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# EXPERIMENTAL STUDY OF A HEATING UNIT WITH AN IR EMITTER

S. A. Tanaeva and I. P. Vasilenko

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*Processes of IR heating are studied with application to the development of ecologically pure sterilizers.*

IR heating characterized by high purity, accuracy, and efficiency is more often used for thermal treatment of materials and products [1]. In the present paper radiative heat transfer is studied experimentally as applied to the development of ecologically pure and energy saving sterilizers. In contrast to the available methods of sterilization by vapor and electric heating that require a long pre-starting period for the maintenance of the operation conditions, the proposed unit, due to the small time lag of halogen incandescent lamps, is switched on only for the period of a technological cycle. This sharply reduces electric energy consumption, especially under the conditions of underloading or temporary stoppage of a conveyor.

A sterilizer is a battery of radiative heaters placed above the moving conveyor belt. The unit consists of several sections or modules with emitters – halogen incandescent lamps. Series halogen lamps have certain dimensions and operation parameters that determine the dimensions of the modules.

The aim of thermal treatment is to heat metallic or glass containers, before finished product packing, to a certain temperature, with the heating time limited and stipulated by the velocity of the conveyor belt motion. On this basis the dependence of temperature on time, i.e., the heating rate, is the main parameter.

A sterilizer based on radiative heating is characterized by a complex system of radiative heat transfer including the following elements: an IR emitter – a spiral of a halogen lamp, effective reflectors, selectively adsorbing walls of a lamp shell, and a heated object of complex shape. From a mathematical viewpoint, the problem of the choice of lamp power and of rational arrangement of the system of reflectors, and the optimization of the position of emitters is an inverse problem of radiative-convective heat transfer. Its calculation necessitates knowledge of the initial radiation characteristics of the entire heat transfer surface as well as of the temperatures and fluxes of the resultant radiation on each surface. Due to the uncertainty of a number of the parameters and the complexity of solution for a chamber with a heated object of complex shape, main attention was paid to the experimental study. The study was conducted on a pilot unit where variation of the conveyor belt motion velocity was simulated by variation of the time of holding of the heated object in the working zone of the sterilizer. This differs somewhat from the real picture of heat transfer but still makes it possible to estimate heating rates and optimize the design.

For a preliminary estimate of the parameters, the minimum power necessary to provide the assigned level of temperature was calculated, and a series of curves on the kinetics of heating flat plates made of materials used for the production of packing containers was obtained experimentally at various radiation densities of an incandescent body. Analysis of the experimental data enabled us to roughly choose the versions of the arrangement and the quantity and rated values of halogen lamps, and to develop a module scheme shown in Fig. 1. The tubular halogen incandescent lamps are placed on the upper and side walls of the heating section so that their axes are parallel to the motion of the conveyor belt. The spectral intensity of module radiation is determined mainly by spiral radiation and depends on the power supplied to it [2]. Electric power was supplied to each lamp by a separate regulated source, thus making it possible to more easily control heating when choosing the modes of thermal treatment. In the experiments a time picture of temperature distribution over the surface of the studied objects with

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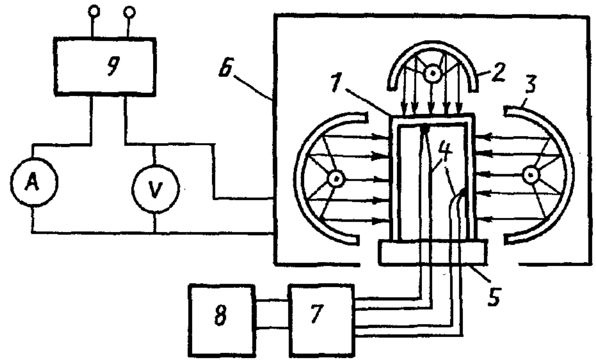
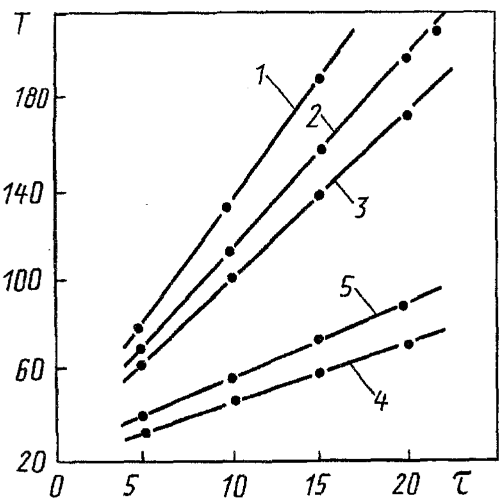



Fig. 1. Schematic of the experimental module of a sterilizer: 1, heated object; 2, halogen lamps; 3, reflector; 4, thermocouple; 5, element of a conveyor belt; 6, sterilizer body; 7, commutator; 8, temperature recorder; 9, stabilizer.



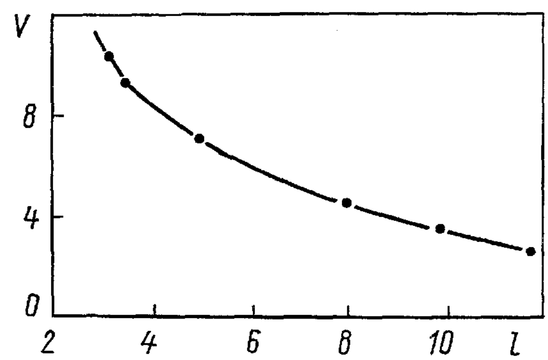




Fig. 2. Curves of radiative heating of a container surface element. Distance from the source to the surface: 1) 2.5 cm; 2) 3.5; 3) 5; 4) 12; 5) 12 cm (side lamps are switched on). $T$, °C; $\tau$, sec.

Fig. 3. Dependence of surface heating rate on the distance to the radiation source. $V$, deg/sec; $l$, cm.

different design modifications of the heating chamber was registered. The reflectivity of the studied glasses within the range of wavelengths from 0.5 to 9 $\mu$m is small and does not exceed 5-7 %. Spectral absorptivity greatly depends on the wavelength, layer thickness, and temperature and smoothly passes from nearly complete transparency, when $\lambda < 3$ $\mu$m, to opacity, when $\lambda > 4.2$ $\mu$m.

To more completely use radiation, its multiple transition through the heated body was controlled by reflectors. The effect of flat and cylindrical reflectors that are simplest and most convenient for manufacture on the temperature field and heating rate was studied. Analysis of experimental data leads to the conclusion that in this case it is preferable to use cylindrical reflectors with an incandescent body placed in the reflector focus.

The operation of the sterilizer is demonstrated on heating glass packing containers with a volume 0.25 liter. Figure 2 presents the dependences of the container surface temperature on the time of holding in the working zone at different distances from the lamp spiral. Curves 1-4 correspond to the bottom temperature under the condition of radiation only by the upper lamp with a flux density of 125 W from the spiral length unit; curve 5 is obtained with the upper (125 W/cm) and side (37 W/cm) lamps switched on. The rates of surface heating are calculated by curves 1-4. The results of the calculation of the flux density 125 W/cm are given in Fig. 3 in the form of the dependence of the rate of surface heating on the distance from the heating element. The obtained data were used to design the working chamber of the sterilizer. Figure 3 shows that the distance of the heated element from the lamp spiral substantially affects the rate of temperature growth.

Since the heated object is usually three-dimensional, but not flat, and it is not possible to perform heating from below due to the design features of the conveyor belt, there arise additional difficulties in controlling the temperature distribution over the height of the working zone. Analysis of experimental data indicates that it is more expedient that the packing containers be placed on the conveyor upside-down or on the side and that, once they have passed the sterilization unit, they be automatically turned to the position preparatory to loading. This is energetically more profitable because it considerably reduces the time of object holding in the sterilizer and diminishes undesirable temperature drops over the surface. Different versions of the arrangement of emitters, reflectors and the heated object were studied. In this case the temperatures of different surface elements, i.e., of the side wall (minimum and maximum temperatures), bottom, and throat, were registered. The voltage supplied to the halogen lamps was controlled so that the heating rates of different surfaces differ as little as possible.

Similar IR radiation is used to sterilize medical instrument. For this purpose a closed chamber is used, on the walls of which halogen incandescent lamps were positioned. The instrument is placed in a quartz container on a grid in the center of the chamber, temperature is assigned and maintained automatically. The time of sterilization depends on the type of instruments and is 10-60 min. Analyses performed in a bacteriological laboratory showed complete sterility of medical instrument.

Thus, the conducted studies indicate that infrared radiation may be successfully used in sterilizers of different types.

## REFERENCES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