Computer simulation of the safety of radio electronics production in an emergency situation

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Abstract
The article is devoted to computer modeling in the problems of ensuring the safety of production processes in the organization of radio-electronic and instrument-making industries under the influence of damaging factors of emergency situations. The organization of any production is associated with the establishment of a number of technological processes, both basic and related. Ensuring safety and sustainability are one of the important accompanying processes of radio-electronic and instrument-making industries. At present, these processes are coming to the fore, especially when it becomes relevant to establish production in the conditions of predicted emergencies. Manufactured products-radio-electronic devices must also meet the requirements of thermal, radiation and mechanical resistance. If you do not take into account the risk factors of failure of devices and electronic components, then even a small deviation of the environmental parameters from normal values will lead to a man-made accident. This is especially true for devices operating under conditions of ionizing radiation, large temperature differences, and mechanical influences.

Keywords
Computer modeling, computational experiment, safety, production process, organization of radio-electronic and instrument-making industries, striking factors, emergency situation

1. Introduction

The organization of any production is associated with the establishment of a number of technological processes, both basic and related. Ensuring safety and sustainability are one of the important accompanying processes of radio-electronic and instrument-making industries (REI) at present, these processes come to the fore, especially it becomes relevant when it is necessary to establish production in the conditions of predicted emergencies. Manufactured products-radio-electronic devices must also meet the requirements of thermal, radiation and mechanical resistance. If you do not take into account the risk factors of failure of devices and electronic components, then even a small deviation of the environmental parameters from normal values will lead to a man-made accident. This is especially true for devices operating under conditions of ionizing radiation, large temperature differences, and mechanical influences, such as the equipment of GLONAS satellites in Earth orbit. The radio-electronic and instrument-making industries are tasked with bringing the uptime of GLONAS satellites to 15 years.

Within the framework of the national security concept of the Russian Federation adopted in 2015, there is a problem of developing a system of taking preventive measures to reduce the risk of emergencies and fires on the basis of preventive measures. Federal Target Program "Risk Reduction and Mitigation of the consequences of natural and man-made Emergencies in the Russian Federation

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until 2015" in accordance with the Concept of Long-term Socio-economic Development of the Russian Federation for the period up to 2020, approved by the decree of the Government of the Russian Federation of November 17, 2008. N 1662-p, it is planned to maintain a high level of security of the country, including the safety of the population and territories from natural and man-made emergencies. Such an approach requires the implementation of a complex of interrelated transformations in terms of resources, terms and stages. At the same time, there should be a change of priorities in protecting the population and territories from dangers and threats of various kinds - instead of a culture of responding to emergencies, a culture of prevention should be in the first place.

The solution to this problem is impossible without describing and evaluating the isolated and combined effects of damaging factors (DF) of sources of emergency situations (ES) in man-made accidents (MA) at radiation, fire and explosive objects of REP. It is impossible to imagine such an assessment of the effects of PF without the use of models and computer modeling.

The aim of the work is to build a deterministic analytical model of the impact of DF on the protected object and its computer implementation.

Tasks that need to be completed to achieve this goal:

- development of the initial model;
- construction of the algorithm of the program operation;
- development of the program interface;
- writing code in C++;
- conducting a computational experiment;
- discussion of the results and conclusions.

2. Computer simulation

2.1. Building a mathematical model

With the advent of computers and computer programs that implement algorithms for obtaining, processing, presenting and using information about objects, it became possible to repeatedly and efficiently perform computational experiments, i.e., conduct computer modeling.

The general structure of the application package consists of the parts described in detail [1]:

In the framework of computer modeling, when creating applications, the following requirements were emphasized: scientific, adaptive, conscious learning, independence and activation of activity, visualization and accessibility in the educational process. Currently, the applications are used in practical classes with students in the direction of "Technosphere Security" and in the section of the discipline of the Safety "Protection in emergency situations".

It is known that substances and materials that can be dangerous from the point of view of fire danger are used in the production of REI. These can be highly flammable liquids

We will construct a deterministic analytical mathematical model of the combustion process of highly flammable liquids (HFL) based on the calculation method presented in [2, 3]. As an example, consider the model "Calculation of thermal radiation from a strait fire". A number of works are known in which the processes of ensuring security in emergency situations are modeled [4-9]. The authors conducted research in this area to create mathematical models describing the impact of damaging factors on protected objects. For more information about this, see [10-13].

Let's take a closer look at modeling the thermal radiation of a strait fire.

The initial parameters of the model.

1. Spilled HFL.
2. The area of the strait (m2).
3. The length of the radius to the center of the spill (m).

Calculated parameters of the model.

1. The effective diameter of the strait is d, m (see formula 1).
2. Flame height (see formula 2).

We calculate the effective diameter of the strait d, m, using the formula

$$d = \sqrt{\frac{4S}{\pi}}, \tag{1}$$

where S is the area of the strait, m2.

Calculate the height of the flame H, m, according to the formula

$$H = 42\, d \left(\frac{m_c}{\rho_{W} \sqrt{gd}} \right)^{0,61}, \tag{2}$$

where m_c is the specific mass rate of fuel burn - up, kg/(m · s);

ρ_W is the ambient air density, kg / m3;

g is the acceleration of gravity, equal to

We determine the angular irradiance coefficient Fq by the formula

$$F_q = \sqrt{F_v{}^2 + F_H{}^2}, \tag{3}$$

where,

$$F_v = \frac{1}{\pi}\left[\frac{1}{S_1} \cdot arctg\left(\frac{h}{\sqrt{S_1{}^2 - 1}}\right) + \frac{h}{S_1}\left\{arctg\left(\frac{h}{\sqrt{a^2+b^2}}\right) - \frac{A}{\sqrt{A^2-1}} \cdot arctg\left(\frac{(A+1)(S_1-1)}{(A-1)(S_1+1)}\right)\right\}\right], \tag{4}$$

$$F_v = \frac{1}{\pi}\left[\frac{(B-s_1^{-1})}{\sqrt{B^2-1}} \cdot\ arctg\left(\frac{(B+1)(S_1-1)}{(B-1)(S_1+1)}\right) - \frac{(A-s_1^{-1})}{\sqrt{A^2-1}} \cdot arctg\left(\frac{(A+1)(S_1-1)}{(A-1)(S_1+1)}\right)\right], \tag{5}$$

where, $A = (h_2 + S_l + 1) / 2S_l$, $S_l = 2r/d$ (r is the distance from the geometric center of the strait to the irradiated object)

$$q = E_f \cdot F_q \cdot \mathrm{t} \tag{6}$$

where E_f - medium-largest thermal radiation density of flames, kWh·m^{-2};

Fq - angular irradiation coefficient;

t - the bandwidth factor.

The result of the calculation is the strait fire hazard indicator «Thermal radiation intensity (TRI)". The threshold values of the TRI are known, with which the values of the TRI obtained during the assessment are compared. The next stage of building a model of the destruction of technical objects and personnel of the REI is the construction of an evaluation algorithm that serves as the basis for writing computer code.

2.2. Building the algorithm

In our case, with the damaging factors of emergency sources, we are dealing with a mathematical model of the impact of thermal radiation. This is an analytical deterministic model where there are formulas and there is no uncertainty in the source data. Based on the basic operations of the method for calculating the intensity of thermal radiation, the authors developed a calculation algorithm that serves as the basis for writing the code of the application program. The algorithm is developed using the Flowchart program, which can be used to create visual flowcharts. For this purpose, pseudocode was prepared using the syntax of the C++ language.

2.3. Program interface

The program interface is designed for user interaction with the program. An example of the interface design is shown in Figure 1:.

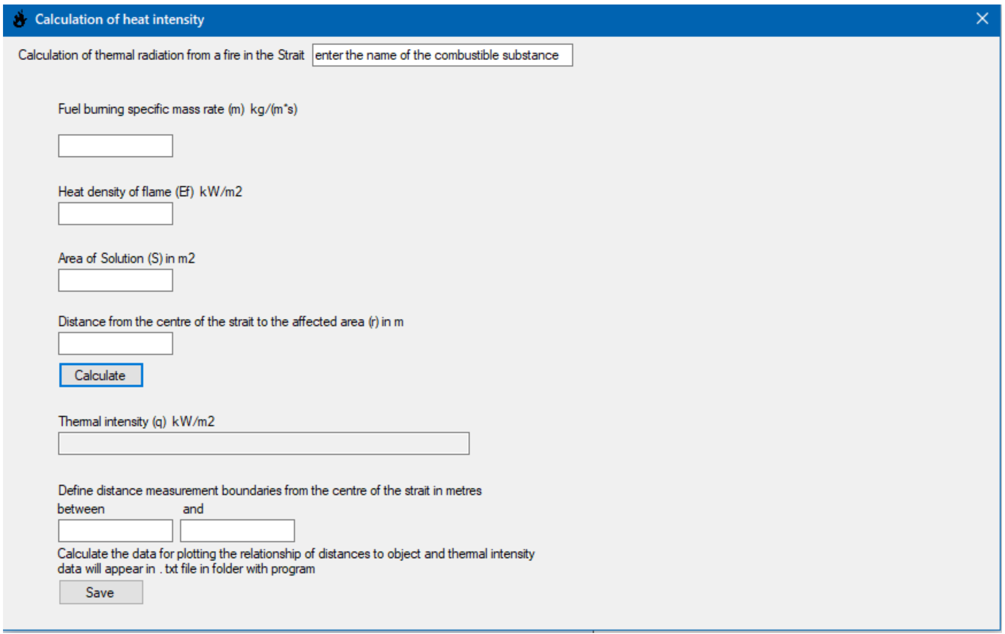

Figure 1: The main view of the window of the computer program «Calculation of the intensity of thermal radiation»

2.4. Computational experiment

Given that it is not possible to conduct a full-scale or even semi-natural experiment, due to its danger and limited resources, we will conduct a computational experiment using computer modeling methods [14-16].

Having built a mathematical model, the calculation algorithm obtained on the basis of the evaluation method and the developed application in the C++ programming language, we will conduct a computational experiment to find the dependence "the intensity of thermal radiation – the distance from the object to the geometric center of the strait".

The aim of the experiment is to find safe distances that can be found by knowing the threshold table values of the intensity of thermal radiation.

3. Results and discussion

The results of the computational experiment are summarized in Table 1. and are presented in Graph.

Table 1
Results of the computational experiment

Head 1	R,m	Q kW/m2
1	12.7	16.345
2	13	14.680
3	14	11.824
4	15	10.020
5	16	8.668
6	17	7.596
7	18	6.717
8	19	5.983
9	20	5.357
10	21	4.824
11	22	4.360
12	23	4.000

Figure 2: shows a graph of the intensity of thermal radiation from the distance to the center of the fire." The graph shows that at a distance of 22 to 23 meters, the intensity of thermal radiation will be from 4 to 4.36 kW / m2. The threshold value when a person already feels discomfort from the action of thermal radiation is 4.2 kW/m2.

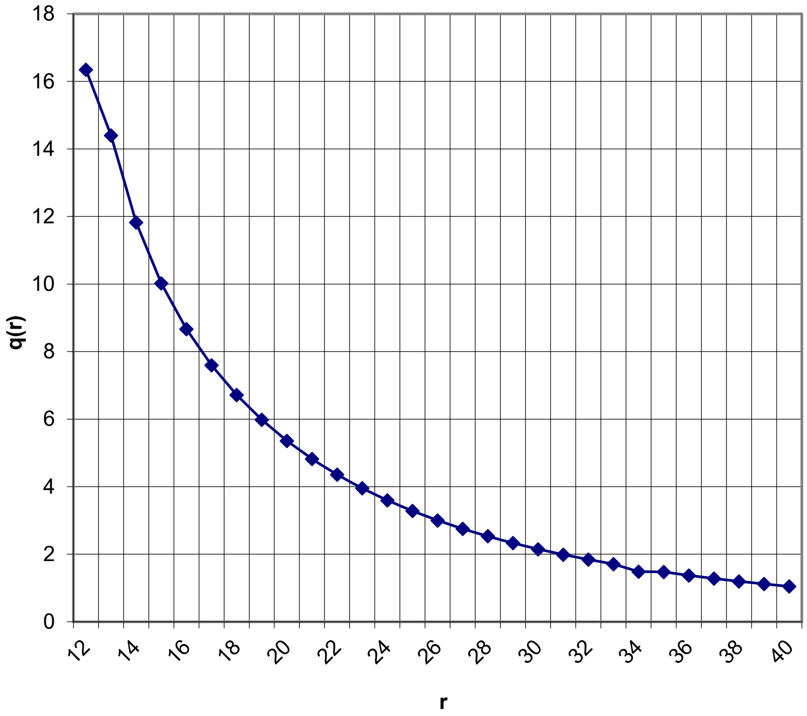

Figure 2: Graph of the intensity of thermal radiation from the distance to the geometric center of the fire source

Thus, with the help of a mathematical model and a built-up graph of dependence, the danger to humans and the fire load of being in the fire zone is clearly visible and it is possible to determine the safe distance, which was 23 m. There is a real opportunity, avoiding routine operations, with the help of a computer application, to predict the parameters of a dangerous phenomenon and to assess the adverse consequences for the person and the equipment of the REI.

Knowing the hazard indicators, you can make management decisions and take actions to organize production in such a way as to minimize damage.

Such actions are called emergency prevention measures. Being in the fire zone, a person has the opportunity to apply methods of protection against emergencies.

4. Conclusion

Thus, in the course of the work, the main results were obtained:

1. A deterministic analytical mathematical model of the process of exposure of the DF to thermal radiation on the object under study is developed.
2. The algorithm of the program is built;
3. Developed the program interface;
4. A computational experiment was conducted, which showed that with the help of the developed computer modeling tools, it is possible to predict the consequences and find the dependence of qi on the distance from the geometric center of the strait fire to the object at risk.
5. Safe distances are determined for the case of a person being in the fire zone. Given that energy sources are concentrated on a small area in the REP production facilities, there is a danger for the personnel of these industries.

The results obtained are a scientific foundation for further research of the possibilities of computer modeling for ensuring the safety of radio-electronic and instrument-making industries under the influence of damaging factors of emergency sources. Based on the results of the study, the authors prepare an application for obtaining a certificate of registration of a computer program, according to a deterministic assessment of the danger of thermal radiation in federal institute of Industrial Property.

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