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MODERN TECHNOLOGIES IN AERODROME GROUND LIGHTS

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Abstract. *Airdrome lighting system is one of the most important ground navigation aid for the pilot at the visual piloting phase. Aerodrome ground lights create the visual picture for the pilot during the final approach – the most risky phase of flight, thus it is required to have high level of reliability and availability. The application of light emitted diode (LED) technologies in aerodrome lights design moves their reliability to the highest level, comparing with previous technologies of lights sources. Meanwhile, this technology causes some restrictions that have to be taken into considerations. The advantages and flaws of LED-type aerodrome lights for modern airfield lighting systems have been analyzed.*

Key words: *LED lights, airport runway, aerodrome ground lights, reliability of aerodrome lighting system, energy-saving, aviation safety.*

Introduction.

Due to the full-scale war initiated by russia, there is currently a "no-fly zone" over Ukrainian territory, and all Ukrainian aviation providers (airports, airlines, etc.) have ceased their operations. Unfortunately, some airports have been destroyed, while the remaining ones are waiting for the time when civil aviation can return to Ukraine.

The importance of planning for the post-war recovery of Ukrainian aerodromes and airports is growing significantly. This planning should include not only the reconstruction of aerodrome infrastructure but also the restoration of various types of equipment necessary for flight operations.

As it is indicated in ICAO Standards and Recommended Practices [1]: «Human beings are two-dimensional animals. From the moment we first start to crawl, we interpret visual cues and use our sense of balance to travel over the surface of the earth. This long and gradual learning process continues as we later take charge of various types of mechanical transport on land or water, by which time we have years of accumulated experience on which to draw. As soon as we take to the air we have a third dimension to cope with, and this means that all our years of experience in solving two-dimensional problems are no longer sufficient». These statement of international normative documents demonstrate the whole importance of all researches connected with visual piloting phase – what pilot see, how accept and process the visual information, what are the requirements to ground navigation aids to create maximum safety and minimum stress for the pilot at this extremely important phase of flight.

There are two methods to control an aircraft in flight: manually or with an automatic pilot. The pilot can manually control the aircraft by either referencing the instrument panel or using visual cues from the outside environment. One of the most challenging tasks for the pilot is performing the final approach and executing the landing maneuver. During the approach, the pilot must carefully manage speed and continuously make simultaneous adjustments in all three dimensions to maintain the correct glide path to touch the runway in the aiming point. This maneuver requires good visibility or under the low visibility condition the pilot uses the ground navigation lights as the main source of information about the physical dimensions of the runway and approaches to it.

Airdrome lighting system is one of the key component of any instrumental and non-instrumental runway, intended to be used in different weather conditions. It allows to provide the aircraft flights with high level of safety at night, twilight and under adverse weathers conditions. This system is considered as navigation aid for the pilot at the most important phase of flight – visual piloting, which is the part of any flight. The modern system of airport lighting equipment is a complex multi-element system that contains many airfield lights located almost on the entire territory of the airfield. Such a system ensures visual contact of the aircraft crew with ground landmarks during take-off and taxiing, as well as during the transition to visual piloting after the height of the decision to land in adverse meteorological conditions during the day and at night. Ensuring the reliable and trouble-free operation of all airdrome lighting system is possible with reliable and timely information about the real technical state of the electrical parameters of its elements.

Problem statement.

In the past the aerodrome lighting system was considers as the most numerous and most expansive system as far as it had hundred elements, placed in the large square of the aerodrome territory and its vicinity (approach zone). This system was also considered as less reliable because of many elements with comparatively low reliability (mean time between failures (MTBF) is about 1500 – 2000 hours) – the aerodrome lights.

Indeed, the technologies of XX century couldn’t give higher life time of the halogen light sources, that is why the quantity of aerodrome lights was increased to compensate comparative low level of reliability, significantly added to the costs of airfield lighting system. Functional redundancy in the subsystems of the airfield lighting system, aimed at improving the overall reliability of the system, has led to an increase in the number of components. Consequently, this has resulted in higher installation and operational costs and has complicated the maintenance of the system, especially for large aerodromes with several runways.

In accordance with document [1]: «The amount of information that can be absorbed from a comparatively short length of the approach light pattern when viewed at high speed in low visibility is strictly limited. Since only a few seconds of time are available to see and react to visual aids in the lower visibilities, simplicity of pattern, in addition to standardization, is extremely important».

So, evidently, the using of more reliable aerodrome ground lights will bring many benefits to both parties – to the pilots, making the process of visual contact

establishing more simple, fast and reliable thus increasing flight safety level; and to the aerodrome, simplifying the process of aerodrome ground lights maintenance and reducing all the costs (including indicators of the energy consumption) connecting with it design and operation.

The goal of this article is to analyze advantages and flaws of LED technology applied in aerodrome ground navigation lights.

Advantages of LED aerodrome lights.

From the early development of civil and military aviation, it became clear that aircraft flights needed to be conducted not only during the day but also at night. Consequently, the airfield lighting system gained an important place in navigational airfield equipment. It has become one of the most extensive and vital navigational systems at the airfield, requiring substantial effort and financial resources for its maintenance. ICAO requirements, connected with maintenance recommendations [2,3,4] of aerodrome ground lights, criteria of it up state, configuration at the airfield, requirements to their power supply, automation lights monitoring, measuring lighting characteristics and indicators of the energy consumption – all of them are directed to support the high level of availability, as far as flight safety risks are in strong dependence.

Scientific and technological progress, namely using the LED technology in aerodrome lights design, may contribute in both: increasing the reliability and making possible the reducing of costs of aerodrome ground lights due to possibility of using the reducing configuration in some subsystems.

About twenty years of experience of operation of the aerodrome lights has shown that LED light sources have much higher level of reliability comparative with halogen lights. This advantage of LED technology makes the aerodrome lights one of the most reliable elements of the aerodrome equipment, that is the reason of reducing flight safety risks at the visual piloting phase.

The use of LED airfield lights during airfields and airports construction, restoration/modernization requires meeting certification requirements according to the following criteria: lighting characteristics, functionality, climatic requirements, structural (frangibility), electrical and reliability parameters.

Ensuring compliance with the stated requirements for the construction of LED lights in aerodrome lighting systems, and for forming the light signal, will help to avoid wrong decision making during visual piloting stage (especially in time-constrained condition, adverse meteorological situation etc.).

The wide range of functions performed by subsystems of airfield lights leads to the creation of a large number of variants of airfield lights designs, which differ by: the number of light fittings in the assembly, radiation direction, the location of the light emitting source, type of optical element or optical system as a whole and others.

Design features of LED equipment are related to the scattering angles of the luminous flux of the LED light signal. It is the detection and observation of LED light signals at the airfield that directly affects decision-making when establishing visual contact. The lighting characteristics are normalized in accordance with the ICAO requirements [2], (Figure. 1), and provide the necessary orientation during the visual piloting stage. When developing the designs of LED airfield lights, it is

necessary to take into account the asymmetry of spatial radiation. The use of LED modules in the construction of airfield lights has a number of advantages.

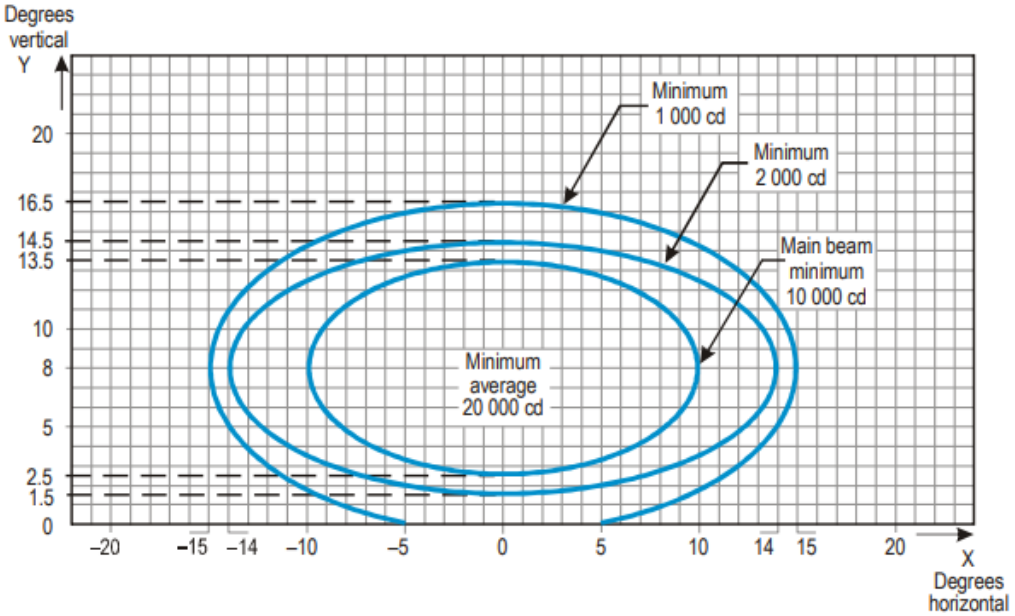

Figure-1. Isocandela diagram for approach center line light and crossbars (white light)

A source: [2].

The most significant advantages of the LED airfield light include (the examples for explanation is in accordance with [5]):

- low energy consumption – use less than 50 W, with a power factor of 0,95, compared to incandescent fixtures that require 150 W or 200 W lamps;
- high level of mechanical performance – IP67 design prevents water, dust and insect entry; low-profile and small in size to withstand heaviest jet blast, even when installed at threshold/runway end; two opposite screws ensure easy and stable leveling; leveling and aiming in azimuth of the light are easily performed with the dedicated aiming device;
- high quality of lighting and color characteristics – use of LED light source eliminates filter replacement and color shifts when viewed at various angles or CCR step settings; rendering index in the range of 80-95) and an optimal directional pattern with the ability to create directional light (fully dimmable lights, respecting the response curve of traditional halogen lights.). It is possible to solve the asymmetry of spatial radiation by means of proper secondary optics, which should be done taken into consideration the light's location (approach, edge, threshold, end lights etc).
- high reliability of LED module – average MTBF of 56000 hours at full-intensity and more than 200000 hours under typical operating conditions, resulting in significant reduction of ongoing maintenance costs and periodic relamping expenses;
- possibility to add more lights in the cable line without increasing CCR size in case of replacement the quartz-incandescent lights by the LED ones;
- the possibility of installation on same mounting device as most elevated

halogen lights, for a straightforward replacement;

- the possibility of using automation systems for lights control and monitoring in compliance with aviation safety requirements (including runways, taxiways and apron lighting).

Flaws of the LED aerodrome lights.

The utilization of LED technology in aerodrome lighting systems, however, has several specific features that must be taken into account. Firstly, such lights have minimal infrared radiation, which impose some restrictions, indicated in international Standard [2., p.10.5]: «Note 2. The energy savings of light emitting diodes are due in large part to the fact that they do not produce the infra-red heat signature of incandescent lamps. Aerodrome operators who have come to expect the melting of ice and snow by this heat signature may wish to evaluate whether or not a modified maintenance schedule is required during such conditions, or evaluate the possible operational value of installing LED fixtures with heating elements. Note 3. Enhanced vision systems (EVS) technology relies on the infra-red heat signature provided by incandescent lighting. Annex 15 protocols provide an appropriate means of notifying aerodrome users of EVS when lighting systems are converted to LED».

So, the pilots can't use the enhanced vision system of the aircraft during the visual approach at low visibility condition if airfield lights are LED type, which is evidently the flaw of this technology comparative with the previous ones (which have infrared radiation).

As well as, the maintenance strategy of LED lights have to be revised for the aerodromes with cold seasons (with snow and frost). It should be considered that without thermal radiation, procedures of removing frost from the lights need to be conducted more frequently, otherwise the situation is possible that the pilot can't see the operating up-state lights due to snow or frost layer over the light fixture.

Both of these aforementioned issues can be addressed by implementing a heating system, but this significantly increases energy consumption and probably reduces the reliability measures.

Secondly, during the modernization/reconstruction of an aerodrome's lighting system, possible difficulties should be considered when replacing conventional lights with LED ones, when using the old power supply system. This approach may be cheaper, but in such cases, each light would require an individual power supply system, significantly reducing the reliability of LED lights and potentially causing malfunctions. Therefore, when equipping an aerodrome with LED lights, it is better to do so in conjunction with a power supply and control system specifically designed for these lights from the outset. Overall, global experience in operating aerodrome lights based on LED technology indicates that it is modern and promising for use in aerodrome lighting systems.

Summary and conclusions.

Most of Ukrainian airports will require the renovation or even full restoration after the finish of full scale war, namely airport infrastructure, runway and aerodrome navigation equipment, including elements of airfield lighting system and its power supply structure.

Modern airfield lighting systems require the implementation of new

technologies in elements of aerodrome equipment, especially the ones that have influence to flight safety. The main requirements of international standards as well as advantages and peculiarities of LED aerodrome lights have been considered in details.

The overall conclusion about perspectives of using the LED aerodrome lights is absolutely positive – they meet all requirements, may easily replace the previous lights, operate with antecedent power supply system, have extremely high level of reliability. The application of LED lights will help to reduce the amount of electricity consumption, increase operational, technical and economical characteristics.

Meanwhile the minor flaws of LED light have to be taken into account – revision of maintenance strategy and proper informing of airlines, whose aircrafts use EVS.

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