Hz) electric fields only.

50 Hz electric field protective means must meet the requirements:

- Stationary shielding devices — to requirements of GOST 12.4.154-85. Occupational safety standards system. "Screening devices for protection from power frequency fields. General technical requirements, basic parameters and dimensions";
- Screening (conductive) suits — to requirements of GOST 12.4.172-87 Occupational safety standards system. "Individual screen set for protection from power frequency fields. General technical requirements and methods of control".

In practice individual protective means (protective suits) are effective and convenient personal EMF protection in cases of maintenance and repair work on functioning equipment. It can be used when the others protection ways are impossible.

Protective suits (PS) are special protective clothing and used as a rule in cases of static electric field, power frequency (50/60 Hz) electric field (EF) and radiofrequency (RF) EMF occupational exposure.

Individual protective means from static electricity include: anti-electrostatic clothing, anti-electrostatic shoes, and safety devices anti-electrostatic (rings and bracelets), and hand protection means.

There are some special requirements for individual protective means. The typical PS consists from different constructive elements made of electrically conductive materials: coveralls (or jacket and pants), helmet with face shield, gloves and feet protective means (socks, boots and (or) shoes). All elements are electrically connected to produce a "cover" around a human body, which allows the EMF values decrease to permissible levels.

The modern shielding complete set for protection from power frequency electric fields represents the hi-tech product creating closed electrical spending space around of human body (individual "Faraday cage"), excepting penetration of electric field even very high intensity inside of screening spaces. Possessing high conductivity, complete sets shunt human body, excepting course through body displacement and pulse currents.

Conductive (screening) suits for bare-hand (hot-line) work besides protect user breath from dangerous air-ions formed as a result of air ionization under high voltage exposure. Shielding complete sets of the best world manufacturers combine high protective characteristics with demanded sanitary-and-hygienic parameters. Such complete sets are developed in Germany, USA, Japan, etc. Complete sets are widely applied today all over the world at repair and service of extremely high voltage (EHV) installations, in particular at carrying out of various kinds of works on energized transmission lines. In Russia application of individual shielding complete sets is obligatory at repair and service of the equipment in EHV installations zone of influence. Check of screening suit shielding properties is carried out by means of phantom of human body is developed. Phantoms were applied to determination of capacitive currents in human body, EF levels on human body surface on ground potential; values of capacitive and air-ion currents, EF intensity on body surface under hot-line works maintenance. Now phantoms are used for qualifying tests of screening suits in setup of FSBSI "Research Institute of Occupational Health". According to GOST 12.4.172-87, screening suit factor of shielding should not be less than 100.

There is the problem of RF EMF individual protective mean standardization and testing in the Russian Federation. New Standard: GOST 12.4.292-2013 Occupational safety standards system. "Shielding set for personal protection from radiofrequency electromagnetic field exposure. General technical requirements" was developed and introduced in 2014.

According this standard PS is for workers protection from RF EMF exposure in the frequency range from 10 kHz to 300 MHz by electrical component and in the frequency range from 300 MHz to 60 GHz by power density.

The main characteristic of PS that determines its' safety properties based on reflection or absorption energy, is the shielding effectiveness of whole PS. According the goal of adequate evaluation of RF EMF PS screening characteristics the research was directed to develop the correct RF EMF individual protective characteristics assessment method.

2. METHODS

The method of RF EMF protective suit (PS) safety properties assessment is tested. The aim of PS efficiency evaluation is to assess the shielding effectiveness at three points according to the most critical human body parts location: the head, chest and groin. Also it is rational to examine these points for PS design features and elements connection control.

The protective suit testing is carried out by special setup use (Fig. 1), which allows to measure RF EMF levels intensity without as well as with PS inside it's cavity and calculate the shielding effectiveness for the corresponding frequency.

Testing setup includes radioparent human body phantom (head, trunk and extremities), measuring probe connected to personal computer by optic fiber and RF EMF source (RF generator connected with antenna through amplifier). Phantom is placed in EMF spatially homogeneous for all body parts. EMF measurement are carried out at selected radiofrequency in three control points (head, breast and groin) at fixed distances from RF EMF source in two phantom positions: in front and back to the RF EMF source (with and without PS).

RF PS protective properties are determined by the EMF intensity attenuation degree and expressed by shielding factor (K_{SE}). K_{SE} is evaluated by electric field component in EMF frequency

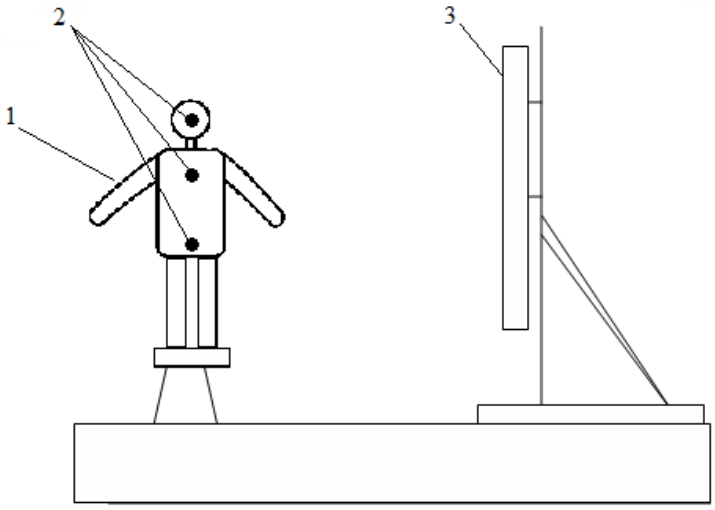

Figure 1: The setup for protective suit testing: 1 — human body phantom, 2 — control point, 3 — RF EMF source.

range from 10 kHz to 300 MHz (Eq. (1)) and by power density in EMF frequency range from 300 MHz to 300 GHz (Eq. (2)).

$$K_{SE} = 20 \log \frac{E_1}{E_2}, \tag{1}$$

where E_1 — RMS value of electric field strength of RF EMF without PS, E_2 — RMS value of electric field strength of RF EMF with PS.

$$K_{SE} = 10 \log \frac{PD_1}{PD_2}, \tag{2}$$

where PD_1 — RMS value of RF EMF power density without PS, PD_2 — RMS value of RF EMF power density with PS.

The shielding effectiveness testing results for 2 different PS models (Sample 1 and Sample 2) were evaluated by the RF EMF power density according Eq. (2) at frequencies: 900, 1800, 2100 and 2600 MHz. The measurements were carried at 3 control points and 2 phantom positions (back and front) during 6 minutes each one.

3. RESULTS

The results of suggested method testing in two different PS sample are presented in Fig. 2 and Fig. 3.

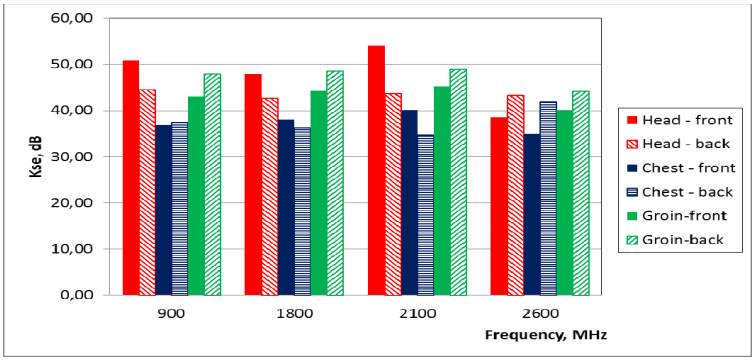

Figure 2: Frequency dependence of shielding effectiveness for PS Sample 1.

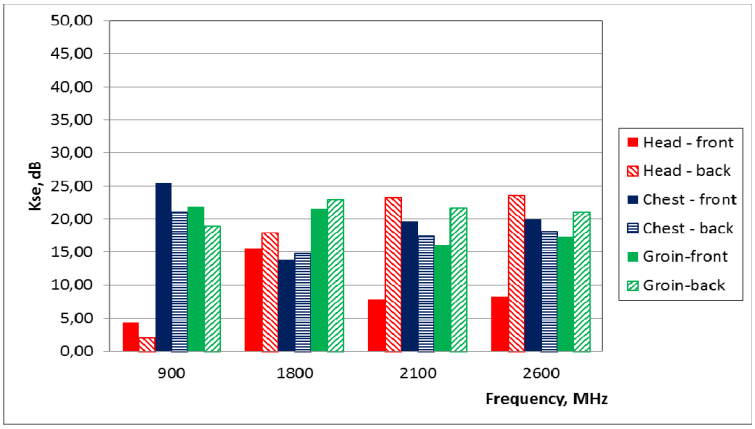

Figure 3: Frequency dependence of shielding effectiveness for PS Sample 2.

The shown diagrams allow to compare the protective properties of selected PS samples. According Technical Regulations of the Customs Union "Personal protective means safety" K_{SE} must be not less than 30 dB [1].

The results show that Sample 2 (Fig. 3) is not in compliance with requirements for RF PS because K_{SE} is less than 30 dB for all frequencies and testing points. The lowest K_{SE} values are obtained for head control point, which may be caused by helmet construction defects.

The Sample 1 (Fig. 2) provides the good RF EMF protection in considered frequency range, its' K_{SE} is from 40 to 54 dB, and therefore corresponds to RF PS requirements.

4. CONCLUSION

Suggested method of RF EMF individual protective mean efficiency testing help to solve the problem of staff electromagnetic safety, and allows including this principle into standardized approach in Occupational safety standards system. Thus, we extend the system of individual protective means from EMF exposure (as human health risk factor) control.

The results obtained by suggested safety properties assessment testing method allows to determine PS RF EMF protection factor (in dB) and develop recommendations for construction upgrade. The shielding efficiency of PS material must be higher then protective suit, therefore the shielding effectiveness properties of material must be 30 dB at least, or higher.

Furthermore, the obtained data of shielding effectiveness suggest that there is the relationship between protective properties and RF EMF values. Proposed method of PS shielding effectiveness evaluation can help analyze those relationships in future studies.

REFERENCES

1. TR CU 019/2011 Technical Regulations of the Customs Union "Personal protective means safety", (in Russian).