Spectral characteristics of the treated surfaces in the operating mode with complex waveform current

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Abstract. An efficiency indicator of installations with infrared emitters is the power factor, which depends on the electrical mode. The object of the research is frosted glass surfaces. These surfaces are affected by electromagnetic radiation from infrared emitters of different types. The subject of the research is the operation modes of installations with infrared emitters, powered by complex waveform current. The purpose is researching the spectral characteristics of the glass surfaces under the influence of changes in the amplitude and frequency of the supply voltage. The obtained data has been used to select the effective modes of installations with infrared emitters. The conducted research has shown increasing the intensity of the transmission spectrum for both considered surfaces in the mode with complex waveform current supply.

1. Introduction
Installations with infrared emitters are used in industry (heat treatment, painting cars, drying different product), agriculture (seed disinfection, insect control), the food industry etc. [1-4].

We need to know the ratio of the values of different systems (light, photosynthesis, vital, bactericidal) to quantify the processes of radiation energy conversion. In this research, we have used the values of the power factor of the installation and the emitters to evaluate the efficiency of infrared heating installations [1-4].

The radiation intensity increases, when a high-frequency alternating current flows through the radiating element, due to the force effect of the electromagnetic field on the charged particles (electrons and ions) of the material. Heinz Maeccker established the influence of current frequency on the gas discharge radiation [5]. O. A. Popov and S. A. Svitnev proved increasing the efficiency of ultraviolet radiation sources, operating on the phenomenon of induction discharge, in bulbs with argon and mercury. Increasing the efficiency of non-ferритic induction UV lamps by power, the diameter of the bulb, the argon pressure and the operating frequency were established in works [6, 7]. Work [8] proved the influence of wave processes of various kinds on the behavior of charged particles, because the main parameter of the wave process is the frequency. In work [9], the processes in electrodeless high-frequency radiation sources were researched. The main elements of sulfur lamps are a high-frequency power generator, a discharge bulb with plasma, a matching device (inductor, resonator). It was proved that the radiation spectrum shifts from 320-650 nm to 430-800 nm, when the rotation
speed of the bulb and the excitation frequency of the induction discharge changed.

In [10, 11, 12], the authors have researched physical models of installations with optical emitters operating in the range of infrared, visible, and ultraviolet waves. In [12], the possibility of controlling the harmonic composition of emitters was shown.

Substances are converted to the atomic state to research their absorption spectra. Spectrophotometric methods are also used for researching the absorption spectra of thin films, obtained, for example, by vacuum thermal sputtering with direct vapor condensation of the applied material. However, there is no information in the literature on methods for researching the absorption capacity of processed products, depending on the electrical modes of operation of installations with infrared emitters [13, 14].

2. The purpose of the paper
The purpose of the paper is researching the spectral characteristics of the glass surfaces under the influence of changes in the amplitude and frequency of the supply voltage.

The following tasks have been solved:
- developing a methodology for research on physical models of installations with white and red emitters under different electrical conditions;
- determining the operating modes efficiency of the emitters based on the research results of energy indicators and radiation spectra;
- developing a research methodology of the optical characteristics of processed products using physical models of installations with white and red emitters under different electrical conditions.

The assessment of the energy efficiency of the installations is based on the value of the power factor of the installation and the individual values of the power factor of the radiator.

3. Experiments
The research has been conducted for two electrical modes: the normal mode with 50 Hz current supply and the new mode with complex waveform current (CWC) supply without a constant component. In the normal mode, the load was powered by a single-phase 220/110V transformer with no-load tap changer (A-X1, A-X3). In the new mode, the power supply was implemented through a single-phase transformer and a choke operated in saturation mode and used to regulate the shape (the harmonic composition) of the supply voltage (current). The choke allows us to change the current spectrum (voltage) with the content of even and odd harmonic components with frequencies of 102 - 103 Hz [12].

The experiments have been performed on physical models of installations with white and red emitters (R127 flask, E27 base, power – 250 W, flask diameter – 130 mm and flask height – 195 mm):
1. IKZ 220-250 R127 E27;
2. IKZK 220-250 R127 E27.

As the processed products (surfaces), we selected transparent products, which allow us to quantify the energy parameters (radiation, colorimetric) during the propagation of an electromagnetic wave from the emitter based on the spectral characteristics:
1. product type 1 - flat surface – 250*250 mm (matte) TU 5921-002-96646333-2007;
2. product type 2 - flat surface – 250*250 mm (matte) TU 5921-002-09438560-2014.

In the research work, we used an AvaSpec-ULS 2048-USB2 fiber-optic spectrometer with software and an ANALYST 2060 - electrical energy quality analyzer for measuring electrical parameters.

The functional diagram of the laboratory installation for conducting experiments in the normal (50 Hz current) and new modes (with CWC) is shown in Figure 1. In the normal mode, the saturation choke was excluded from the circuit.
The first part of the experiments was made to research the transmission spectra of the processed products (flat matte surfaces) of type 1 and 2 under different electrical operating modes of the installation with mirror infrared emitters. When the white reflective emitter affected to the treated surfaces, the transmission intensity in the normal mode was 50 000 a.u. for surface 1 and 45 000 a.u. for surface 2. In the new mode, the transmission intensity has not changed. At the same time, the power factor of the installation in the normal and new mode was 0.72 and 0.95. The individual power factor of the emitter in these modes was equal to 0.986. Frequency adjustment has also changed the intensity of the reflection spectrum. It has varied from 4 000 to 6 000 a.u.

In the second part of the experiments, we have researched the transmission spectra of processed products (flat matte surfaces) of types 1 and 2, the frequency spectrum of the supply voltage was adjusting.

Figures 2 and 3 show the radiation spectra of installations with white and red reflective emitters and the spectra of the treated surfaces of type 1 and 2. In Figure 2, at a wavelength of 700 nm, the radiation intensity of the white emitter is 62 000 a.u., and for the treated surfaces of types 1 and 2 – 42 000 and 38 000 a. u. These indicators were the same for the normal and new operating modes of the installation. When we were adjusting the frequency spectrum and voltage, the intensity at a wavelength of 700 nm for surface type 1 increased to 56 000 and 60 000 a.u. and for the surface type 2 – to 49 000 and 54 000 a.u. (figure 3).

Figure 4 shows the radiation intensity at the wavelength of 720 nm of the red emitter is 56 000 a.u., and for the treated surface of type 2 - 34 000 a.u. Figure 5 shows that, when we were adjusting the frequency spectrum of the supply voltage, the radiation intensity of the red emitter at a wavelength of 720 nm increased to 62 000 a.u, the treated surfaces of type 1 – 44 000 a.u. and the surfaces of type 2
Figure 3. Transmission spectra of the treated surfaces, when the frequency spectrum of the supply voltage is adjusted and the installation (white reflective emitter) is powered by CWC: 1, 2 - transmission spectra of the treated surface of type 1; 3, 4 - transmission spectra of the treated surface of type 2.

Figure 4. The radiation spectrum of the red reflective infrared emitter (250 W) and the transmission spectrum of surface 2 (flat matte surface), when the installation is powered by CWC: 1 – the radiation spectrum of the emitter; 2 – the transmission spectrum of surface 2.

Figure 5. The radiation spectrum of the red reflective infrared emitter (250 W) and the transmission spectra of the treated surfaces of types 1 and 2, when the installation is powered by CWC: 1 – the radiation spectrum of the red emitter; 2 – the transmission spectrum of the treated surface of type 1; 3 - the transmission spectrum of the treated surface of type 2.
4. Conclusion
Experiments have shown that using CWC allows us to get positive effects in installations with infrared emitters with different types of the treated surfaces. To do this, it is advisable to adjust the frequency and amplitude of the supply voltage. When the installation is operating at a lower stage of the transformer's NLTC (OLTC), the power factor increases with a decrease in the inductance of the windings; the radiation spectrum of the emitters and the spectral characteristics of the treated surfaces change. Individual performance indicators of installations with infrared emitters do not deteriorate when using CWC.

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