Computational experiment of the thin-film electroluminescent display devices applicability in aviation

D A Evsevichev¹, O V Maksimova², M K Samokhvalov³

¹ Department of Aeronautical Engineering, Ulyanovsk Civil Aviation Institute, Ulyanovsk, Russia
² Research Department, Ulyanovsk Civil Aviation Institute, Ulyanovsk, Russia
³ Department of Electronic Instrumentation Design and Technology, Ulyanovsk State Technical University, Ulyanovsk, Russia

Corresponding author’s e-mail address: first32007@yandex.ru

Abstract. The development of methods and means of testing the applicability of thin-film electroluminescent indicator devices as displays in aircraft is carried out. Thin-film electroluminescent displays are used in equipment and systems that require high image quality and reliability, as well as a long service life of the devices. The result of the performed work is the ExpAT program, which allows to carry out a computational experiment to test of the applicability of the TFEL indicator devices in aeronautical engineering. As a result of the computational experiment, variants of structures of thin-film emitting structures that meet the operating conditions of indicators in avionics are shown.

1. Introduction

Among modern information display devices, thin-film electroluminescent (TFEL) indicators occupy their own special niche. They are successfully used in medical equipment, control systems for industrial facilities, control and measuring equipment, in transport, in communication systems, and aviation equipment [1, 2]. According to many experts, TFEL displays have a number of advantages over various modern display devices created using other technologies. The main manufacturer of TFEL devices in the world is the company Beneq and, in particular, the division of this company Lumineq, which is responsible for the production of products using TFEL technology and industrial production of products using layer-by-layer atomic deposition technology [3].

The advantages of this kind of displays over other modern indicators is lighting (brightness, light output) and operational (vibration resistance, shock resistance) characteristics, which is relevant for aviation technology [4]. The disadvantage of the device is the need to use high frequency alternating voltage.

In this regard, the question arises of the applicability of indicator devices, which will be powered from a 200 V network with a frequency of 400 Hz, as displays in the TFEL aircraft. The presented work is devoted to the analysis of applicability based on the developed mathematical apparatus.

2. Analysis of the basic ergonomic requirements for display devices

An important element of the cockpit is the information display that ensure the functioning of the man-machine mode. General safety and ergonomics requirements for information display facilities,
harmonized with the international standards ISO 9241-3: 1996, ISO 9241-8: 1997 and described in GOST R 50948-2001 “Information display facilities for individual use. General ergonomic and safety requirements”. Those parameters are the visual parameters of the display (characteristics of display and perception of information), emission parameters of the display (characteristics of electrostatic, alternating electric and magnetic fields generated by the display). Those parameters must be in the optimal range of values for displays. For accurate reading of information and ensuring comfortable conditions for its perception, work with displays should be carried out with such combinations of values of brightness and contrast of the image, external illumination of the screen, angular size of the sign and viewing angle of the screen, which are included in the optimal or maximum permissible (for short-term operation) ranges.

According to the above standards, it is possible to identify the main ergonomic and safety requirements for the means of displaying information from the pilot's workplace (cockpit):

1) the viewing angle should be between 130 ° and 180 °;
2) the brightness of the display is determined by the brightness of the sign and must be at least 35 cd/m² for displays on a cathode ray tube and at least 20 cd/m² for flat screens;
3) uneven brightness of the screen working area and elements of the sign should be no more than 20%;
4) the brightness contrast inside the sign and between the signs must be at least 3:1;
5) the intensity of the electrical component of the alternating electromagnetic field of the display should be no more than: 25 V/m - in the frequency range from 5 Hz to 2 kHz and 2.5 V/m - in the frequency range from 2 to 400 kHz;
6) the magnetic flux density should be no more than: 250 nT - in the frequency range from 5 Hz to 2 kHz and 25 nT - in the frequency range from 2 to 400 kHz.

Most of the parameters presented are provided by various display manufacturing technologies. However, the brightness parameters and characteristics are of particular interest, since they are provided not only by the design and technological features of the manufacture of a particular display, but also by the features of their operation.

The choice of the optimal information display means for the aviation specialist from the point of view of manufacturability, ergonomics and safety implies consideration [1, 2]. These include CRT displays, liquid crystal displays, OLEDs, and TFEL displays. A comparative analysis of the above displays in terms of operational parameters was carried out in [4]. According to it, it can be concluded that, despite the comparative cheapness of CRT displays, their use in modern cockpits is not desirable, since from the point of view of operation, ergonomics and safety, they have a number of disadvantages that increase operator fatigue and, thereby, reduce flight safety. Such as non-uniformity of the image, poor focusing performance, the presence of errors in color registration, the presence of significant indicators of electromagnetic radiation (strength of the electric component of the alternating electromagnetic field, magnetic flux density), low contrast and viewing angle.

Comparing flat-panel displays, we can conclude that TFEL displays are superior in terms of lighting characteristics to liquid-crystal ones, but they are inferior to displays based on organic LEDs, which, however, is compensated by their high design and technological parameters (mean time of failure, operating temperature range, radiation resistance, vibration and shock resistance). This implies the possibility of using TFEL devices not only in general-purpose equipment, but also in the military, medical, space industry, as well as in important from the point of view of flight safety area - at the pilot's workplace, where sometimes stringent requirements are imposed on the equipment. In addition, a feature of these systems is a decrease in weight and size parameters by reducing the number of its constituent components.

Due to the high image quality, TFEL displays are widely used in information display facilities and are ideal for use in difficult conditions when devices based on other technologies do not give the required results [2]. Electroluminescent displays are most commonly used in equipment and systems that require high image quality and reliability, as well as long device life.
3. Software for conducting a computational experiment of the thin-film electroluminescent display devices applicability in aviation

The result of the research work is the developed algorithm for performing a computational experiment [5]. Based on this algorithm the ExpAT program was developed to perform a computational experiment to verify the applicability of TFEL indicators in aviation technology and analyze the obtained results. The ExpAT program interface is shown in Figure 1.

The program is compiled in the Borland Delphi 7 development environment using the imperative, structured, object-oriented programming language Delphi. The software product allows us to carry out an automated computational experiment with the specified parameters, select and record design solutions that meet the conditions of the experiment and the developed mathematical model, as well as analyze the results. The program allows us to graphically display the found design solutions. In this case, if the total thickness of the TFEL indicator is always marked on the abscissa axis, then on the ordinate axis it is possible to determine various display parameters - average brightness, threshold voltage, maximum allowable voltage, average power, or simultaneously all parameters referred to their maximum value.

The developed system is an application software launched from the Windows operating system. The program works directly with the user, establishing the necessary connections for the calculation.

The program window is divided into three areas:

- The area for setting the experimental parameters (on the left in Figure 1), including the choice of layer materials, operating conditions, intervals for calculating phosphor layers.
- The area for displaying the calculation results (top right in Figure 1), which is a table with the following columns: experiment number, phosphor thickness, dielectric thickness, threshold voltage, maximum allowable voltage, average power, average brightness.
- Area for graphical display of the found design solutions (bottom right in Figure 1). In this graph, on the abscissa axis, the total thickness of the TFEL indicator is marked (the thickness of the phosphor...
and two dielectric layers are added. The ordinate axis is determined depending on the buttons pressed. By pressing the button "by brightness" on the ordinate axis the average brightness is displayed, by pressing the button "by threshold voltage" - threshold voltage, by pressing the button "by maximum voltage" - the maximum allowable voltage, by pressing the button "by power" - the average power, by pressing the button "by all parameters." - simultaneously the relative values of all parameters, they refer to their maximum value.

The developed software product made it possible to carry out a computational experiment to verify the applicability of TFEL indicating devices in aviation technology. The result of the experiment is confirmation of the possibility of solving this problem. As the features of the fulfillment of the conditions of applicability, it should also be noted the totality of the following conclusions obtained:
1) the brightness of the TFEL indicators glow increases with increasing of the films thickness;
2) the number of design solutions that satisfy the search conditions decreases with increasing film thickness;
3) the thickness of the TFEL indicator layers cannot exceed 3 microns for the selected operating parameters;
4) the best solutions are achieved with a film thickness of about 1.5 microns.

Based on the above, it can be concluded that the use of TFEL technology for the production of displays in aviation technology is possible, but requires very precise systems for sputtering layers with thicknesses of no more than 2-3 microns, or you should use means of voltage conversion to higher values in amplitude and frequency.

4. Conclusion
As a result of a computational experiment to test the applicability of TFEL indicator devices in aviation technology, variants of the designs of thin-film emitting structures that satisfy the operating conditions of indicators in avionics were shown.

The presented technique and the software product developed on its basis can be used in laboratories and design bureaus engaged in the design and research of electroluminescent radiation sources, as well as in the industrial sector involved in the production of aviation equipment.

It is also important to note that the developed software product is a fairly universal tool for conducting a computational experiment to test the applicability of TFEL indicators in other specialized equipment. For this, it is necessary to enter in the program window the corresponding limiting specific conditions for the operation of the device and analyze the calculated results.

References
[1] C King 2003 Electroluminescent displays 1 33-44
[2] A Abileah, K Harkonen, A Pakkala and G Smid 2008 Transparent Electroluminescent (EL) Displays 6 10
[3] D Evsevichev, O Maksimova and M Samokhvalov 2011 The 11th International Meeting on Information Display (IMID 2011) 2 768-769
[4] D Evsevichev, O Maksimova and M Samokhvalov 2014 The 8th IEEE International Conference on Application of Information and Communication Technologies (AICT2014) 1 164-167
[5] D Evsevichev and M Samokhvalov 2019 Automation of Control Processes 2 (56) 113-120.