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Saint-Petersburg Electrotechnical University “LETI”

ISSUES OF LIFEGUARD FOR GRADUATE QUALIFICATION WORKS

Workbook

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In the Workbook are observed issues that could be included in the additional section "Life safety" of graduate qualification work for Bachelor students and Specialists, and "Special issues of safety provision" for the Master students.

The Workbook is prepared for Bachelors, Specialists and Masters of all LETI basic education programs.

Approved
by the editorial and publishing board of the University
as a workbook

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INTRODUCTION

Nowadays all Bachelors and Specialists in their curricula have the discipline “Life safety”, and Masters in some areas of training - the disciplines “Special issues of safe instrumentation design” and “Systems for safety control of technical means”.

Graduation qualification work (GQW) is the final stage of training under the educational program and should show the following students’ skills: to carry out calculation of the life safety conditions implementation; to use the rules of lifeguard, industrial sanitation, fire safety and labor protection standards; to evaluate the conditions and consequences of organizational and management decisions, to take the justified risk in decision-making, to use the legal documents in their activities; to manage methods of professional injuries and diseases prevention, the main methods of the personnel protection from the possible consequences of accidents, disasters, natural disasters, the use of modern means of various destructions’ consequences elimination.

The university graduate must meet the highest requirements of the modern society. Having the necessary skills and competencies, the student will feel confident while working abroad or implementing joint projects with foreign partners. The priority tasks of security assigned within the frames of GQW, which leading organizations often put on the first place, are considered necessary and, undoubtedly, important.

This manual explains the life safety (LS) objectives development for Bachelors and Specialists and special issues of safety provision for Masters (SISP), as well as provides the students with the information from legal and other documents to facilitate the problem understanding and to increase the quality of preparation and presentation of GQW additional section materials.

The proposed volume of the additional section in Bachelor's work ranges from three to five pages, in the Specialist's diploma project or diploma work - from 10 to 12 pages and in the Master's thesis - from 8 to 14 pages of text, depending on the selected version of the assignment.

MOTIVATION OF SAFEGUARD ISSUES CONSIDERATION IN THE ADDITIONAL SECTION

The topics of the graduation qualification works are rather various. Each “development” is aimed to have novelty and to make a positive impact for the society, as well as to recognize the performer of the work as a specialist in his field of knowledge, and organization as a leader, reliable partner or executor for the potential customer and consumer of this development. Within the frames of GQW implementation, the student can design a product, technological process or can create a software product. The technological processes include informational and info communicational technologies or technologies of the intercultural communication. Some students have topics related to fundamental research of a new problem, writing a text, drawing out formulas and translating a material to foreign language, which require only a pen as the main tool, and for the output and presentation of results - personal computer (PC) and printer. Some topics are related to experimental research.

The implementation of the chosen task, which will be carried out within the process of GQW preparation or after its completion (implementing the solutions proposed at the student’s workplace), is associated with a certain risk (combination of the damage probability and the severity of this damage). Students face the risks that can have a negative effect on the achievement of the set goal at all stages of the work’s implementation life cycle (development, research and testing, operation and disposal). The main type of risk is considered to be the technical risk (the risk of damage to the company or third party as a result of breakdown of the product, software, the manufacturing process, etc.) and professional risk (the probability of body damage or death, while implementing the contract and in other cases specified by law).

Any proposed new solution (instrument, technology, software product, etc.) can create new dangers and thereby increase the risk. In this regard, the risk assessment (based on the results of the risk analysis procedure, whether the level of permissible risk is exceeded) should be carried out when performing any work, in this case within the frames of GQW preparation.

In order to meet safety requirements and safety for users of the country where they will be used, many products must have certificates of conformity for electrical safety, fire and explosion safety, bio electromagnetic compatibility, vibroacoustic, technical-aesthetic, chemical, biological and other compatibility, as well as safety for other systems in their environment (electromagnetic compatibility, etc.). In order to achieve this, the developer must carry out serious testing trials for each type of hazard for subsequent verification of compliance with set requirements.

Because of the integration of the Russian Federation into the international economic space, implementation of international contracts for research and development, and export of developments abroad, the requirements for products, technologies and software are significantly increasing. If the "development" is of poor quality and poses a certain danger to human health and this will be revealed during work process of the customer, especially in some special cases (in abnormal mode, in the event of parameters deviation beyond the permissible limits in case of an accident), and the customer suffers a damage for his property or have the moral damage, the developer will find himself in a quandary and will have to face the negative consequences.

In case of health risk according to the methodical recommendations of MR 2.2.9.2311-07 “Prevention of the workers stress during various types of professional activity” the following should be outlined.

• The main workloads responsible for the industrial and professional stress during the professional activity are:

- in case of the mental load - long and irregular working day with shift work, business trips, work in a state of time shortage, duration of focused attention, density of signals and messages per unit of time, high degree of the assignment complexity, the expressed responsibility, the existence of a risk for the life;

-in case of visual load - high accuracy of the work performed, the need for high coordination of sensory and motor elements of the visual system, i.e. coordination of vision with the system of the body movement, the time of operation with optical instruments and the time of operation directly with the screen of video display terminals (VDT) and personal computers;

-in case of physical loads - dynamic and static muscular loads associated with lifting, moving and holding various weight, considerable effort applied to control units and hand tools, repetitive hands motions of different amplitude, performing regular bents of the body, prolonged maintenance of physiologically unpractical body poses while working.

• The main distinguishing feature of all modern types of work activity is insufficient level of general motor activity and stay in physiologically unpractical body positions while working (uncomfortable, fixed, forced).

• The peculiarity of the state of professional stress development is the combination of unfavorable factors of workload with psychological and organizational stresses. Psychological factors are related to the organization of work: freedom in decision-making, the level of influence and control of one's own working situation, the choice of ways and terms for the task fulfillment and control. Organizational structure and interpersonal relationship at work are the strongest factors that can cause industrial stress.

• Allowable workloads provide changes (fluctuations) in the physiological parameters of various functional systems of the body in the dynamics of the work shift within the limits of physiological norms of the body's stress.
• Prolonged and intensive impact of unfavorable factors of the labor process exceeding the normalized (permissible) values and corresponding to the harmful class 3 according to the G 2.2.2006-05 "Guidance on hygienic assessment of working environment factors and the work process. Criteria and classification of working conditions", forms professional stress.
• Formation of occupational and professional stress includes the stages of a sequential transition of a functional state from stress to fatigue, from fatigue to overstrain. The analysis of the physiological characteristics of these states allows to evaluate them from the point of view of functional levels, intra- and intersystem connections in the central nervous, neurohumoral, cardiovascular and neuromuscular systems, and also with the degree of neuro-emotional tension of labor activity.
• The nervous-emotional tension of labor (classes 3.2, 3.3) leads to the "depreciation" of the adaptive mechanisms of the body and the functional insufficiency of the pituitary-adrenal system, the hyperactivation of free radical oxidation processes, and the violation of lipid metabolism. This fact is expressed in increase of the average atherogenicity index and in its steady increase during the period of person's employment that can lead to the risk of atherosclerosis and other cardiovascular diseases.
• Prolonged overstrain from the impact of intense neuro-emotional stress promotes the development of occupation-caused diseases: atherosclerosis, coronary heart disease, hypertension, neurotic disorders, etc.

Stress, which occurs under the influence of excessive and prolonged physical load, contributes to formation of occupation-caused diseases of the musculoskeletal system and the peripheral nervous system. Accounting of the factors of professional stress formation is in the basis of the methodology of calculating the risk of developing these pathologies.

Methodical recommendations of MR 2.2.9.2311-07 provide methods for calculating the risk of occupational chronic stress development under the stress factors during the work process. The methodical recommendations provide instructions on the organization of work and rest regimes for the employees in the field of mental activity with different intensity of work, visual-labor employees (users of video display terminals and personal computers), and workers. In addition, the recommendations describe the measures to correct the unfavorable functional condition of mental employees under the influence of industrial stress - factors, measures to prevent development of stress for visual-labor employees,

stress of workers and organizational and psychological measures for prevention of occupation-caused stress.
If the goal of the additional section of the GQW is to assess technical and occupational risk, then after the analysis of hazardous and harmful factors and development of protective measures, it is necessary to assess the risk of occupational chronic stress development influenced by stress factors of the work process. Caring out the assesment is obligatory especially for students of training programs and specialties not directly related to technology, for example for students of the Humanities Faculty or the Faculty of Economics and Management.

RISK FACTORS TO BE CONSIDERED

To assess the risk of "development", it is necessary to identify possible hazards and stress factors. GOST 12.0.003-74 * "Hazardous and harmful production factors. Classification" identifies all potentially hazardous and harmful factors that should be taken into account and for which protection measures should be taken. Hazard identification is the most important process for the developer. If a factor is not detected at the first stage, this can affect the safety in the future, especially in emergency cases.
Almost everywhere are dangerous factors that determine electrical and fire hazards, which should be analyzed in detail with the development of appropriate protective measures. Many modern technological processes use laser radiation. In this case, it is necessary to determine the class of the laser, to reveal the hazards corresponding to this particular class and to provide for the protection measures. Often within the frames of implementation the technological process (including research) are used new chemical dangerous substances, which are stored in certain containers and then used for various purposes. The violation of sealing and improper use during the execution of the technological process can lead to serious consequences. To avoid this there should be defined the classes of hazards, predicted the consequences in case of an emergency, and should be provided the protection measures. Sometimes one can find substances that do not even have in Russia the maximum allowable concentrations or roughly safe levels, although the new standards for substances are constantly being developed and published every year. It is possible that developers will have to look for information about them in foreign documents.
There are also numerous harmful factors-physical, chemical, biological and psycho-physiological, which also should be analyzed. It is impossible to describe all possible examples of harmful factors and their impacts, which can be estimated in the GQW additional section. It is necessary to analyze each case separately.

CONSIDERED ISSUES FOR PROTECTION FROM HAZARDOUS AND HARMFUL FACTORS

For the developed (used) devises, technologies, software products or any scientific work, the first task is to assess the technical and professional risk in order to prevent the negative impact of these harmful and hazardous factors, to evaluate employer working conditions and, if the risk exceeds a certain value, to develop measures for creation of harmless, safe and effective conditions for employee's work.

These issues are quite extensive and in professional activity are solved with the help of technical and organizational methods of protection. For this are developed technical requirements to ensure safety factors, also are designed safety sections in technical descriptions or operating manuals, and much more.

Realizing that in the additional section of the GQW all issues can not be considered for objective reasons, the main executor of the work-the student and his supervisor are invited to choose from one of the possible options of the tasks - one or several key issues, that are most significant and fit the developed within the frames of GQW practical task. This issues are coordinated with the consultant from the Department of Life Safety, who provides the student with methodological assistance while writing the section.

Section "Life safety" or section "Special issues of safety provision" are carried out in the form of a calculated individual task related to the topic of the graduate qualification work. The main goals of the section are to systematize and expand knowledge on the previously studied discipline "Life safety", to develop practical skills in solving professional activity tasks and to demonstrate knowledge, skills and competencies to the supervisor, reviewer and members of the state exam committee. In order to carry out this part of the work, the student will need to refer to some legislative and regulatory documents, the detailed list of which are provided in the text of this training manual, as well as in the list of the recommended literature or can be found by the student himself. It is extremely undesirable to borrow materials from questionable sources available on the Internet.

Thus, the graduate of the university receives additional knowledge on a specific development, while studying independently GOST, sanitary and epidemiological rules and regulations, rules, guidelines, technical regulations. On the basis of personal experience, the authors of this publication note that a well-prepared and self-written section of the "Life safety" or the "Special issues of safety provision" with use of new normative documents often draws the attention of specialists and managing staff of organizations that have been working for a long time, but because of their work load did not have the opportunity to upgrade their qualifications in the field of Life safety.

The result of studying additional normative and reference materials, as well as independent work on the section would increase the professional level of the graduate. The bachelor, specialist or master will feel more confident in difficult situations which occur during the professional activity than a person with less knowledge, and therefore would have opportunity for the promotion.

ADDITIONAL SECTION "LIFE SAFETY" FOR BACHELORS AND SPECIALISTS

General requirements for the section

Due to the limited of the graduate qualification work and the short time given to the bachelor for its preparation, the bachelor together with his supervisor can choose one or several specific issues for analysis, which are subsequently agreed with the consultant. The GQW “Life safety” section of the specialist should be more meaningful and should cover broader list of issues under consideration. At the protection of the graduate qualification work are evaluated professional competencies defined in federal state educational standards, the main ones are the following:

• the ability to use the fundamentals of personnel and citizens protection from possible consequences of accidents, disasters, natural disasters, as well as the use of modern protection means of different types of destructions and basic measures to eliminate their consequences;

• the ability to navigate in the basic regulatory and legal acts in the field of safety provision;

• the ability to carry out general assessment of safety conditions;

• the ability to organize occupational and health safety measures during the operation and maintenance of devices and systems, to use the principles of technological processes mechanization and automation, to use the principles of selection and operation of equipment and accessories, methods and measures of labor organization that ensure efficient, environmentally and technically safe production;

• possession of skills for organization and technical equipping of workplaces, development of operational plans for primary production units, risk assessment and identification of measures to ensure environmental and technical safety of materials, equipment and technologies being developed;

• the ability to master the basic methods of occupational injuries and occupation-caused diseases prevention;

• the ability to organize and implement a system of measures for occupational and health safety in the process of operation, maintenance and reparation of the equipment;
• the ability to take justified risk in decision-making;
• the ability to apply knowledge of quality management approaches, to develop "human-computer" interfaces;
• the ability to calculate the provision of life safety conditions;
• the ability to assess risk and determine safety measures for the equipment and technology being developed;
• the ability to navigate in basic methods and systems of technosphere safety provision, to choose reasonably the known devices, systems and methods for protecting human and natural environment from various hazards;
• the readiness to use knowledge on the organization of labor protection, environmental protection and safety in emergency situations at the economic objects;
• the ability to use the knowledge about the fundamental organizational safety of various production processes in emergency situations;
• the ability to analyze the mechanisms of the hazards effect on humans, to determine the nature of the interaction of the human body with the dangers of the habitat, taking into account the specific mechanism of toxic effects of harmful substances, energy impact and combined effects of harmful factors;
• the ability to identify hazardous, extremely hazardous areas, areas of acceptable risk, etc. Fig. 1 shows in the form of structural diagram possible tasks and questions, covering all the main sections of the training course “Life safety”.

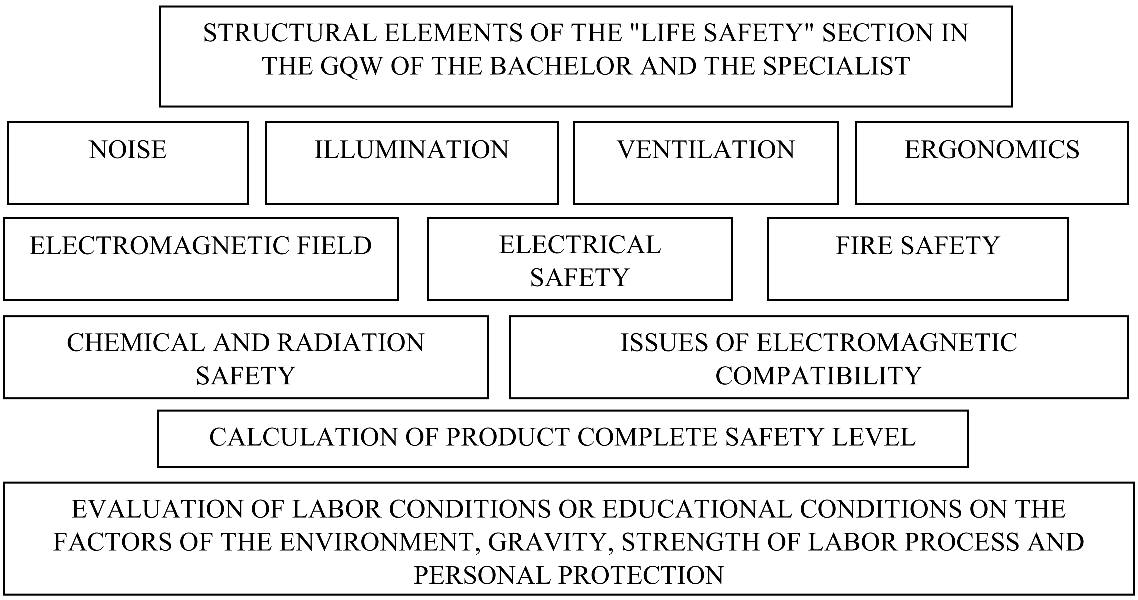


Fig. 1. Structural elements of “Life safety” section

Possible variants of tasks for specific hazardous or harmful factors that will be selected as the main ones for subsequent consideration:
Noise:
- of the developed equipment;
- of the ready equipment being used.

Calculation of the efficiency of noise reduction in working premises by acoustic screens (GOST 31287-2005).
Drawing up a noise map of the workplace (GOST R 52797.1-2007).
Calculation-forecast of noise emissions from the installed technical means in the premises (GOST R 52797.3-2007).
Calculation of requirements for noise emission by the equipment to ensure sanitary standards for a given type of activity.
Illumination.
Calculation of the protective angle and the choice of lamps to limit the luminosity (GOST ISO 8995-2002).
Calculation of the number of lamps to meet the requirements for workplace illumination (by the coefficient of use by the point method).
Calculation of the lamps arrangement to ensure uniformity of illumination in the premises.
Ventilation.
Calculation of the inlet air flow.
Calculation of the outlet air flow.
Calculation of the chemicals concentration in the air of the work area.
Ergonomics.
Justification / calculation of text readability on the video screen of the display terminal (GOST R ISO 9241-3-2003).
Calculation of the dimensions and design characteristics of the workplace (GOST R ISO 14738-2007).
Justification of the conformity of the means for displaying information of collective use to visual requirements (GOST R 52870-2007).
Justification / analysis of the layout of the indicators and control units of the equipment / installation.
Justification / analysis of the type (design) of the indicators and the equipment control units.
Calculation of the information display means characteristics, necessary to represent a given amount of information.
Electrical safety:
- operation of the developed equipment;
- operation of the existing equipment;

- adjustment and repair of the equipment.
Calculation of minimum gaps for the main isolation of the equipment considering the expected operating conditions (GOST R IEC 60065-2005, etc.).
Preparation of a set of measures to ensure the electrical safety of the equipment.
Calculation of the neutralizing system of the product.
Calculation of emergency damage parameters of the equipment isolation, at which the equipment protective shutdown may occur.
Selection of a set of measures to ensure the inaccessibility of hazardous parts of the equipment.
Calculation of the equipment body voltage in emergency mode with the selected protection system.
Calculation (analysis) of the risk of electric shock of a person in case of possible malfunctioning of the equipment in the expected operating conditions.
Classification of operating and storing conditions of the equipment.
Calculation of the required integrity safety of the equipment (GOST R IEC 61508-2-2007).
Calculation of the equipment resistance to failures and interruptions in the supply network voltage (GOST R 51317.4.11-2007).
Fire- and explosion safety.
Definition of the category of the premises for explosion and fire hazards. Calculation of the criteria. (Technical Regulations on Fire Safety Requirements and Code of Practice SP 12.13130.2009).
Calculation of excess explosion pressure (gas / flammable liquid / dust).
Calculation of the specific fire load.
Calculation of the intensity of thermal radiation.
Calculation / selection of protection mean in case of overcurrent / short-circuit currents of the equipment.
Calculation of the equipment elements' heating temperature in the nominal and in emergency operation modes.
Calculation of the efficiency of heat removal from the circuit elements in the body of the device.
Calculation of explosion hazard of dangerous environment from sparking in case of damage to the circuit element.
Calculation of the required conductors' cross-section (conductors of printed circuit boards / mounting wires of the device / power supply cord).
Preparation of a set of technical measures to ensure fire safety of the equipment.
Justification of the need, the choice of means of firefighting alarm and the calculation of their required number in the premises.

Calculation of the parameters of damage to the electrical isolation of the equipment, which may cause a fire.
Calculation of the elements of the system operating under excessive pressure:
- thickness of walls of vessels, hoses;
- safety devices.

Electromagnetic fields (EMF).

Calculation of the energy exposure under the influence of EMF on personnel serving the equipment:
- in the rated operating mode;
- in emergency mode.

Calculation of the permissible residence time in the EMF coverage zone.
Calculation of the screen parameters, providing the necessary EMF attenuation.
Calculation of the magnetic field strength from two conductors with a current.
Calculation of the safe distance from the EMF source.
Classification of the used laser according to the degree of generated radiation danger (SP 5804-91).
Calculation of the safe distance for observing the reflected radiation of the used laser

Chemical and radiation safety.

Determination of the hazard class of toxic process waste (SP 2.1.7.1386-03). Calculation / assessment of the public health risk when exposed to chemicals polluting the environment (P 2.1.10.1920-04).
Calculation of the depth of the dangerous chemical substance cloud spread as a result of an accident.
Calculation of the permissible residence time in the zone of ionizing radiation source.
Calculation of the effectiveness of the protective screen from the ionizing radiation source.
Assessment of working conditions and the risk of occupation-caused diseases.
Preparation of sanitary and hygienic characteristics of the employee’s working conditions / classification (R 2.2.2006-05).
Hygienic assessment of the intensity of the employee’s work process (R 2.2.2006-05).
Assessment of the safety of the workplace.
Assessment of the risk of the occupation-caused chronic stress development under the influence of the work process stress factors (MP 2.2.9.2311-07).
The same options can be chosen by the master students when writing an additional section in their thesis.

SPECIFIC FEATURES FOR PREPARATION OF THE SECTION FOR STUDENTS TECHNICAL FIELDS

The goal of the section “Life safety” development is the search for specific engineering solutions aimed to ensure safe and harmless human activity in production and in everyday life.

At the same time, the measures being developed can concern both the engineering equipment and the means and conditions for its design and manufacturing. These solutions and means should be oriented towards ensuring safety in everyday (normal), conditions of the emergency. The fundamental for achieving the goal is solution of the problem on the basis of the requirements of legal and technical documentation (standards, norms, rules).

When carrying out the work under the research plan, the attention should be paid to ensure their safety.

The tasks of the section are:

• identification of hazard and harmful factors affecting a person;

• selection and calculation of the characteristics of the person protecting means from the effects of identified factors.

Features of the section “Life safety” in the areas and specialties of training "Radio engineering", "Radio electronic systems and complexes", "Design and technology of electronic equipment", "Info communication technologies and communication systems" are related to the studied and developed systems for:

• creation and operation of devices and systems based on the use of electromagnetic waves and intended for the transmission, reception and processing of information, obtaining information about the environment, natural and technical objects, and also about the impact on natural or technical objects in order to change their properties;

• creation of radio- electronic, calculating, nano-electronic and microwave devices, technological production processes, technological materials and technological equipment, methods and tools for tuning and testing, carrying out quality control and maintenance of electronic equipment, methods for designing of the electronic devices, development of the technological processes;

• to create conditions for the information exchange at a distance by wire, radio, optical systems, its processing and storage.

For example, during the study and development of television systems, are studied the main characteristics of vision, the shape and spectrum of the television signal, the characteristics and parameters of the television image, color and its perception, colorimetric bases, light-signal converters, photosensitive of matrices, signal-light converters: kinescopes, liquid crystal and plasma panels, digital television broadcasting systems, etc.

These questions may be of interest when considering the section of life safety from the standpoint of human electrical safety in high-frequency circuits, protection from electromagnetic fields of high and ultra-high frequencies, creation of information display facilities that satisfy ergonomic requirements, as well as the requirements and methods for testing systems for constructive informational and operational compatibility, as recorded, for example, for security television systems in GOST R 51558-2000.

The main features of the “Life safety” section in the fields and specialties of training "Electronics and Nano Electronics" are related to theoretical and experimental research, mathematical and computer modeling, design, construction, production technology, use and operation of materials, components, electronic devices, and vacuum and plasma devices of the solid state microwave, optical, micro- and nano electronics of various functional purposes.

For example, some technological processes require the use of clean rooms. How should be organized the ventilation system, especially if the air support comes from below so that people, especially women, do not get colds? This is one of the tasks that must be solved by designing the ventilation itself or by developing organizational measures (used working clothes, etc.).

The main features of the section of the “Life safety” in the fields and specialties of training "Computer Science", "Applied Mathematics and Informatics", "Software Engineering", "Information Systems and Technologies", "Information Security" are related to:

• with computers, systems and networks, automated information processing and control systems, computer-aided design and information support systems, software of automated systems;

• with the use of mathematics, computer programming, information and communication technologies and automated control systems;

• with the software industrial production for information and computing systems for various purposes;

• with research, development, implementation and maintenance of information technologies and systems;

• with development and operation of means and systems for the information protection of computer systems, ensuring the security of computer systems against malicious software and information impacts in case of threats in the information sphere.

The issues that can be considered in the supplementary section “Life safety” are related to the safety of work places equipped with computers, the ergonomics of software and workplaces.

Ergonomic requirements and principles, ergonomics of human-system interaction, guidelines for the convenience of software application are set in the state standards of the series GOST R ISO 9241, GOST R ISO 9355, GOST R ISO 10075, ISO 11064, GOST R ISO 15534, GOST R ISO 15536, GOST R 55241, GOST 29.05, GOST R ISO 13406-1-2007, GOST R ISO 13849-1-2003, GOST R ISO 14915-1-2010, GOST R 50923-96, GOST R 50948-2001, GOST R 50949- 2001, GOST R 52324-2005, GOST R 52870-2007, GOST R 53454.1-2009 and other standards, and for information technology - in the standards ISO / IEC 9995, ISO / IEC 13066 and others.

The main features of the section "Life safety" in the fields and specialties of training "System Analysis and Control" is related to the design and control of complex systems, resources, processes and technologies. Along with other issues in the additional section "Life safety" can be considered issues related to the functional safety of electrical, electronic, programmable electronic systems in accordance with the requirements of the standards of GOST R IEC 61508.

The main objectives in case of development related to safety is creation of an architecture that meets the security software requirements with the respect to the level of security integrity, the analysis and evaluation of software requirements from the hardware, selection of suitable set of tools.

The main functions of software safety are:

• allowing to reach a safe state and to maintain it;

• associated with the detection, notification and error handling of hardware programmable electronics;

• associated with detection, notification and error handling of sensors and devices;

• associated with the detection, notification and processing of errors in the software itself;

• associated with periodic testing of functions in real time;

• connected with periodic testing of functions in an autonomous mode;

• having interfaces between software and programmable electronic systems, etc.

The features of the "Life safety" section in the fields and specialties of training "Electrical engineering" are related to production, transmission, distribution, conversion, use of electric energy, control of energy flows, design and production of elements, devices, and systems that implement these processes.

When designing some equipment, standards directly related to it must be taken into account. In particular, safety requirements for electric thermal equipment and generators for their supply are given in GOST 12.2.007.9-93 (IEC 519-1-84), GOST 12.2.007.9.1-95 (IEC 519-3-88), GOST R 50014.3 -92 (IEC 519-3-88) and GOST 12.2.007.10-87. In the book by V.A. Bukanin "Safety Assurance in the Design and Operation of Induction Electric thermal Installments" (St. Petersburg:

JSC “Art of Russia”, 2011), the specifics of ensuring such security are described in details.

Often the result of the development is the draft of a laboratory stand for use in educational and scientific laboratories, represented in the form of a power unit (an electromechanical object, for example, an electromechanical converter of electrical energy, an electric drive with a frequency converter, a semiconductor converter of electrical energy), and control system based on microprocessor control devices. In this case, in terms of providing safety for such developments, the issues of ensuring mechanical safety, electrical safety issues, as well as issues of functional safety are relevant.

If the result of the development is a mathematical model of the object and the control system (for example, a resistance furnace with a temperature control loop, a frequency-controlled lathe feeder, an autoclave with an automatic control system) and in the work are observed the issues of the system operation in under control and disturbing influences (for example, for a controlled electric drive as a control influence can be considered the setting of rotation speed, and as a disturbing effect can be the change of mechanical moment of the load), it is offered to analyze in more detail the limiting / emergency operating modes of the system. To reach this aim, should be determined the list of parameters of the object operating mode and calculated their maximum permissible values (for the electric drive - the permissible speed of rotation, for the autoclave - the maximum permissible pressure), then should be implemented the nonlinear blocks in the mathematical model that allow to limit the value of control actions and provide the protection against excessive values from the disturbing effects in the control system model.

The peculiarities of the “Life safety” section in the fields and specialties of training “Bio engineering systems and technologies” are connected with the area of technical systems and technologies, whose structure includes any living systems and which are connected with the living systems state control and with the maintenance of optimal working conditions for a person.

Every year such equipment becomes more and more perfect, application of new technologies and devices developed by engineers allow struggling even more successfully with existing diseases. However, with the increasing efficiency of equipment, the danger of using electrical medical devices remains the same, so the developer must pay special attention to the safety of using new technologies and new devices for carrying out various medical activities. The developer of the medical equipment must take into account the safety not only of the patient, but also of the personnel performing the necessary manipulations with the help of the created equipment. It is very important to accomplish the norms given in the regulatory documents. The main document regulating the requirements for the safety of electrical medical equipment is GOST R 50267.0-92 “Medical electrical equipment”. This standard describes the basic safety requirements and tests that are conducted with samples of medical equipment to meet these requirements. In case if there is a possibility of harming the health from interaction with the equipment being created and in the standard are not presented the measures to prevent these hazards, such activities should be sought in normative documents describing more particular cases.

In the nomenclatural classification of medical devices (except for medical devices for in vitro diagnostics), according to the classification, four classes are distinguished according to the classes depending on the potential risk of use: class 1 - with low risk; class 2a - with an average degree of risk; class 2b - with increased risk and class 3 - with a high degree of risk. When classifying medical devices, each of them can only be assigned to the one class. At the same time, their functional purpose and application conditions, as well as such criteria as duration of application, invasiveness, the presence of a contact with the human body or the relationship with it, the method of introduction into the human body (through anatomical cavities or surgically), application for vital organs and system (heart, central circulatory system, central nervous system), use of energy sources.

When classifying medical equipment for in vitro diagnostics, each medical device can only be assigned to one of the following classes: class 1 - with low individual risk and low risk for public health, class 2a - with moderate individual risk and / or low risk for public health, class 2b - with high individual risk and / or moderate risk for public health, class 3 - with high individual risk and / or high risk for public health.

One of the main tasks of the nomenclature classification is the equipment identification in the information exchange for performance of state functions for registration of medical devices, control of the production, condition and use of medical devices on the territory of the Russian Federation, primarily for the control of the medical devices safety. Section “Life safety” of graduate qualification work of bachelor student in case of development of new or modernization of existing medical devices and systems should contain:

• a structural diagram of the interaction of medical equipment with a human (patient and operator);

• a brief description of the expected functioning of the equipment;

• analysis of harmful and hazardous factors during normal operation or in case of violations;

• identification of the main injurious factors and description of measures to protect from them and to prevent their occurrence;

• conclusion report on the possibility of safe use of medical equipment. In the case of the development of new and modernization of old medical technologies and techniques, the “Life safety” section should contain:
• a brief description of the technology, the expected result of its use;
• enumeration of the types of interaction of a human (the operator and the patient) with the technique necessary for the implementation of this technology;
• analysis of harmful and hazardous factors in the normal implementation of the technique (technology) and in the event of emergency conditions and operator errors;
• measures to ensure the safety of manipulation of a given technology (technique) and prevent the occurrence of operator errors and emergency modes;
• conclusion report on the possibility of using this technology (technique) in medical practice.
The main features of the “Life safety” section in the fields and specialties of training “Instrument-making” are related to creation and operation of devices intended for obtaining, recording and processing information about the environment, technical and biological objects. In this case, the “Life safety” section is prepared taking into account the general requirements above, and highlighting one or several of the most significant stress factors for consideration.

THE MAIN FEATURES OF THE “LIFE SAFETY” SECTION FOR THE STUDENTS OF HUMANITARIAN AND ECONOMIC FIELDS

For the “Life safety” section of GQW of the bachelor in the field of training “Advertising and public relations” the following questions should be observed:
• when carrying out activities in the field of improvement the organization image, promotion of the goods and services to the market, development of measures to improve the image of the organization, goods and services, as well as development, preparation of the production, distribution and distribution of promotional products, including text and graphic, presentational materials within the frames of traditional and modern means of advertising - to show during advertising actions that goods and services primarily meet modern security requirements, and to provide the proof of product’s conformity to the requirements of the regulations on electrical safety, fire and explosion safety, electromagnetic compatibility and other standards;
• in case of participation in formation of effective internal communications, creation of the favorable psychological climate in the team, motivation of employees for active work and development of the organization – to carry out the audit of the labor protection management system in the organization and make the

assessment of working conditions by factors of the environment, the severity and tension of work, attestation of workplaces;

• when carrying out various types of work on advertising and public relations – to take necessary measures to protect labor, personal health and health of colleagues, security measures in case of fire and other emergencies.

In the section "Life safety" section of GQW of the bachelor in the field of training "Linguistics" the following questions should be observed: while carrying out various types of work on the organization of business negotiations, conferences, symposiums, seminars, acting as a mediator in the field of intercultural communication – organization the necessary events on labor safety, personal health and health of colleagues, security measures in case of fire and other emergencies.

In the "Life safety" section of GQW of the bachelor in the field of training "Innovation" should observed the following issues:

• during organization of pre-commissioning activities and customers' acceptance tests - ensuring the safety of these works;

• when conducting technological audit – caring out audit pf labor safety management system;

• when preparing the information materials on innovative organizations, products, technologies – prepare also the information materials on the state of safety of the organization;

• when caring out formation of databases and the development of documentation – form the database of the available regulatory documentation for life safety;

• when preparing materials for certification and certification of new products – make the evidence of products conformity to the requirements of regulatory documents on electrical safety, fire and explosion safety, electromagnetic compatibility and other standards;

• when carrying out structural and system modeling of the project life cycle – to carry out modeling of safety issues at all stages of the life cycle, from design to disposal;

• when carrying out the development and implementation of quality systems - development and implementation of quality control system of labor and health safety.

In the "Life safety" section of GQW of the bachelor in the field of training "Management" and "Quality Management", the students can observe the state safety issues, including protection in emergency situations in the organization that is chosen as an example for addressing the main problem. As a rule, organizations prepare annual reports on their work, and some of them must be published on the Internet. In this reports the student can observe how the top managers, who are already familiar with the problems of the life safety handle with it.

If it is impossible to find the materials, then in the “Life safety” section of the GQW the student can consider other issues, in particular:

• carry out the assessment of labor conditions and possible diseases obtained because of the performance of a specific job by a specialist who will use the development in the future (in the extreme case, the student can make an assessment for himself);

• develop documented procedures for the entire life safety system in the organization or on its individual aspects;

• develop requirements for the life safety management in the organization on the basis of the latest legislative and regulatory documents (if this has not already been done).

In connection with the issuing of GOST R 54934-2012 / OHSAS 18001: 2007 “Labor and health safety management systems. Requirements”, operating from the beginning of 2013, the labor and health safety approach should be changed because of growing legal requirements, improving economic policies and other measures to support best practices in the field of the labor and health safety approach, as well as because of increasing concern of stakeholders with the labor and health safety approach issues. The awareness in achieving and demonstrating significant results is reflected in the organization's policy and objectives in the field of the labor and health safety and reflects in reducing risk in the field of the company labor and health safety management through its management processes.

In order to assess the performance of indicators in this area, many organizations conduct the analysis or audit of safety and health management. However, carrying out such analyzes and audits itself may not be enough to ensure the organization's confidence that its activities does not only comply with legal requirements and its own policy in the field of the labor and health safety at the present time, but will continue to meet the requirements in future. Analyzes and audits to ensure their effectiveness should be carried out within the frames of structured management system in the organization.

The success of this system depends on adherence to the idea of labor and health safety approach at all levels and in all functional structures of the organization and, in particular, on the adherence of top management to it. This type of system gives organization an opportunity to develop a policy in the field of labor and health safety; to identify goals; to establish mechanisms to achieve the commitments contained in the policy; to carry out necessary measures to improve their activities; to demonstrate the system's compliance with modern requirements.

Thus, the “Life safety” section of the GQW can be devoted to the organizational measures aimed providing the life safety approach by the managers, on the basis of the provisions of the Labor Code of the Russian Federation and state standards

GOST R 54934-2012 / OHSAS 18001: 2007, GOST R 12.0.230-2007, GOST R 12.0.007-2009, GOST R 12.0.008-2009 or GOST R 12.0.009-2009 on problems of labor protection management system in the organization. Elements of the labor and health safety management system can be coordinated or integrated with the relevant elements of other management systems, such as a quality management system, an environmental management system, an information protection system or a financial management system.

In the “Life safety” section “Stages of the documented procedure for the quality of life safety systems characteristic of an organization (or enterprise)”, are described the stages of one of the “Life safety” sections or, in general, the entire complex of the “Life safety” provision, which can be included in the documented procedure for the organization.

The main sections of the “Life safety” in relation to the organization can be the following: general planning of activities in the field of life safety; technologies for monitoring and attestation of workers and training places; In-depth training in the field of life safety of individual groups of personnel; providing the food and rest; planning and provision of special life safety measures for the emergency cases; provision of “Life safety” with preparation of the organization's infrastructure (buildings, premises, equipment); financial support of life safety processes and others.

As an example (for the beginning) of the organization of work on electrical safety Table. 1 and on the structural diagram of Fig. 2 show the stages of the documented procedure.

Table 1

Events, activities	Person responsible for activity	Performer	Co-performer	Announced person
Planning of the organizational events for electrical safety	Senior engineer	Senior energy engineer	Head of the office for labor protection	Head of the office
Collection and analysis of new requirements of the legislative and regulatory framework for electrical safety	The same	The same	The same	The same
Carrying out the audit and estimation of current condition of electrical safety in divisions of the company	Head of the office for labor protection	-« -	Head of the office	-« -
Analysis of the audit results for compliance with the identified security inconsistencies	Senior engineer	-« -	Analytical office	-« -

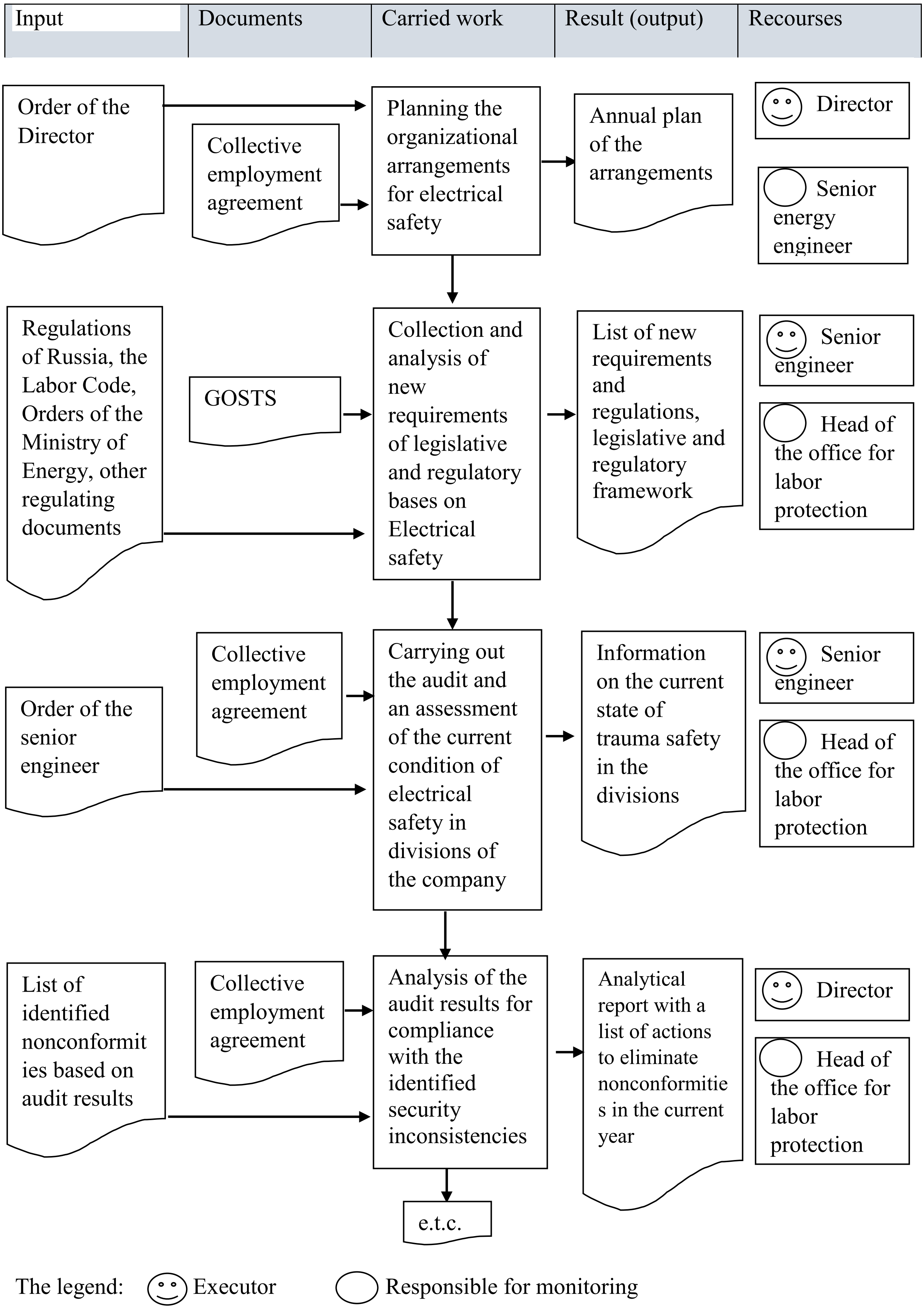


Fig. 2. Block diagram of the documented procedure

Section “Life safety” in the GQW can also be devoted to the assessment of working conditions in accordance with P 2.2.2006-05 “Guidelines for the hygienic assessment of the working environment factors and the work process. Criteria and classification of working conditions” dated July 29, 2005 on the factors of the working environment, the severity and intensity of work with the filling of the relevant tables, as well as on the evaluation of trauma safety.

In the case of the additional section “Life safety” of the specialist, for the observed object or development is carried out the identification of hazardous factors, and is assessed the technical and occupational risks of the effects of these factors at all stages of the life cycle. The necessary calculations are made and protective measures are planned in accordance with the relevant requirements and regulatory documents. Also is assessed safety in emergency situations.

The section “Life safety” of the specialist in the technical field should usually consist of the following subsections: “Characterization of the conditions of use”, “Analysis of hazardous and harmful factors”, “Basic requirements for the system from the position of safety” and “Protection in emergency situations”.

ADDITIONAL SECTION “SPECIAL ISSUES OF SAFETY PROVISION” FOR MASTER STUDENTS

It is desirable to carry out the section implementation in the form of a scientific research on safety issues.

Some of the master students in the technical fields of training had in their curricular the disciplines “Special issues of the design of safe instrumentation” and “Systems for ensuring the safety of technical control means” some of them studied special safety issues for specific developments being carried out in other disciplines. Thus, they can apply the acquired knowledge when preparing of an additional section special issues of safety provision.

When designing safe systems, including the research (at the first or the initial design stage), one of the main tasks is to assess the risk of negative events for both the system and the human. Creating something new, the person thereby creates the conditions for the occurrence of negative consequences both in the conditions of standard application of the system, and in the unforeseen and unplanned conditions.

The normative documents for the equipment, development or research which the master student implements, prescribe that the technical means intended for the systems must possess constructive, informational and operational compatibility, be convenient and safe in operation, and the system itself - possess functional safety.

Possible variants of tasks for specific hazardous or harmful factors that will be selected as the main ones for subsequent consideration may be factors that were considered earlier, or in addition to them, the following:

• Development of the set of measures to ensure the safety of the designed device or technological process (for various stages of its life cycle).

• Development of programs and test procedures for the equipment and technological installations to verify compliance with safety requirements (for separate parameters of electrical, fire, explosion, climatic and mechanical stability / strength to external factors, electromagnetic compatibility (EMC), etc.).

• Analysis and optimization of measures to improve the functional safety of the equipment related to the general safety.

• Analysis of factors characterizing the working conditions (severity, tension, stress factors) of the employees performing research, testing, adjustment, operation of devices and technological installations.

• Development of proposals for optimizing the parameters of devices or technological installations that affect working conditions.

in the additional section of the special issues of safety provision in the GQW the following tasks can be proposed for development:

• Classification and characteristics of the electromagnetic environment (GOST R 51317.2.4-2000 GOST R 51317.2.5-2000).

• Noise interference tests. Types of the required tests (GOST R 51317.4.1-2000).

• Programs and methods for testing of technical means for measuring and control of industrial processes for noise interference immunity and control of such means (in accordance with GOST 29073-91).

• Programs and methodologies for the required equipment testing for emission interference.

• Ensuring the requirement of immunity to electromagnetic interference of technical means used in residential, commercial and industrial areas (GOST R 51317.6.1-2006, GOST R 51317.6.2-2006).

• Influence of functional safety requirements on the degree of rigidity of tests and quality of the performance criteria in the conditions of interference (GOST R 51317.1.2-2007).

• Ensuring the requirement to limit interference emissions from technical means used in residential, commercial and industrial zones (GOST R 51317.6.3-99, GOST R 51317.6.4-99).

• Equipment for information technology. Ensuring the requirement of immunity to electromagnetic interference and limiting the generated interference (GOST R 51318.22-2006, GOST R 51318.24-99).

• Ensuring the requirement of electromagnetic compatibility to power supplies of teleautomatic devices (GOST R 51179-98).
• Features of ensuring noise immunity of analog circuits.
• Features of ensuring noise immunity of digital circuits.
• Noise filtering.
• Suppression of impulse noise.
• Separation of circuits as a means of providing EMC.
• Limitation of interference emission in switching devices.
• Earthling as a mean of providing EMC.
• Shielding as a mean of providing EMC.
• Protection of the microprocessor from impulse noise.
• Means to improve the noise immunity of cables.
• Means to provide lightning protection of the equipment.
• Features of voltage-dependent resistors for interference protection.
• Features of using pass-through capacitors for interference protection.
• Features of using the ferrites for interference protection.
• Ensuring the stability of the equipment to deviations in the parameters of the supply network and insufficient quality of electricity in general-purpose power supply systems (in accordance with GOST R 54149-2010, GOST R 51317.4.11-2007).
• Influence of the harmonics of the consumed current on the provision of EMC.

After the sections "Characteristic of the application conditions" and "Analysis of hazardous and harmful factors, characteristic for the equipment" in the section "Basic requirements for the studied (developed) system from the viewpoint of compatibility and safety" is carried out the research on the risk of the negative factors exposure selected for consideration and recorded in the terms of the additional section of the GQW; also are mentioned the main requirements for the design of the system in accordance with the technical regulations, as well as the degree of rigidity of tests for electromagnetic, mechanical, climatic factors, on which the system should be tested, so that these negative factors would not appear during the operation.

At all stages of the life cycle of the equipment, devices and systems of all kinds (hereinafter - equipment), there must be ensured the conditions under which they do not pose a danger to a person. For this purpose, within the frames of their designing and construction is used a certain concept (policy) and are taken into account some general principles that allow to ensure the necessary integral level of safety.

Unlike the general issues discussed in the discipline "Life safety", in the special disciplines the main attention is paid to special safety issues that are more specific and which the product developers should observe more careful. These issues are related to general technical safety issues in design and construction of the equipment in relation to the specialty; to the peculiarities of interaction “human-machine” and factors influencing the system operating conditions; to the features of electrical, fire and explosion safety; to electromagnetic, mechanical, acoustic, climatic and technical-aesthetic compatibility, as well as to the decision making by the equipment developers on the degree of rigidity of tests and on the methods for conducting them.

It should be also mentioned that in general, the risk represents a certain balance between safety and profitability for the customer, the effectiveness of the costs, the requirements, and others. It is not always immediately understood that on the safety issues, including ergonomic aspects, one should spend more efforts, because it greatly increases the cost of the equipment. Often the customer buys a cheaper option, although less reliable and secure than satisfying all the safety criteria, but more expensive. It is necessary to understand and remember the rule that additional costs are always paid off in the process of exploitation, and there are not only social but also economic effects.

To create a safe system, one could use the provisions of GOST ISO / TO 12100-2-2002 “Safety of equipment. Basic concepts, general principles of manufacturing” (although this may not be entirely applicable to the developed system), namely:

• to eliminate or reduce the risk by making the design and assembled parts of the installation safe from the very beginning;

• to take all necessary measures to protect against risk, which can not be eliminated;

• to inform the customer about the residual risk, which may happen because of insufficient protection measures taken, indicating the need for special training, as well as the need to provide the necessary personal protective equipment;

• in appropriate conditions of use, to minimize all possible inconveniences.

The common security problems that must be solved for any system are as the following:

• Avoid sharp edges, corners, protruding parts, uneven surfaces and holes that can cause injury.

• Ensuring the safety of the equipment by limiting noise, vibration, electromagnetic fields and other energy fields as a result of optimal design.

• Taking into account the rules of design and construction of mechanical loads.

• Taking into account the data on the properties of materials (mechanical properties, corrosion, aging, abrasion, inhomogeneity and toxicity of the material).

• Application of safe technologies, processes and energy conservation.

• Compliance with the principles of ergonomics and engineering psychology. All elements of “human-machine” interaction, such as controls, signal and digital indicators should be designed in a way as to ensure a clear and unambiguous interaction between the operator and the installation. This will reduce the stress loads and physical efforts of the control panels operators, as well as possible errors at all stages of the system operation.
• Observance of safety principles in the design of control systems (errors in the design or in the arrangement of the controls must be avoided, measures should be taken to allow the operator to interfere with the operation of the control system: for example, a visual indication unit and unambiguous representation of faults in the case of electronic circuits; it is required to use the reliable control elements that can withstand shocks, vibration, cooling, heat, humidity, dust, aggressive materials or environment, static and alternating electromagnetic fields, as well as to use the elements with a certain type of failure, duplication of critical elements, automatic control, etc.)
• Prevention of electrical hazards (protection against electric shock, short circuit and electric overload).
• Prevent the risk of fire and explosion (protection from ignition and spark discharges).
• Information to the customer (should be included in the delivery of the system and clearly define its main purpose, as well as the instructions required to ensure safe use). This information should not obscure the design flaws, but should warn the customer about the residual risk that can not be excluded or significantly reduced in the design, and against which the protection devices are completely or partially ineffective; also the information should cover the issues of transportation, commissioning, use (and, if necessary, decommissioning), dismantling and disposal.
• Signals and warning devices (visual and audible signals can be used to warn of a hazard, must be used in case of the dangerous event, be unambiguous, clear and distinguishable from other signals and easily recognizable). They should be designed so that their verification would be simple, and information to the customer should prescribe caring out of such a check on a regular basis. Developers should consider the risk of saturation with warning signals, especially when they are made too often, and, therefore, are generally ignored.
• Marking, signs, or pictograms, warning labels for unambiguous identification (name and address of the manufacturer, series and type, serial number); for compliance with mandatory requirements (for example, when working in an explosive atmosphere); for safe use (the need for the use of personal protective equipment, data relating to the adjustment of protection, the frequency of

verification, etc.). The inscriptions must be in the language of the country where the installation is used; the signs (pictograms) that are well-understood are preferable to inscriptions; the marking must comply with accepted standards.
• Accompanying documents, in particular the operating manual.

The students must pay special attention to protection of the “development” in emergency situations. If the development is intended to exclude an emergency or to mitigate its consequences, then the student should write about it. But in any case, the equipment, technology, software product should not create an emergency situation and should be sustainable in an emergency situation, at least limitedly. It is recommended to consider the reliability requirements (criteria of durability, maintainability, etc.), mechanical stability, for example, to earthquakes, single shocks, vibration, etc. (selection of the severity of the tests), and to negative effects of the power network (dips, emissions, interruptions supply voltage), the magnetic fields of industrial frequency (interference from the mains when non symmetry and the presence of circulating currents in the neutral conductor) and pulsed magnetic fields, such as from lightning or other pulses (choice of severity of the tests).

The additional section “Special issues of safety provision” for the field of training “Management” and “Quality Management” can be devoted to organizational safety issues conducted by the heads of organizations and related to the development of methods and means to improve the safety and environmental performance of technological processes, with the improvement of the quality of work on safety working conditions, health of workers in general. It is encouraged to develop a draft of safety policies in the organization, to compile documented procedures for safety-related processes, to compile known Sheukhart control charts, Pareto diagrams, Ishikawa diagrams, etc., (not in the sense of equipment, but in order to study possible problematic issues, display them on diagrams and provide a technology to search for the true causes of the safety problem under consideration in order to effectively solve it).

The same approaches can be used as for the construction of the Ishikawa diagram: collection and systematization of all causes; grouping of these reasons; their ranking and analysis of the resulting picture.

THE MAIN FEATURES OF SAFETY PROVISION FOR RISK FACTORS

Electrical safety

High voltage of the power supply network is one of the significant hazards that exists in almost any process of development of electrical, electronic and radio electronic devices or in the performance of most types of work related to the operation of a newly developed or ready (purchased) equipment, and also in the process of its set up or reparation.

The device must be safe in the process of reparation and operation, i.e. in any operational situations the possibility of service personnel and unauthorized persons hitting by the electric current, electric arc trauma, should be excluded.
The safety requirements, recorded in the Electrical installation rules, state standards, the Rules of the technical operation of electrical installations of consumers, are provided by the designer by means of adopting the appropriate circuit solutions and by choosing the device design, and by the consumer by observing the necessary safety measures during the equipment operation.
The risk of electric shock occurs when the person touches live conductive parts (direct touch or direct contact) or to non-conductive parts of the equipment, accidentally turned on to be under the voltage in case of resistance decreases or in case of the shortage on one of the live parts (indirect touch or indirect contact). In the equipment using a voltage higher than 1000 V, an additional hazard arises in case of dangerous approaching the live parts due to electric breakdown of the air gap “human - current carrying part”.
The electrical safety of the equipment should be provided by the main protection (main insulation, use of a small extra-low voltage, protective frame), and in case of failure of the main protection, i.e. insulation damage, breakdown from the high voltage side to the low voltage side or damage to the frame - additional protection .
The necessity of using these or other means of protection against human injury by electric current is established by the Electrical installation rules and state standards. It is required on the basis of the analysis of the expected equipment operation conditions and possible malfunctions to identify situations in which there is a risk of electric shock to a human and to justify the selection of the necessary technical methods and means of protection. In this connection are given references to normative documents, according to which protection against electric shock should be provided.
Electrical insulation as a type of basic protection serves to reduce to a permissible value the current flowing through the human body when accidentally touched by the conductive body and the leakage currents between live parts or the current carrying part and earth. The choice of insulation of the product and its parts depends on the value of the working voltage, the possibility of access to the product by unauthorized persons and non-electrical personnel, as well as from operating conditions. For the equipment being developed, the required values of the strength of the electrical insulation and the value of its resistance must be indicated.
Coating of current-carrying parts with varnish, enamel and other similar materials is not sufficient to protect against electric shock by direct contact with these parts and to protect against transfer of electric arc from current-carrying parts of the

equipment to other metal parts. The design of the frame, casing (shell) of the equipment is the main mean of ensuring the unavailability of live parts. Depending on the expected operating conditions, the development of the equipment must be designed to perform a certain degree of protection (IP code). The shells must be connected to the main parts of the equipment in a single structure, close the hazardous area and be removed only with the help of a tool. It is not allowed that the screws for fixing current-carrying and moving parts of the product and for securing its shell were common.

The design and materials of the input devices must prevent the possibility of accidental contact with live parts, the short-circuit of conductors by independent metal objects and the closure of conductors on the frame or to each other.

Additional requirements to ensure the unavailability of live parts with voltages above 1000 V are regulated by the Electrical installation rules points. 1.1.35, 2.2.28- 2.2.30, 4.2.26, 4.2.57-4.2.67, 4.2.86-4.2.93.

Blocking (electrical, mechanical and electromagnetic) prevents erroneous actions of the operator and excludes the possibility of access to current-carrying live parts.

Alarms (usually automatic), labels and boards are used to indicate the turn on status of a part of the equipment, the presence of voltage, the mode of operation, the prohibition of access to the inside of the installation without taking appropriate measures, etc.

The alarm should be carried out in accordance with the requirements set out in GOST 12.4.026-76 *, and placed in places convenient for viewing. For light signals, colors should be used in accordance with GOST 12.2.007.0-75 * p. 3.8.2.

Marking and coloring used to improve recognition of parts according to their functional purpose 9 Electrical installation rules, point 1.1.28).

The marking consists in putting a symbol on the corresponding element (block, terminal, plug connector, drive). Distinctive painting is made for open current-carrying parts (Electrical installation rules, point 1.1.29) and for external insulation of conductors (GOST 12.2.007.0-75 * p. 3.9.5).

Neutral or protective grounding should protect people from electric shock when touching metal non-conductive parts, which may be energized as a result of insulation damage, i.e. when the current-carrying part is closed to the frame of the electricity receiver (GOST 12.1.030-81). The need for their implementation is established by the Electrical installation rules point. 1.7 depending on the level of voltage used in the equipment and the operating conditions that determine the risk of electric shock. The protective method (protective earth or neutral) is selected depending on the type of current and neutral mode of the network. A protective tripping is recommended if safety can not be provided by grounding or neutralizing of the device or if it is difficult to be performed.

The design of the entire set of measures to ensure the electrical safety of the operation of the equipment may be too large for final qualification work (especially bachelor's), therefore some electrical safety issues may be proposed for development, for example:

- Calculation of minimum clearances for the main insulation of the product taking into account the expected operating conditions (GOST R IEC 60065-2005, etc.).
- Calculation of the system of neutralizing of the equipment.
- Calculation of the parameters of emergency damage to the insulation of the equipment, in which an RCD may occur.
- Selection of a set of measures to ensure the inaccessibility of hazardous parts of the equipment.
- Calculation of the contact voltage to the equipment frame in emergency mode when the selected protection system presents.
- Calculation (analysis) of the risk of electric shock to a human in case of possible malfunctioning of the equipment in the expected operating conditions.
- Classification of operating and storage conditions.

As a system is understood the set of devises having electrical or functional connections among themselves. An electrical installation is a set of machines, apparatuses, lines and auxiliary equipment intended for production, transformation, transmission, distribution of electrical energy and its transformation into another type of energy.

The safety of the installation for service personnel should be ensured in all possible normal and emergency operational situations. According to the safety conditions, electrical installations are divided on:

- electrical installations above 1 kV with effectively earthed neutral;
- electrical installations above 1 kV with insulated neutral;
- electrical installations up to 1 kV with solidly earthed neutral;
- electrical installations up to 1 kV with insulated neutral.

The selection of the neutral mode is made depending on the technical requirements and safety conditions that are required for the system.

The principles of providing security conditions in the system differ from the principles applied to individual devices. Due to the fact that some parts of the equipment included in it can have galvanic connection among themselves, the intensity of processes affecting the safety conditions is determined by the equivalent parameters of all devices and communication lines between them (active and inductive resistance of current-carrying parts, insulation resistance and capacity relative to the frame).

In accordance with the Electrical installation rules, the following are used as safety measures for installations (in addition to the measures for ensuring the electrical safety of individual devices):

• monitoring of network isolation;
• protection against earth faults;
• protective shutdown;
• separation and step-down transformers.

Insulation control allows to detect early the insulation faults and take measures to eliminate them, thereby improving the electrical safety conditions in DC networks and AC networks isolated from the ground (with a small capacitance relative to the ground).

In networks with voltages up to 1 kV isolated from the ground, devices for automatic control of equivalent insulation resistance and (if appropriate) post-control monitoring are used. In solidly earthed neutral networks with voltages up to and above 1000 V usually is used the insulator monitoring with zero-sequence current transformers which allows to identify and, if necessary, to disconnect the network section where the insulation resistance has decreased.

Isolating transformers carry out protective isolation of networks. This technical measure is designed to perform many functions that increase the safety conditions in electrical installations. Isolating transformers allow to unstrap the protected area from the rest of the network by mean of galvanic isolation. At the same time, due to the increase in insulation resistance and the decrease in capacitance, the contact voltage at a single-pole contact is significantly reduced. If in the network there are power receivers that are characterized by a low insulation resistance, then they should also be supplied through an isolating transformer. This allows to maintain high insulation resistance of the entire network and to ensure its effective control. When supplying major receivers from a four-wire network with a neutral grounding, the isolation transformers in addition to improving the safety conditions increase noise immunity and prevent the removal of hazardous potentials through the neutral wire.

Protection from the hazard of high voltage switching to the low voltage side in case of insulation damage between the windings of the step-down transformers is provided by grounding of one of the terminals or the middle point of the secondary winding.

In order to protect against electric shock when touching the current-carrying parts of the sections of the system that allow a temporary removal of the operating voltage, are used protective cut-out devices. If the interruptions in the power supply of the receivers are not permissible, then protective shunting should be used

in the network with isolated neutral and small capacity of the network relative to the ground.
When designing an electrical installation, it should be mentioned that all the zeroed-up electrical equipment frames are connected to a single system through a neutral wire. In this case are possible the regimes where dangerous potentials arise on the frames of both faulty and serviceable electrical receivers. The basic requirements for ensuring the correct functioning of the system of zeroing are provided in the Electrical installation rules and GOST 12.1.019-2009.
When developing the project, it is necessary to identify situations in which there is a danger of electric shock to a person and to justify the selection of the necessary technical methods and means of protection based on the analysis of the system composition and operating conditions, as well as possible failures.
The processes of installation, adjustment, tests, as well as experimental studies of the equipment characteristics are associated with the use of portable power tools, instrumentation, standard and non-standard laboratory equipment requiring mainly power from a 220 V network and a frequency of 50 Hz. During the work implementation, as a rule, the part of the protective shells (casings) is removed, the locks are disconnected and, therefore, there is the possibility of access (touching) the live parts of the equipment being under voltage.
Portable power tools (including ones for soldering joints) have easily damaged power cords.
The metal frame of the instrument is usually connected with one of the poles of the measuring circuit and, consequently, equipotential to the point of the electrical circuit with respect to which the measurement is made. In addition, there are possible modes when dangerous potential differences arise between the instrumentation frames.
During the operation of the equipment, electrical insulation damage may occur. Closures of current-carrying parts on the frame of the equipment lead to the appearance of dangerous voltages, and closures between the windings of the power transformer create the danger of electric shock when a person touches live parts that were previously considered safe.
In this regard, it is necessary on the stage of work preparation to provide technical measures to prevent the dangerous effects of electric current on a human.
The safety of work can be provided separately or in combination with each other by the following technical methods and means incorporated in the design of the used power tools, instruments, laboratory equipment and the supply network:
• guarding devices, including shells, casings, providing unavailability of current-carrying parts for touching;
• isolation of live parts (working, additional, reinforced, double);

• protective grounding;
• zeroing;
• using of small voltages;
• protective shutdown;
• separation of networks (separation transformer);
• equalization of potentials;
• warning signals, locks, safety signs;
• individual protective equipment and safety devices.

The choice of measures to ensure safety is based on the features of the work location; the type of the power supply network (including the neutral mode) and the voltage in the electrical installation; the parameters of the available power tools, instruments and equipment, the degree of protection of their shells; accessibility for the contact of live parts with dangerous voltages; existence of possible specific individual regime during measurements and tests.

When developing the project, it is necessary to identify situations in which there is a risk of electric shock to a human and to justify the selection of the necessary technical methods and means of protection based on an analysis of the conditions of work, measurement modes and possible equipment malfunctions.

The process of performing of many graduate qualification works is connected with making calculations, modeling processes or designing products on a PC, or is devoted to preparation and adjustment of an original software product.

PC and its peripheral devices require, as a rule, power from the network voltage of 220 V and a frequency of 50 Hz. At the workplace can be located also office equipment, desk lamp and other devices, also powered by a 220 V network.

During operation, here may occur damage to protective sheaths, insulation of current-carrying parts of devices and power cords, which create the danger for a person touching either directly to bare live parts, or to metal non-current parts of devices that are under voltage due to insulation damage. In this regard, when preparing the workplace, it is necessary to provide technical measures to protect against the dangerous effects of electric current on the human.

Safety of works can be provided separately and in combination with each other by the following technical methods and means incorporated in the design of devices and the supply network:

• guarding devices, including shells, casings, providing unavailability of current-carrying parts for touching;
• isolation of live parts (working, additional, reinforced, double);
• protective grounding or zeroing;
• using small voltages;
• protective shutdown;

• using separating transformers;
• warning alarms, interlocks, safety signs, and construction measures that reduce the risk of electric shock.

The choice of measures to ensure electrical safety is made on the basis of the presence in the premises conditions that create an increased or special danger of electric shock to human, the type of the power supply network (voltage, frequency, neutral mode), the permissibility of an emergency power failure and the design features of the devices used, for example:

• degree of shell protection,
• device protection class,
• availability of metal non-conductive parts accessible for contact, on which dangerous voltage may appear due to operational damage.

When preparing a section, it is necessary, on the basis of the analysis of working conditions, equipment and possible malfunctions, to identify situations in which there is a risk of electric shock to a human and to justify the selection of the necessary technical methods and means of protection.

Ensuring the electrical safety of medical devices has some features compared to conventional production or household products. General technical requirements and test methods for them are presented in GOST 12.2.025-76.

Equipment, depending on the degree of protection from electric shock is divided into four types:

• H - having a normal degree of protection;
• B - having an increased degree of protection;
• BF - having an increased degree of protection and an isolated working part;
• CF - having the highest degree of protection and an isolated working part.

The equipment of III class shall be designed for power from an external source with an alternating voltage not exceeding 24 V or with a constant voltage not exceeding 50 V and shall not have external or internal circuits with a higher voltage. Equipment with external power supply, designed for use in the premises not intended for medical purposes, and having a working part intended for electrical contact with the patient's body, must be manufactured according to class II or III. Equipment of types BF and CF should have a working part, isolated from the metal parts accessible for touching. Equipment with the external power supply, designed for use in the premises not intended for medical purposes, and having a working part intended for electrical contact with the patient's body, must be manufactured according to class II or III. Equipment without the working part must be manufactured according to type H or B. Type H is allowed to produce equipment that is in operation outside the patient reachable area (laboratory products, sterilizers, etc.). The equipment with the working part that does not have electrical contact with the heart, as well as the devices connected to them, must be manufactured in type B, BF or CF. The equipment with the working part that does not have electrical contact with the heart, intended for therapeutic treatment of the patient with a constant electric current or low-frequency current, should be designed according type BF or CF. The equipment with a working part that has electrical contact with the heart, as well as the devices connected to them, must be made according type CF. When testing such equipment, the increased in comparison with industrial devices requirements for permissible leakage currents, electric strength and electrical resistance of insulation are applied. There are some features of electrical safety for induction electric thermal installations and radio-frequent radio engineering systems. In particular, the basic electrical scheme for analyzing the electrical safety issues of the high-frequency induction installation are significantly different from the commonly used electrical schemes of one kind of current or a dual current type, in which there is a link of a rectified DC. Here it is necessary to talk about a system of a triple kind of current whose electrical circuits have a galvanic coupling between themselves (Fig. 3).

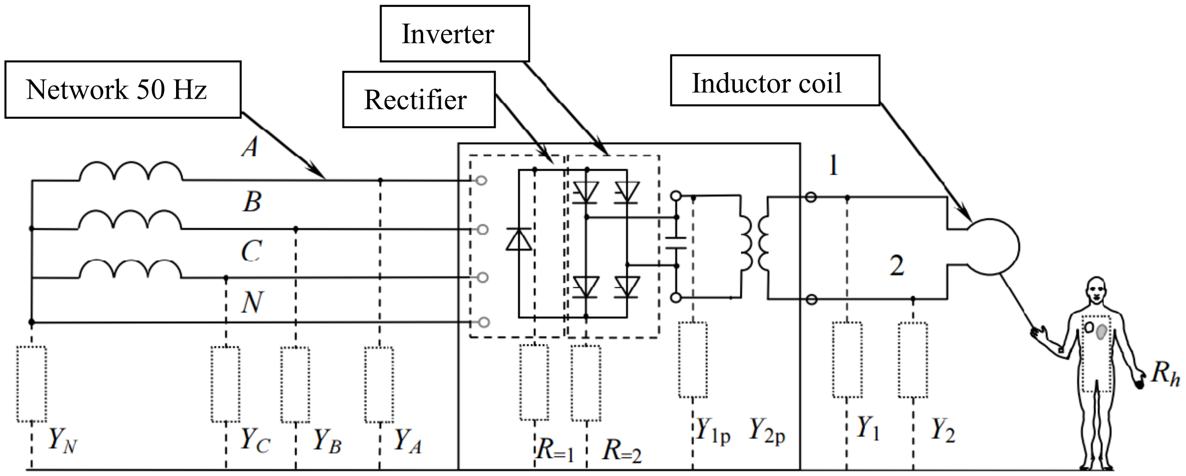


Fig. 3. One of the specific equivalent circuits of a high-frequency installation for the analysis of safety issues

Usually there is a frequency converter, which is a separate device and is connected to a 50 Hz network. The alternating current of the industrial frequency is converted into a direct current by means of rectifiers according to certain rectification schemes. The rectified current is converted by an inverter into a high-frequency current. There are developments of the induction installations in which a single powerful rectifier feeds several inverters, so the DC network can be quite long. The safety conditions and electrical insulation control systems can be seriously influenced by the leakage currents on the rectified voltage side due to the peculiarities of the dual-current systems. Taking into account the experience of the negative effects of leakage currents from thyristor switches, which, due to the nonideal thyristors, caused an electric shock when touching the inductor after turning off the power by these switches, it is necessary to take this circumstance into account and try to assess these leakage currents. The induction coil can be connected directly to the power source or to the secondary winding of the transformer.

Thus, random direct or indirect contact is possible with three parts of the electrical circuit: high-frequency, the side of the industrial frequency and the rectified current circuit.

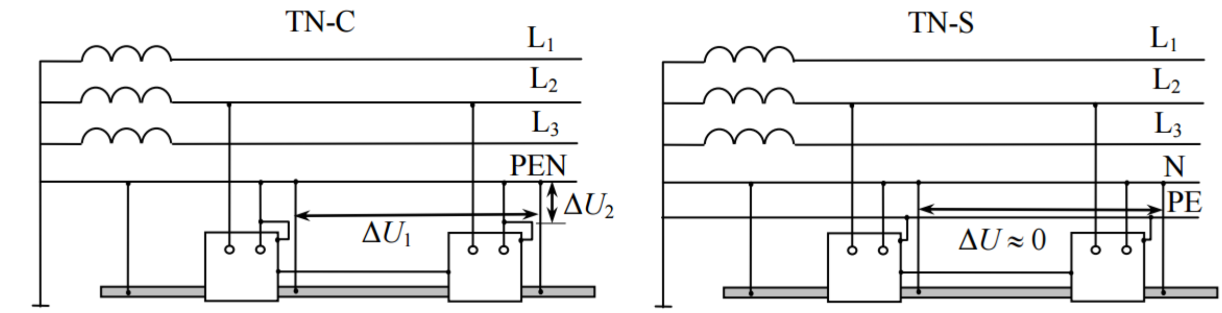
In the individual task for calculating the electrical safety conditions of a human, can specify the conditions under which it is necessary to assess the risk, and in case of the unacceptable risk, can choose protection with the account of the uncertainty in the state of rationing of high-frequency currents and information on the leakage currents of diodes, transistors or thyristors. Such tasks can be offered to the master students for scientific research.

A separate task that the bachelor student can solve in his additional section is to find the current flowing through the human body, in case of the direct touch of the high-frequency part of the inductor without electrical isolation.

For the equipment of information processing that includes all types of electrical, electronic and telecommunications equipment, including local computer networks, there are special requirements for the use of grounding (in the case of the TN-zero system) and for compensation of the potentials for the purposes of electromagnetic compatibility and signal transmission without distortion (GOST P 50571.21-2000 (IEC 60364-5-548-96)).

When performing zeroing and compensation of potentials (the connection of all conductive elements in the building: the equipment casings, metal elements, for example, central heating pipes, sewerage, water supply, etc.), it is not recommended to use the TN-C system due to the voltage drop and compensation currents in case of failure (Fig. 4, a).

The current load caused by an asymmetrical load in three-phase networks and the short-circuit currents flowing through the neutral conductor are divided between the PEN conductor, third-party conductive parts, shields and cable sheaths, and conductors intended for information exchange, causing the interference. Repeatedly for this reason, low-frequency jitter was observed on the image of monitors located near the passage of power supply cables. The compensating current of 5 A, flowing through the zero wire, can create an induction of an external field of more than 400 nT, and thereby cause instability or distort the image of monitors made on the basis of a cathode-ray tube.



Current-conducting parts in the building *a* Current-conducting parts in the building *b*

Fig. 4. Features of zeroing and compensation of potentials:
A - appearance of compensation currents in the TN-C system;
B – absence of compensation currents in the TN-S system

The closing current will flow through the PEN conductor and create a voltage drop $\Delta U = \Delta U1 + \Delta U2$. The TN-S system is more resistant to the formation of compensation currents due to the fact that the current of the neutral conductor flows only along the zero conductors, without causing a fall in the protective PE conductor, and therefore ΔU (Fig. 4, b). As a task for the student can be to estimate the voltage drop and the current flowing through the zero wire, to assess the risk of simultaneous contact with the two PC units.

Fire and explosion safety

Fire and explosion safety should be provided in accordance with the Technical Regulations on Fire Safety Requirements, Fire Safety Standards NPB 247-97, Fire Safety Rules in the Russian Federation, certain building codes and regulations, and state standards. Below are briefly outlined the issues that can be addressed in the additional section of the GQW.

Calculation experimental method for determining the probability of fire in the electronic equipment. The probability of the occurrence of the emergency fire hazard regime in the component part of the equipment (failure of the component parts and the occurrence of a short circuit, overload, increase in the transient resistance, etc.) according to NPB 247-97 is determined on the basis of reliability data.

If there are appropriate reference on the reliability data of the component parts of the equipment, the probability can be determined through the total failure rate of the equipment with the introduction of a coefficient that takes into account the share of fire-dangerous failures (short circuit, open circuit, contact failure, etc.), defined by the formula $Q = Nn/Ne$, where Nn, Ne- ranges of fire-hazardous and possible values of the electrical parameter characteristic (current, power, resistance, etc.).

The emergency fire hazard test mode of the equipment is characterized by the magnitude of the fire hazard range of the electrical parameter, at which the appearance of fire may occur. For example, a typical fire hazard mode is a short circuit; the characteristic electrical parameter of this mode is the short-circuit current.

A fire hazard range is determined during the tests. To do this, should be founded the maximum and minimum fire hazard values of the characteristic parameter and its boundary values, which are possible during its operation.

Assessment of the fire hazard of the electrical equipment. Is carried out by the algorithm given in GOST R IEC 60695-1-1-2003.

The fire hazard is peculiar for any electrical circuit. The choice of materials, components and the design of equipment itself, the fire risk should be reduced so that it is not significant, even in emergency conditions, with improper operation or with errors made in the production of the equipment. It is preferable that the equipment would not become a source of ignition, but if one does occur, the fire hazard should be limited by the device itself and the fire would not spread beyond the body frame of the device. In case if the devices themselves are exposed to fire hazard from an external source, it is important that they do not contribute to the spread of the fire more than building materials or structures that are a source of fire.

The fire hazard of the equipment depends on their technical characteristics, operating conditions, maintenance (taking into account the number and qualifications of the personnel), the environment in which it is used, and also the possible damage to property due to a fire, including the equipment itself. The assessment of the fire hazard of the equipment should include a description of the product, as well as the characteristics of the environment and operating conditions.

The fire hazard is estimated in the following stages:

- determine the purpose of the equipment (for example, belonging to a certain type of electrical device) and characterize the situation in which these equipment is used;
- identify the fire scenarios relating to this equipment;
- choose fire hazard criteria;
- interpret the results.

Determination whether the equipment is located in fire hazardous or explosive areas. It is based on the calculated values of the parameters associated with the spatial and temporal characteristics of the existence of fire-hazardous materials and explosive mixtures in them (Regulation for electrical installations, GOST R 51330.9-99). Classification of zones is a method of analyzing and classifying the environment in which an explosive gas mixture may be presented in order to select electrical equipment and devices for electrical installations the use of which shall be safe in the presence of this mixture. Classification is carried out taking into account the separation of explosive gas mixtures by categories and by groups.

In practice, it is very difficult to guarantee the operation of industrial objects associated with the manufacturing operations of combustible materials, so that flammable gases do not present in the air and ignition sources do not arise in the electrical equipment. Therefore, in case of presence of the explosive gas mixture should use electrical equipment, the design of which minimizes the probability of the ignition source occurrence. At the same time, it is necessary to take into account the fact that if the probability of occurrence of an explosive gas mixture is small, then the requirements for explosion protection to the design of electrical equipment can be less stringent.

To determine the class of the explosive zone, there should be determined the sources and leakage rates. Since an explosive gas mixture can occur only when a flammable gas or steam is mixed with air, it is necessary to ascertain the presence of any of the combustible materials in the area under consideration. First of all, it must be found out whether combustible gas or steam (also flammable liquids and solids that can form gas or steam) is produced inside the technological equipment, which can not be completely closed. In addition, there must be identified the technological equipment containing the explosive gas mixture inside and the sources of leakage of flammable substances, as a result of which an explosive gas mixture can be spread from outside.

If an item of the equipment causes a leakage of combustible material into the atmosphere, it is necessary to determine the degree of leakage according to the definitions given in the national standard on the basis of the frequency and duration of the leak. Having established the degree of the leakage, it is necessary to determine its intensity and other factors affecting the class and size of the zone.

Requirements for electrical equipment in fire-hazardous areas (Regulation for electrical installations, Chapter 7.4). In the fire-hazardous areas is used the general electrical equipment. In this case, the degree of protection of the electrical equipment body must correspond to the class of the fire-hazardous area. When choosing the electrical equipment installed in fire hazardous areas, it is also necessary to take into account the environmental conditions (chemical activity, atmospheric precipitation, etc.) (point 7.4.11 of the Regulation for electrical installations).

Requirements for electrical equipment in hazardous areas (Regulation for electrical installations, Chapter 7.3). The selection and installation of electrical equipment for explosive areas is based on the classification of hazardous areas and explosive mixtures.

Determination of the conformity of the materials with the requirements for the limitation of flammability. Parameters, requirements, test methods, classification. Fire resistance is the ability of structures to withstand high temperatures in a fire and fulfill their operational functions. Flammability is the ability of a material to burn when it is heated or when it comes into contact with a source of fire. All materials and structures according to their flammability are divided into three groups: non-combustible, difficultly combustible and combustible. The requirements for the used materials are formulated on the basis of the requirements for the functional fire hazard of the premises (building) listed in the Technical Regulations on Fire Safety Requirements. The class of functional fire hazard of buildings, premises, and fire compartments is one of the classification characteristic of any buildings, premises, and fire compartments, determined by the designation and operation features of the abovementioned object, including the features of implementation of technological production processes in the buildings, premises, and fire compartments.
Parts made of non-metallic materials on which are located the live elements should be resistant to ignition and the spread of combustion when exposed to a flame. Classification of materials for flammability should comply with GOST R 50377 (V-1, V-2, HF-1). The material class must correspond to the purpose of the part in the equipment. The fire resistance limit of a building is assessed in accordance with GOST 30247.0-94 and is indicated by one or more uppercase letters of the Latin alphabet and digits showing the time of fire persistence in minutes.
The limit states of building structures for fire resistance are:
• R - loss of bearing capacity due to collapse of the structure or occurrence of ultimate deformations;
• E - loss of integrity as a result of through cracks formation or openings through which combustion products or flame spread on the unheated surface;
• I - loss of heat-insulating capacity due to a rise of temperature on the unheated surface of the structure up to the limit values for the given design determine the purpose of the equipment (for example, belonging to a certain type of electrical equipment) and characterize the situation in which these equipment is used.
Methods for material testing are provided in GOST R IEC 60950-2002.
Checking the compliance of used structural and electrical insulating materials with the requirements of heat resistance. Parameters, requirements, test methods. Parts of electronic equipment made from non-metallic materials used for external parts, parts that hold conductors and support connections in a certain position, must be heat-resistant. The heat resistance of structural and electrical insulating materials is determined in accordance with GOST 27570.0 at a temperature (75 ±2) °C for external parts and (125 ±2) °C for parts holding live parts in a certain

position. Tests can be carried out by pressing the ball into the material in accordance with GOST R 50377.
Allowable temperature rise of the elements. Requirements, methods of provision. During normal and emergency operation of electronic equipment, none of the structural elements should have a temperature above the permissible values specified in GOST 12.2.006, and for computer equipment - GOST R 50377.
Verification of the conformity of used structural and electrical insulating materials with the requirements of tracking stability. Parameters, requirements, test methods. The connecting parts between live parts of electronic equipment, made of insulating materials, should be resistant to the formation of conductive bridges. If the device is operated under extremely severe conditions, then these materials must comply with KIT 250. Tests of electrical insulation materials for tracking should be carried out in accordance with GOST 27473.
Tests of materials on resistance to the effects of heated elements. Parameters, requirements, test methods. Parts of the electronic equipment from non-metallic materials must be resistant to the effects of heated elements.
External parts of non-metallic materials and parts made of insulating materials that keep current conductors in a certain position (other than contact connections) must bear the effect of heated elements having a temperature of 550 ° C.
Parts made of non-metallic materials that hold in a certain position the electrical connections through which flows a current of 0.5 A or more must be resistant to impacted elements having a temperature of 750 ° C if electronic equipment is operated under the supervision.
Parts of electronic equipment made from non-metallic materials that hold electrical connections must be resistant to the effects of heated elements having a temperature of 850 ° C if electronic products are permanently under the voltage and unattended.
Tests for resistance to the effects of heated elements should be carried out by heated wire in accordance with GOST 27483 and heated spiral according to GOST 28913.
The heated spiral test is performed on samples of hard electrical insulating materials in order to simulate the thermal effect of overloaded bare conductors. The test shall be carried out on the shells of the product, located at a distance of less than 13 mm from the conductors, which are heated in emergency conditions to a temperature sufficient for ignition.
Testing with heated wire should be carried out in accordance with GOST 27483.

Electromagnetic compatibility

Special problems of ensuring the safety of the equipment requiring a separate solution include issues of electromagnetic compatibility. In this case, EMC is the ability of the equipment to function with the required efficiency in the electromagnetic environment and not to create unacceptable electromagnetic interference for other technical means. Electromagnetic interference, i.e., any electromagnetic phenomena that may degrade the functioning of the installation, are in most cases an integral part of the environment and must be therefore taken into account in the analysis of safety. The object of awareness is the electromagnetic emission from the source of interference (noise emission), i.e. generation of the electromagnetic energy by the source of interference, which can be emitted into space in the form of electromagnetic fields or spread along the conductive wires. Based on the definition of EMC, within the frames of caring out the analysis of safety, two main issues should be considered, namely, the noise immunity of the device itself and interference emission from it. The level of EMC - the established level of electromagnetic interference used to determine the emission and noise immunity limits - is the level that can be exceeded by electromagnetic interference with low probability. Electromagnetic compatibility is ensured only if the levels of interference emission and noise immunity are controlled so that at a named place where the equipment is located the total level of emission interference is below the level of interference immunity of each component, apparatus or system located at this place.

In the electromagnetic environment when the equipment is operating can be met *the conductive low-frequency electromagnetic interference* (steady deviations, oscillations, dips and interruptions in the power supply system, distortion of the sinusoidal supply voltage, non-symmetry of voltages in three-phase power supply systems, frequency deviation, induced low-frequency stresses, components of voltage in AC power supply networks and voltage of signals transmitted in power supply systems), *the conductive high-frequency electromagnetic interference* (introduced or induced voltages and currents representing continuous oscillations, unidirectional transient processes or vibrational transient processes), *emitted low-frequency* (electric and magnetic fields) and *high-frequency interferences* (electric, magnetic fields and EMF caused by continuous oscillations and transient processes), as well as *electrostatic discharges*.

Unacceptable interference is considered to be large in levels of conductive interference transmitted to the power supply system, usually from power sources (lamp generators, thyristor and transistor generators), as well as radiated interference (electromagnetic fields) from different systems emitting electromagnetic energy and power cables. Thus, developers should focus on the issues of the impact of poor-quality electricity from power systems and external electromagnetic fields from other sources of EMF on the equipment operation, as well as issues of negative impact of the equipment on the power grid and other electrical and electronic devices located in the electromagnetic environment next to it.

At present, in Russia have been issued and operate numerous standards for EMC. If we talk about noise immunity, then according to the requirements of GOST R 51317.1.2-2007 (IEC 61000-1-2-2001) "Compatibility of technical means of electromagnetics. Methodology for ensuring the functional safety of technical facilities with respect to electromagnetic interference" to ensure functional safety, i.e., the absence of unacceptable risk of causing harm associated with the malfunction of the equipment (including the possible predictable wrong use of the equipment) under the influence of electromagnetic interference, it is necessary to assess their possible impact on the overall risk and perform the design or installation so that the risk associated with possible exposure to EM interference, would be reduced to the permissible value.

With respect to EM interferences there should be:

• developed a concept to understand the designation of the equipment and the conditions of its operation;

• assessed possible risk and degree of danger of disrupting the operation of the equipment and its components;

• developed the conditions that ensure functional safety and the necessary measures to ensure it;

• carried out the design and development of the equipment with the required level of safety (in particular, systems related to safety);

• made the validation, i.e. confirmation of the established level of functional safety, at the place where the equipment is located;

• organized the operation and maintenance with an established level of functional safety;

• made a modification with an assessment of possible changes in the design and characteristics of the equipment or process for safety;

• organized the safety monitoring with the registration of failures and the impact of these failures on safety for subsequent analysis.

The main steps to ensure the functional safety of the equipment in relation to electromagnetic interference are:

• determination of the design and functions of the equipment;

• determination of the electromagnetic environment in the place where the equipment is located;

• establishment of security requirements;

• reliability analysis;
• EMC testing;
• changing the design or installation rules to reduce the risk to the acceptable level;
• validation to demonstrate that the product is functioning in accordance with established requirements;
• development of operating and maintenance manual to ensure the required functional safety during the life cycle.

The main requirements for functional safety of the equipment should the following ones:

• external electromagnetic interferences should not cause failures in work, and together with failures for other reasons, only lead to acceptable risk;
• internal electromagnetic interference should not affect any part of the equipment, especially electrical and electronic systems related to safety;
• when choosing criteria for determining the results of immunity tests, fault risks should be analyzed that can cause a temporary recoverable without intervention or with operator intervention or an unrecoverable termination of certain functions during the operation of the equipment under critical electromagnetic conditions.

If the developer assumes that there is a probable critical impact of some kind of interference on the functional safety, he should also think about the necessary means of protection.

For example, if it is revealed that the security system can be affected by RF EMF from other equipment located in an electromagnetic environment, a protective electromagnetic shield or cover may be provided during the design; might be put filters; provided equipotential bonding or grounding, use of redundancy principles (duplication and parallel connection of elements); the printed circuit boards can be designed using multi-layer printed circuits, in which there are grounded layers and decoupling capacitors, shielding of wires, etc.

The necessary technical solutions to reduce electromagnetic interference are determined specifically for each case on the basis of existing experience or as a result of research. For example, the separation of electric power lines from information lines, aims to minimize the cross interferences of information lines induced by a strong current in the power system. Lines providing electrical power are separated from the lines carrying information. It must also be taken into account that the electric field, which can induce interferences on the information lines (voltage spikes), decreases with increasing of the distance. Spatial separation of group lines (lines with duplicate signals are separated from one another) leads to a reduction in the cross interferences induced by the current of power systems. To reduce the sensitivity of safety-related systems from EMF that can be induced to power systems or signal lines or to be caused by static discharges, are used such as methods screening and filtering.

Common cause errors (caused by radiation) can be detected by an antivalent comparator. To detect the same induced voltages in the group signal transmission lines, all duplicate information is transmitted with antivalent signals (e.g., logic 1 and 0).

To detect failures in sensors of safety-related systems, an independent reference sensor can be used to monitor the performance of the sensor. In this case, all input signals in the lead-in time intervals are checked by this sensor to detect faults in the operation of the monitored sensor.

According to GOST R 51317.1.2-2007 (IEC 61000-1-2-2001), if there is a potential risk of harm caused by electromagnetic interference, the equipment as a whole or its individual components must be tested after manufacturing, either in laboratory conditions or in production conditions. This is especially important for safety-related items and functions. The manufacturers of the product must compare the volume and complexity of the tests, including additional tests, on noise immunity to ensure functional safety with risks and with consequences of interference rejections, and also take into account the existing experience of functioning of the equipment under conditions of significant electromagnetic interference and determine the severity of the tests and drawing up the test plans.

To ensure safety, the designers and manufacturers must establish test rigidity levels based on the maximum possible interference levels for specific operating conditions. In addition, for the guarantee, it is recommended to select higher test rigidity levels with a certain “safety factor” and conduct two series of immunity tests, namely, testing non-safety elements and safety-related items but with a greater degree of rigidity than the first.

When conducting tests for a particular interference, it is desirable to determine its level at which there will be a disruption in the operation of both hardware and software, and a security risk will arise. This may be required to determine the assurance coefficient for the noise immunity. In some cases, for example when testing the electrostatic discharges and breakdowns, this can only be done for the experimental sample (since it can fail without the possibility of subsequent recovery), but this can be justified in order to reduce subsequent additional costs.

After the functional safety test has been carried out, a report on the effect of interference on functional safety shall be prepared. In addition to general points concerning the type of equipment, location and other issues, it should include data on critical electromagnetic interference, on structural elements, installation and installation conditions, maintenance elements, taking into account the aging of

equipment, which can be further taken into account by other developers and consumers.
For most products, it would be possible to recommend testing for immunity to electromagnetic interference of the following types:
• magnetic fields of industrial frequency in accordance with GOST 50648-95;
• pulsed electromagnetic fields in accordance with GOST 50649-94;
• radio frequency EMF in accordance with GOST R 51317.4.3-2006;
• conductive interference induced by radio-frequency electromagnetic fields in accordance with GOST R 51317.4.6-99 (IEC 61000-4-6-96);
• static discharges in accordance with GOST R 51317.4.2-99;
• microsecond impulse interference in accordance with GOST R 51317.4.5-99 (IEC 61000-4-5-95);
• nanosecond impulse interferences according to GOST R 51317.4.4-2007;
• conductive interference 0 ... 150 kHz according to GOST R 51317.4.16-2000;
• dips, short interruptions and changes in the power supply voltage in accordance with GOST R 51317.4.11-2007, fluctuations in voltage supply in accordance with GOST R 51317.4.14-2000.
The degree of rigidity of the tests is chosen based on the levels of possible electromagnetic interference at the workplace of operation of the equipment and taking into account the consequences of failures in work, as well as the costs associated with establishing the necessary interference immunity, which can be significant. In this regard, the requirements of interference immunity should be settled with caution.
The results of tests of the EMC equipment as a whole or its individual elements, for example, control and protection systems should be classified according to the criteria for deterioration in the quality of functioning or termination of the planned functions. The following performance criteria can be recommended:
• A - normal operation in accordance with the requirements set by the manufacturer, the test customer or the user;
• B - temporary termination of the function or deterioration of the functioning that disappears after the cessation of the interference and does not require operator intervention to restore operability;
• C - temporary termination of the function or deterioration in the quality of functioning, the restoration of which requires operator intervention;
• D - termination of the function or deterioration in performance that cannot be recovered due to damage to the elements or software, or data lost.

Providing protection against external factors

External effects on the equipment (climatic and mechanical) have a different physical nature and vary widely.

Climatic effects on physical nature are divided:

• temperature effects (short-term and long-term);
• exposure to moisture (short-term and long-term);
• exposure to salt mist;
• the effect of atmospheric pressure;
• exposure to solar radiation;
• exposure to dust;
• exposure to mold fungi. These climatic external influences are objective factors - the conditions in which the operation, storage and transportation of products are carried out.

Mechanical effects on the equipment by the physical nature can be divided:

• on the vibrations that cause acceleration;
• impacts, i.e. mechanical stresses and deformation of the structure. Vibrations are divided into short-term and long-term; impacts on linear and centrifugal. Analyzing the criticality of the influence of external influences on the equipment, it is possible to identify among all external influences:

• effects that cause reversible changes;
• effects that cause reversible failures;
• effects that cause immediate accumulation of destruction;
• effects that cause irreversible accumulating changes;
• effects that cause irreversible failures.

Climatic and mechanical characteristics determine the following performance of the equipment:

• mechanical strength, rigidity and quality of construction, reliability of the parts functioning, assembly units and product blocks under the influence of external mechanical factors, ensuring stability when subjected to vibration and shock, linear and angular acceleration;
• resistance of the structure to the effect of the complex of climatic factors (heat, moisture, salt fog, radiation, biological factors, etc.);
• lifetime in service.

There is a series of standards that define test methods for resistance to external influencing factors of machines, instruments and other technical equipment, starting with general requirements (GOST 30630.0.0-99) and ending with specific requirements, for example, on individual components (determination of the dynamic characteristics of a structure, vibration test or random wideband vibration using a digital test control system), transport and storage tests (GOST R 51909-

2002) or the effects of aggressive and other special environments (GOST R 51802-2001). Terms and definitions for external factors are given in GOST 26883-86.

The equipment are manufactured in different climatic versions: moderately cold climate, tropical, etc. Categories, conditions of operation, storage and transportation in terms of the impact of climatic factors of the external environment are given in GOST 15150-69 "Machines, devices and other technical equipment. Categories for different climatic regions. Categories, conditions of operation, storage and transportation with regard to the impact of climatic factors of the environment".

The main attention in tests for resistance to climatic external factors affecting machines, instruments and other technical equipment is given to the methods of testing for exposure to humidity in accordance with GOST R 51369-99.

The following types of climatic tests are distinguished:

- high temperature test;
- low temperature test;
- temperature change test;
- frost and dew test;
- test for exposure to high humidity;
- test for the external impact of water;
- a test for exposure to solar radiation;
- dust test;
- atmospheric pressure test;
- a test for the effect of increased hydrostatic pressure;
- salt fog test;
- wind resistance test;
- leak test;
- a test for biological effects. Test methods are defined in GOST R 51369-99, GOST R 51372-99, GOST R 51802-2001, and others.

The following types of tests for mechanical stress are determined:

- test to determine the presence and absence of resonant frequencies of structures;
- vibration test;
- impact and stability testing;
- linear load test;
- acoustic noise test.

At the place where the installation is located, negative external factors can act on it in the form of vibration and shock loads of various nature, including man-caused and natural, for example earthquakes. The equipment must keep its parameters within the limits set in the terms of reference, standards and specifications for a particular series or its type. General requirements regarding the resistance to mechanical factors for many types of the equipment are laid down in GOST 17516.1-90 “Electrical equipment. General requirements regarding the resistance to mechanical external factors”.

For most types of the equipment, the mechanical design group is M1 or M2, i.e. it can be placed directly on building structures (for example, on foundations) of enterprises with external sources generating vibrations with a frequency of no more than 35 Hz, and without impact sources located in the same premises, or M3 with impact sources located in the same room (for example, press equipment, hammers or other impact mechanisms).

For equipment M1 and M2, only sinusoidal vibration is normalized from external influencing factors, the level of which is noticeable. The nominal values of the maximum amplitude of the acceleration are 5 m / s2 (or 0.5 g) for the frequency ranges 0.5 ... 35 Hz and 0.5 ... 100 Hz for the groups M1 and M2, respectively. In addition to sinusoidal vibration, the same as for M1, for M3 equipment, the nominal values of peak shock accelerations (maximum acceleration amplitude of 30 m / s2, or 3 g) and the duration of shock acceleration (2 ... 20 ms) of multiple impacts, which is considered insignificant. With the technical and economic study carried out upon agreement between the customer and the developer, higher requirements for resistance to certain types of external factors that may be selected according to the relevant tables of GOST 17516.1-90 may be established.

For the installations operating in areas of seismic activity, resistance (strength) requirements are imposed for sinusoidal vibration for 1 min based on the intensity of the earthquake and the level of installation placement above the ground. The choice of the equipment group and additional requirements is carried out according to the tables of the mandatory Annex 6 of GOST 17516.1-90. The requirements for testing are laid in GOST 17516.2-90 “Equipment for electrical engineering. Test methods for resistance to mechanical external factors”.

Also, the test methods for resistance to mechanical external influencing factors of machines, instruments and other technical equipment are determined in accordance with GOST R 52862-2007 (IEC 60068-2-65-2003) (tests for the impact of acoustic noise (vibration, acoustic component)) and GOST R 52762-2007 (IEC 60068-2-75-1997) (tests for the impact of strikes on the shell of products).

Acoustic noise can cause considerable vibration of components of the assembled equipment, which may differ from vibration caused by external mechanical action. Especially sensitive to acoustic action are relatively light equipment, the dimensions of which are comparable with the length of the acoustic wave in the frequency range under consideration and for which the mass per unit of surface is small (for example, disk antennas or solar panels, electronic devices and printed circuit boards, optical elements, etc.).

The test sound levels are high enough and can damage the human hearing. Tests for the effects of acoustic vibration (acoustic noise) are carried out to determine the ability of the sample to operate and maintain its performance under the influence of normalized acoustic noise of high-intensity. In this regard, various types, methods and test modes can be used for caring out sound tests: an acoustic field in the reverberation test chamber (for individual shells, for example, a rocket fairing shell or a gas cooler for a high-pressure nuclear reactor), wave tests (external devices of airborne vehicles and etc.), tests by the method of volume resonance or by the standing wave method.

The rigidity of acoustic tests is determined by the total sound pressure level (from 120 to 170 dB) and the duration of the tests (from 60 to 2 seconds).

GOST R 52762-2007 establishes three test methods for determining the ability of a test sample to withstand the impact on the shell of normalized stiffness and to confirm the ability to maintain the required level of operability and safety of the equipment when the shell is exposed to the set number of strokes and their rigidity.

The degree of rigidity of the tests is determined by the value of the energy level of the impact (from 0.14 to 50 J) and the number of strokes. For the tests may be used a pendulum, a spring impact device and a vertical impact device.

Issues of ergonomics

According to GOST R ISO 6385-2007 "Ergonomics. Application of ergonomic principles in design of the production systems" the ergonomic principles are used to design the optimal working environment in terms of comfort, safety and personnel health, including enhancement of the existing professional skills, acquisition of the additional professional skills in order to achieve the necessary technological efficiency and economic efficiency.

Within the frames of the design process should be considered the basic relationships between the personnel and the equipment. The person should be considered as the main component and an integral part of the system being developed.

The main objectives of the ergonomic equipment design are to eliminate discomfort, ensure the safety of the maintenance personnel and increase the productivity of his work by providing information, biophysics, energy, space-anthropometric and technical-aesthetic compatibility.

In accordance with the provisions of GOST R EH 614-1-2003 "Equipment safety. Ergonomic principles of construction. Part 1. Terms, definitions and general principles" when applying the ergonomic principles in the design of a working system, it is important to take into account human abilities, skills, constraints and needs when considering the interaction between the operator, work equipment and working conditions. The ergonomic working system increases safety, productivity and labor efficiency, improves the working and living conditions of a person and reduces the harmful effects on his health.

The design deals mainly with the interaction of the operator and the working equipment, as well as the separation of functions and interaction of the operator and the working equipment. The goal is to design a working system that is consistent with the means, limitations and needs of the person. Therefore, it is necessary to analyze the working task in the design process.

The product should be designed taking into account the size of the body of the intended group of operators. The following should be considered:

• the size of the body of adults, children and the elderly, especially for household equipment (static and dynamic, in appropriate clothing and / or with personal protective equipment);

• the space for the movement of the body and its parts;

• the safe distances;

• available sizes (for operation, repair and maintenance) using, for example, anthropometric templates, layouts or computer models.

When designing the equipment, the following principles must be taken into account:

• the handles and pedals of the equipment must conform to the shape and functions of the anatomy of the arm or leg, as well as the body size of the operator's group. Handles for manual work equipment must be designed so that the operator can properly take on them and carry out the intended movement;

• frequently used control units, handles and pedals must be positioned so that they are easily accessible to the operator in a normal working posture. Other important control units, such as emergency devices, should be located so that the operator can easily reach them; less frequently used control units should not be located within the reachable area, unless this is required by the work assignment;

• height and other functional dimensions must correspond to the operator's data and the type of the performed work and adjusted or selected, for example by regulation;

• the type, location and adjustability of the seating position should be provided taking into account the size of the operator, his position and the performed functions;

• the sufficient space should be provided for the movement of parts of the body participating in the work so that the work assignment can be performed in a comfortable position and with convenient movements; changes of the posture should be easy.

The posture of the body of the operator at work should not cause any harm to health.
When designing the equipment, the following principles should be taken into account:
• unnatural postures, for example curved or bent, as well as monotonous activity leading to fatigue, should be excluded. It should be possible to change the posture.
• the equipment should be designed to allow the operator to choose working positions, alternating with sitting, standing and walking. Sitting is generally preferable to standing.
• the basic necessary posture and appropriate body supports should be provided. Supports should be sized and positioned to avoid the unstable position of the body. The poses must correspond with the efforts. Technical means should be designed to provide the required impact and avoid physical overloads. In order to implement these requirements for manual working equipment, it is important to arrange the control arms the way that they are not intercepted during operation.
Work equipment should be designed so that the movements of the body or its parts correspond to the natural rhythms and ways of doing the work. Particular care should be provided to ensure that the operator does not make frequent or prolonged movements with a strong rotation of the joints.
When designing the working equipment, the following principles should be taken into account:
• when using work equipment, the fixed operator positions should be avoided;
• motions requiring high accuracy should be performed with minimal effort;
• for manual movements requiring high accuracy, auxiliary means should be used (for example, lifts, guides, locks, etc.);
• the efforts that require rotation or inconvenient position of the joints of the hands and palm should be avoided;
• the working equipment should be designed to avoid repetitive (monotonous) movements that can lead to damage, illness or injury.
The requirements of the working equipment to the physical efforts of the operator when applying them must be rational. When dealing with the control units the efforts depend on the mass, shape, size, mass distribution and position of the control units; on the duration and frequency of effort; on the operator's posture (sedentary or standing) and on the direction of movement; on the rules and methods of work, as well as on the abilities of this group of operators (for example, sex, age, health status, body structure).
When designing the working equipment, the following principles should be taken into account:

• in case if the required effort cannot be provided by the corresponding muscular group, should be used the mechanical auxiliaries;
• avoid prolonged static muscles tension (such as the work of hands over the head). The weight of a hand tool can cause a significant fatigue of the muscles with prolonged exposure, so this effect should be eliminated, for example by suspending or using levers;
• to reduce the applied force, gravity must be compensated;
• control units, handles and pedals of the work equipment should be designed so that the applied force is minimal and does not cause harmful effects on the health or safety of the operator;
• taking into account the requirements for working with manual equipment, the mass must be distributed in order to reach an appropriate balance;
• depending on the required effort, the size, shape and position of the control units, the uneven load on the body and its parts must be avoided. The more frequent and longer the exposure is, the more it should be performed in the sitting position of the operator.

With the increase of the level of the technical systems automation, the requirements to the operator's physical capabilities are reduced and the requirements to his intellectual abilities (perception and processing of information) are increased. Work equipment should be designed to take into account the operator's mental capabilities, health and safety are not compromised, and the efficiency of the work system is improved.

When designing, the following should be considered:
• the operating equipment must be designed so that its use does not overload the operator's intelligence;
• the information required to complete the work assignment must be presented in such a way that the operator can easily perceive it;
• the information for the operator should be presented in such a way that it is easily understood and applied in the work, i.e., it should be given the opportunity to review both the entire operating system and its individual parameters;
• in the interacting systems, similar locations and assignments of conventional images, symbols and commands should be provided.

Indicators and signaling devices must be designed, matched and arranged so that they are consistent with the characteristics of human perception and with the task being performed.

Especially it is necessary to consider the following:
• Indicators and signaling devices must be designed to ensure their clear and unambiguous perception. This applies primarily to emergency indicators and signaling devices.

It should take into account the intensity, duration of the signal, color, shape, magnitude, contrast, as well as excess over optical and sound backgrounds. With an alarm, the effect is amplified if the sound and optical signals act together;
• in order to avoid information redundancy, should be limited the number and types of indicators and signals necessary for the task to a minimum;
• indicators and signaling devices should be designed to provide the operator with clear and unambiguous information, unnecessary information should be avoided;
• indicators and signaling devices should be located so that a reliable, unambiguous and quick orientation in them and their recognition is easy. At the same time, the importance and frequency of individual information elements, as well as the feedback within the work task, should be taken into account. The form and content of this information must be unambiguous and well known to the operator. The form and variability of information must meet the relevant requirements.
Control units and their functions should be designed, selected and arranged so that they correspond to the physiological characteristics of the person (especially his movement capabilities) and parts of his body (hands, fingers, legs or other parts of the body) that participate in the control actions. In this case, it is necessary to take into account the speed and accuracy of efforts, as well as the requirements for their application. The correct design of the control units leads to a reduction of human errors.
When designing, the following should be considered:
• the number of control units should be kept to the minimum required. Control units should be arranged so that the positions necessary for the job were achieved clearly and unambiguously. To achieve this, it is necessary to take into account the sequence of location, importance and frequency of individual movements;
• the type of construction and the location of the control units must correspond to the operating instructions;
• the control units must be designed and arranged to minimize the hazard to health and life of the operator, taking into account the possibility of accidents, frequency of use, etc.;
• the operating stroke and the operational counteraction of the control units should be selected depending on the task assignment and the physiological characteristics of the operator, based on biomechanical and anthropometric data;
• the functions of the control units should be easily distinguishable to avoid confusion with other similar or with neighboring control units;
• the location and movement of control units, their operation and the information associated with them must match each other;
• control units, especially start-up devices, should be selected, designed and arranged to avoid unintended impact on them;

• when the operator switches from one machine to another (similar type and similar functions), the control units should be arranged to avoid confusion and reduce the number of errors;
• the control panel must be designed with respect to form, position and locks so that human errors would be avoided.
The type and method of operating the working equipment, as well as the separation of functions between the operator and the work equipment, are of particular importance for ensuring the interaction between these various elements.
Especially it is necessary to consider the following:
• the working equipment must be located so that the danger to the operator from the adjacent working equipment is avoided.
• methods of transporting the auxiliaries and materials should be designed to minimize the risk of this operation to a minimum.
• the components of the working equipment should be located the way to contribute to the effective performance of the work assignment and health, safety and well-being of the operator. For example, the distance between the parts of the working equipment must be sufficient for the operators pass and movement of materials, and also provide opportunities for monitoring the equipment.
• when placing the indicators on the control units, the operator should receive clear and unambiguous information from the data from the indicators, while the indicator and the control must match each other
•the operating rhythm of the operator's movements should not be associated with the cycles of a semi-automatic or automatic machine or conveyor belt. Independence of the operator's actions can be provided by additional equipment, robot, etc.
• the manual working equipment must be designed to fit the anatomy of the hand in size, weight and shape and allow the operator to perform natural movements when using it.
• it should be possible for the operator to perform operations on the left and right sides.
• since designers know in advance the environmental impact factors when using specific equipment, this should also be taken into account.
The design of the working equipment can be described in the application of system modeling as a methodological process, and such basic tasks as defining the goal, establishing requirements and assessing compliance with ergonomic criteria, are integral parts of this process. At the same time it is necessary to take into account the main constructive and human factors.
The design process can be divided into four stages:
1. Development and specification of technical requirements.

2. Development of a preliminary design project (or projects).
3. Development of a detailed design project.
4. Implementation.

At the stage 1, are developed and refined the relevant system requirements to create a list of functions performed. At the stage 2, the designer develops the sketch documentation sequentially until the moment when it is necessary to determine the concept of further work. At the stage 3, the designer continues to develop the project until the results are obtained, on the basis of which it is possible to create working design documentation. At the stage 4, the designer updates the last details and creates the final design project. The operator must participate in this process as early as possible. This should be taken into account by specialists of organizations, ordering devices for their employees and coordinating the technical project with developers t.

GOST R ISO 6385-2007 "Ergonomics. The application of ergonomic principles in the design of production systems" recommends that when designing production equipment, hardware and software tools, emphasis should be placed on intellectual as well as physical and technical aspects related to equipment. Displays and control units (in general, these are conventional devices or components of video display terminals) are the main components of the interface, which should provide interaction and information exchange between a person and a technical system. It should be designed taking into account many human characteristics:

• the interface should provide the user with adequate information and quick overview for providing detailed information about the parameters;
• those elements of the interface that must be located in accessible area should be designed so that they are easily accessible and controlled, and those that should be in sight should be designed so that they can be easily observed;
• all signals, displays and control units must be operated in such a way as possible to reduce the possibility of personnel errors;
• signals and displays should be selected, designed and placed to be compatible with the characteristics of human perception and the tasks performed;
• control units should be selected, designed and placed in such a way as to be compatible with the available personnel stereotypes, the dynamics of the controlled processes and their spatial implementation in the production system;
• the control means should be selected, designed and placed in such a way as to be compatible with the characteristics of the personnel involved in the control and execution of the assignment. Also requirements for qualification, accuracy, speed and physical strength must be taken into account;
• the control units should be located close enough for the correct control when the operator's impact on these units is simultaneous or is consistent and rapid.

However, they should not be too close because of the risk of an inadvertent incorrect control action.
The main ergonomic requirements, which relate to control systems, are the following:
• control units should be visible and distinguishable;
• the operation of the control unit should cause a control action;
• control units should be located outside hazardous areas;
• the direction of movement and the effort to activate must be consistent with the controlled actions;
• information received from indicators (for example, the sound or light signal when ready for launch) must be unambiguous and understandable, should not be excessive, not to overload the operator;
• the means of warning must be unambiguous and easily perceived, verifiable;
• signs, pictograms understood by the operator should be used to warn about the remaining danger.
According to GOST 60519-1-2005, the movement of arms and levers, if possible, should correspond to the direction of the mechanical movements that they control. Pushbutton switches, indicator lights and displays, as well as devices that disconnect the power supply, must comply with IEC 60204-1. In addition to these requirements can be mentioned the requirements of domestic standards for ergonomics and technical aesthetics, as specified in GOST 20.39.108-85, GOST 12.2.007.0-81, GOST 12.2.049-80, GOST 12.2.064-81, GOST 21829-76, GOST 23000-78 and some others.

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