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New method of sterilization and disinfection of objects infected with COVID 19 and prototype test

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Abstract. This paper addresses an issue of utmost importance at present, namely the sterilization/disinfection of objects infected with SARS CoV 2 virus (COVID 19), using an original technical solution. First, general data on COVID 19 virus are presented. The main regulations and technical solutions for sterilization and disinfection are then presented in order to highlight as much as possible the importance of the problem addressed and the degree of innovation of the proposed solution. Next, the proposed technical solution for sterilization and disinfection with the use of infrared radiant panels is presented, a better solution compared to the currently known solutions. The principle concept is presented, then the technical prototype made and the results of experiments performed to establish the characteristics of operation and use of the equipment obtained. The equipment is made using high - performance components and has the possibility of programming according to several operating situations, being equipped with an electronic control unit. The possibilities of completion in several types and dimensions are shown, for several types of objects subjected to sterilization and disinfection.

Keywords: SARS CoV 2, sterilization, disinfection, radiant panel, prototype.

1. Introduction

Viruses and other pathogens of this type pose a real danger to human health. SARS CoV 2 virus (COVID 19) is noted for its increased aggressiveness and rapid transmissibility [1,2,3,4]. Among the necessary measures to reduce the negative consequences of the action of this virus in particular are the sterilization and disinfection of objects that the virus can land on and in contact with which people can become infected. Sterilization is necessary for most components that

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can be used as protection against the virus such as: masks, goggles, visors, gloves, gowns, etc. Sterilization is required on the manufacturing flow of these components after which they are packed in sterile protective foils (specific packaging) until use. Disinfection is required after a period of use of non-disposable protective equipment. Both for sterilization and disinfection, various methods that depend primarily on the characteristics of the virus and the factors that lead to its destruction and second, on the characteristics of the materials the protection components are made of that are to be sterilized, respectively, disinfected without losing their original characteristics. This paper analyzes the solutions that can be used to sterilize and disinfect protective components against COVID 19 and describes an innovative method for these activities using radiant panels, specifying the appropriate details.

2. Characteristics of the COVID 19 virus

COVID-19 is a ribovirus (RNA genome virus) that belongs to the *CORONAVIRIDAE* family . Its name comes from the particular appearance of infectious viral particles (called virions), which have prominent glycoprotein spikes (S) on the shell, which form a *crown* (Fig.1). Corona virions are spherical, relatively large (120-160 nm in diameter) and have the largest genome of all RNA genome viruses. The genome is represented by a single unsegmented RNA molecule (as opposed to that of influenza viruses A, B, C, which is segmented), associated with the N protein. The 2 components form the nucleocapsid, which has *helical symmetry*. The nucleocapsid is covered with a shell (peplos), which originates in the intracellular membranes (endoplasmic reticulum, Golgi apparatus) [5] .

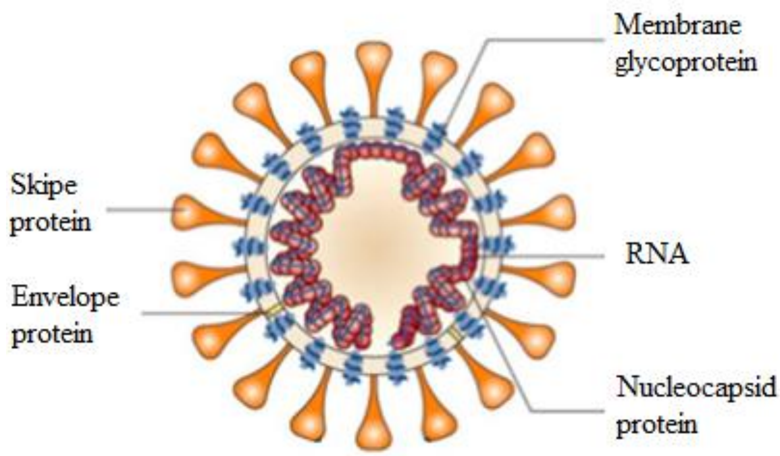


Fig. 1. The structure of COVID 19 virus.

The corona virion consists of a nucleocapsid composed of RNA and N protein, covered by the peplos in which the viral glycoproteins are embedded. On the surface of the virion, E2 (S) glycoproteins protrude in the form of spikes, which give the virions the characteristic appearance of a crown. Another peplos protein is E1 (= M-transmembrane), a minor component of peplos [6].
To identify the most effective solutions for destroying the virus, it should be noted that this virus is not a living organism, but a protein molecule (DNA) covered by a protective layer of lipids (fats), which, when absorbed by the cells of the ocular, nasal or buccal mucosa, changes its genetic code, (mutation) and turns into aggressor and multiplier cells, and causes the disease condition. Because the virus is not a living organism, but a protein molecule, it is not killed, but decomposes on its own. The disintegration time depends on the temperature, humidity and the type of material on which it is located. The virus is very fragile; the only thing that protects it is a thin layer of fat. The heat melts the fat; this is why water above 25 degrees Celsius, or generally a temperature above this value, should be used. On the other hand, this is the reason why any solution that dissolves the fat layer, results in the protein molecule dispersing and decomposing itself. While glued to a porous surface, the virus is very inert and disintegrates in just 3 hours (fabric and porous surface), 4 hours (copper, because it is a natural antiseptic; and wood, because it removes all moisture and does not let it come off and disintegrate), 24 hours (cardboard), 42 hours (metal) and 72 hours (plastic) [7]. As a result, the most appropriate solutions for destroying the virus are those that dissolve fat substances, solutions based on chemicals, radiation and temperate, which will be further detailed.

3. Sterilization and disinfection solutions

3.1. Sterilization solutions

Sterilization occurs on the manufacturing flow of the protective components before wrapping in the specific packaging (sterile protective foil). Sterilization must obviously aim at destroying any contamination. Sterilization is the operation through which microorganisms, including those in a vegetative state, are eliminated or killed from contaminated inert objects, the result of this operation being the sterility condition (according to EN 556 = the condition of a product free of viable microorganisms). There is a theoretical probability of the existence of microorganisms of ≤ 10 ^ (- 6) according to EN ISO 9001 and 9002, as well as EN 46001 and 46002, "sterilization is part of the category of special procedures, the results of which cannot be fully verified by final control of the product, carried out a posteriori, must be subject to validation, supervision of good functioning, as well as ensuring proper storage of sterilized materials. Both the permanent control of the operations and the permanent observance of the established procedures are necessary, in order to ensure the compliance with the specified requirements". There are several sterilization solutions as follows. Sterilization can be performed by: physical methods - steam under pressure (or steam at high / low temperature and pressure), dry heat, chemical methods - ethylene oxide, chemical "sterilizers": formaldehyde and steam at low temperatures and subatmospheric pressure. The hot air sterilizer sterilizes the glassware and instruments that do not support pressure steam sterilization (stainless steel: chromed). The hot air sterilizer is totally contraindicated for textiles, liquids and rubber. The complete sterilization cycle for the hot air sterilizer includes the following phases: - the heating phase of the appliance: the time interval between starting the appliance and starting the temperature rise; duration - depending on the device.- latency phase (homogenization): the time interval in which the propagation and increase of the temperature takes place in order to reach the sterilization temperature in the metal boxes / packages in the baskets; duration depending on the appliance, the nature and quantity of the material to be sterilized.- sterilization phase: the duration depends on the temperature- 180° C, 1 hour or- 160° C, 2 hours- cooling phase: duration depending on the appliance, nature and quantity of the material to be sterilized. A complete sterilization cycle lasts between 4-5 hours. The principle of pressure steam sterilization as performed in the autoclave is to expose each item directly to contact with steam at the specified temperature and time. The ideal steam for sterilization is 100% saturated dry steam (no condensation). The complete sterilization cycle for the pressure steam sterilizer includes the following phases: a) Pre-treatment and preheating phase (pre-vacuuming): the pre-treatment consists of several steam intake and exhaust sequences, performed by a number of pressure variations - purges - (+ 0.8 - + 1 atm./- 0.8 - - 1 atm.) and aims to remove the air from the material to be sterilized at the same time as its necessary wetting before the sterilization phase. In the case of autoclaving aqueous solutions in open containers, the air is removed by a steam stream. b) Sterilization phase: the sterilization time is measured from the moment the sterilization temperature inside the load is reached. Depending on the temperature, the pressure chosen, the sterilization time lasts a number of minutes. c) Post-treatment phase (post-vacuuming): It is intended for normalization in terms of temperature and humidity of the material to be sterilized. All types of sterilizing material, except liquids, are exposed to a vacuum lower than -0.7 bar for a certain period of time. After the post-vacuuming phase, the textiles can have a weight gain of about 1%, which represents a normal humidity during the sterilization process for high pressure saturated steam sterilizers, with pre and post-vacuuming.

As far as the use of dry heat is concerned, the authors propose for sterilization, but also for disinfection, a thermal solution with the use of radiant panels, a solution that will be constructively and functionally detailed in paragraph 4.

3.2. Disinfection solutions

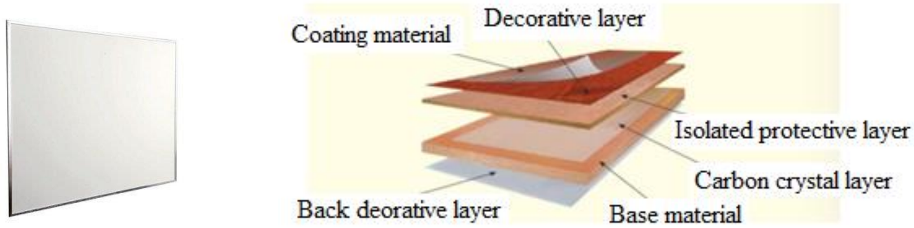
Disinfection is the procedure through which most or all pathogenic microorganisms (99.99%) are destroyed with the exception of bacterial spores, on objects in the inert environment [8]. Disinfection may be carried out through dry heat (buckling and incinerating), wet heat (pasteurization and washing, boiling), with ultraviolet rays and chemical substance means. Buckling is used in the laboratory; buckling of medical-surgical instruments in alcohol containers is prohibited - being ineffective! Incineration is used for contaminated, worthless objects and for potentially contaminating waste, septic, from operating rooms and treatment rooms. Pasteurization: is a method of disinfection of liquids, at temperatures between 55-95° C. After exposure, of varying duration depending on germ resistance, 90-95% of pathogenic microorganisms are destroyed. Disinfection by washing at a temperature of 60-95° C (thermal disinfection) is a complex process to which, in addition to the action of moist heat, is added the action of detergents or other substances, as well as the mechanical action of washing. This procedure is used to wash and disinfect linen, dishes, laboratory glassware, instruments. Boiling in water at a temperature of 100° C or using steam at 100° C destroys in 10-20 minutes the vegetative forms of pathogenic microorganisms, as well as sporulated forms less resistant to high temperatures. **Disinfection with UV is indicated for** the disinfection of flat surfaces and the air in the laboratory storerooms, operating rooms and other enclosed spaces to complete the chemical cleaning and disinfection measures. Recommended: use only lamps for disinfection; lamps for disinfection may be fixed or movable, with UV tubes between 15 and 30 W, intended to operate in the absence of man (with direct radiation) or in the presence of man (with indirect radiation, shielded and without ozone emission). Ultraviolet light tubes must be selectively permeable to radiation with maximum bactericidal power (2537 Angstrom radiation), have a minimum service life of 7500 hours and an appropriate bactericidal power (between 8 and 13.5 W for the 30 W tube). The ultraviolet tube must be perfectly clean before use. The area in which the disinfection is carried out with ultraviolet radiation must be subjected to a thorough cleaning: of all surfaces, and the ambient temperature must be between 15 and 30° C and the humidity of maximum 60%. Direct exposure of persons to UV radiation lamps is not permitted; if the operator of the device is exposed to direct radiation, he will wear protective equipment (goggles, a mask that completely covers the head - with a slit for the eyes - and rubber gloves). Chemical disinfection means the use of chemical disinfectants. In the case of high-level disinfection, the required contact time of the chemical with the treated substrate must be at least 20 minutes. It is mandatory to follow the manufacturer's recommendations. The chemicals and the means by which high level disinfection can be achieved are: - Glutaraldehyde (2%) - Stabilized hydrogen peroxide (6%) - Peracetic acid (different concentrations) - Sodium hypochlorite (5.25%). In the case of medium-level disinfection, the required contact time of the chemical with the treated substrate is 10 minutes. The chemicals that perform the medium level of disinfection are: - Phenols - Iodophors - Alcohols - Chlorine compounds. It can be made with products labeled by the manufacturer and approved as disinfectants (containing other classes of chemicals or combinations thereof) at the concentration of use that destroys Mycobacterium tuberculosis, bacteria in vegetative form, most viruses and fungi. In the case of low-level disinfection, most bacteria in the vegetative form can be destroyed, some viruses, some fungi, but resistant microorganisms, such as Mycobacterium tuberculosis, or bacterial spores are not destroyed. The required contact time of the chemical with the treated substrate is

less than 10 minutes. The chemicals that perform low-level disinfection are: - Disinfectants containing phenols, iodophors, quaternary ammonium substances and foaming agents, - Alcohols (70 ° C, 90 ° C), - Sodium hypochlorite (5.25%).
It is also mentioned that staff performing sterilization and disinfection operations must wear protective equipment: gowns, gloves, aprons, rubber, goggles, etc.

4. Thermal sterilization and disinfection solution with radiant panels

4.1. Principle of operation and technical characteristics of radiant panels

Radiant panels or thermal plasmas run on electricity and emit infrared radiation, radiation invisible to the human eye, and which heats objects, in our case the objects of protection, within their range, without heating the air in their area. Infrared radiation is invisible electromagnetic radiation, penetrating, with strong thermal effect, located in the spectrum between the visible red light range limit and radioelectric microwaves. Infrared rays are not harmful and this is confirmed by the sanitary-epidemiological conclusions. Infrared radiation is not dangerous. The efficiency of the radiant panels is declared almost 100%, which means that at 1 kW of electricity consumed, 1kW of heat will be obtained in exchange. Radiant panels are commercially available but can also be made in different sizes, depending on the dimension and power requirements. In addition, radiant panels have a long service life and are environmentally friendly. Heating in the case of radiant panels is carried out by radiation compared to convection heating, in which case a jet of air is guided over a heated resistance where it takes over the heat it distributes to the environment. The infrared radiation sources used in thermal disinfection equipment are heaters that transform electricity into two components: *radiant heat* 90% and *convective heat* 10%. The front of the source can reach a temperature of approx. 130 degrees Celsius, harmless to touch for short periods. Infrared radiation does not irradiate (maximum gain), as opposed to other methods of heating that are very radiant. Radiant panels can be equipped with adjustable thermostat and a timer enabling efficient temperature control provided with remote control and operating indicator light (LED), overheat protection and digital display allowing access, adjust, quick view of the most important operating parameters of the radiant panel. An example of a radiant panel is given in Fig.2 a. In Fig.2b, the main components of a radiant panel are noted which are: base material, carbon crystal layer, insulated protective layer, decorative layer (optional), coating material and back decorative layer (optional) [9].

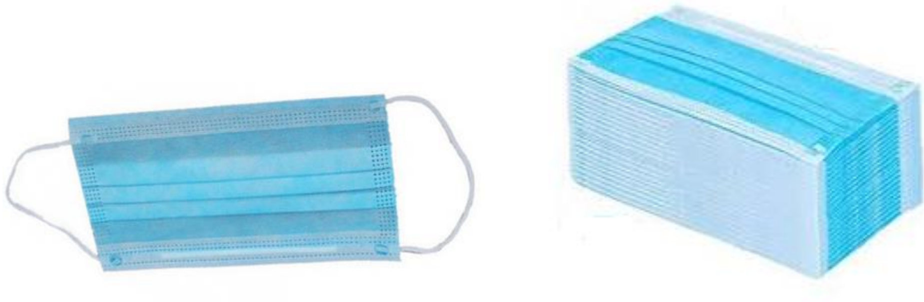


a b

Fig. 2. Radiant panel : (a) general shape; (b) internal structure[9].

4.2. Sterilization and disinfection equipment with radiant panels

As already mentioned, this paper presents a method and the appropriate equipment for sterilization, respectively, disinfection of protective surgical masks (Fig. 3a), with the possibility of extending to other types of objects such as : visors, protective gloves, goggles, gowns and even coveralls, but also disinfection of protective equipment worn by specialized personnel, with appropriate adaptations. Back to the topic, the concrete problem considered is the sterilization of surgical masks of the type specified at the end of their manufacturing process. According to the manufacturer's requirements, a considerable number of masks, hundreds, must be sterilized at the same time in order to correspond to the manufacturing pace. The masks are handled in packages, like the one in Fig.3b.



a b

Fig. 3. Layer surgical mask: (a)individual; (b) in a pack of 50 pieces.

4.2.1. Main components

In order to finalize the project of the sterilization / disinfection equipment considered, we started from a variant of principle represented in Fig. 4.

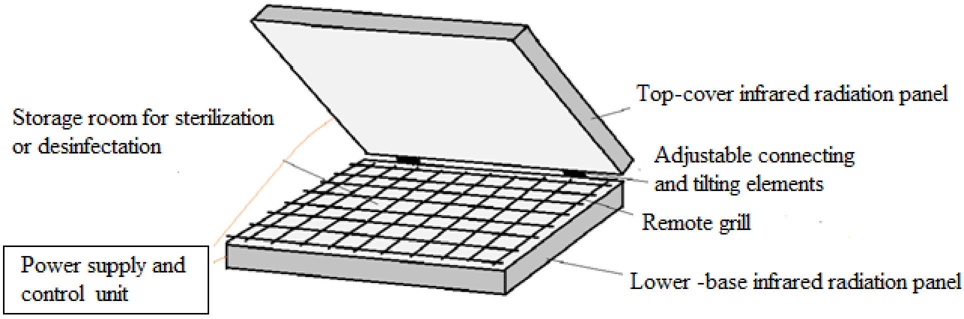


Fig. 4. Principle structure of the designed equipment.

It consists of a radiant support panel (base panel), a radiant cover panel, which can be placed in two similar enclosures, CUIT type, connecting elements and adjusting the distance between the two panels, the support or enclosure in which WE can be place the items for sterilization or disinfection, the electronic control unit and connecting elements to the electricity network. After the power supply and turning on the equipment, the radiant panels will produce infrared radiation which will raise the temperature of the objects under sterilization or disinfection to the level agreed for achieving these processes. The equipment has the components necessary to adjust the operating parameters according to specifications of the beneficiary and those imposed by the objects under sterilization or disinfection. This principle project can be carried out in several sizes depending on the dimensions and number of objects subject to sterilization or disinfection process (of small sizes for a certain number of masks or visors, to large sizes for gowns and coveralls). The use of radiating panels may be as well adapted to disinfect protective equipment dressed up, such as protection gowns or coveralls. For this case, large vertical panels are used next to which the dressed up person stands so that the clothing is subject to infrared radiation and in a specified time to perform disinfection.

The following are technical specifications for the types of equipment that are expected to be implemented. **The first variant** is intended for the disinfection of objects (masks, gloves, glasses, visors, etc.) or equipment (gowns, coveralls, etc.), a variant that is achievable in 3 types and dimensions, according to the specifications below, and is adapted to the category of objects that is to be disinfected: V1: Power : 500w, Dimensions : 500 x 600 x50 mm, Weight : 6 kg, Source surface temperature : 85-90 grdC ; V2: Power : 1kw, Dimensions : 900 x 600x 50 mm, Weight: 10 kg, Source surface temperature 85-90 grdC ; . V3: Power : 1.4 kw, Dimensions : 1250 x600 x 50 mm, Weight: 15 kg, Source surface temperature : 85-90 grdC . **The second variant** is of tunnel type for the disinfection of people wearing ordinary clothes or protective equipment (exposure time 2 minutes). The technical specifications of this variant consisting of 2 modules are : Module 1, adjustable-front-back disinfection, Power : 1.7 kw, Dimensions approx : 1 x 1 x 2 m, Source surface temperature : 95 grdC ; 2-fixed module, side disinfection, Power : 1.7 kw, Dimensions : 1 x 1 x2 m, Source surface temperature : 95 grdC, Support for hand disinfection. The optimal configuration consists of 2 x module 1 +1 x module 2. At the entrance to module 1 there is a chlorine disinfection mat for footwear soles.

4.2.2. Prototype of equipment for sterilization (disinfection) protective masks

Based on the principle sketch in Fig. 4, a prototype was obtained, which is shown in Fig. 5. This prototype has the following main components: box (case) that will include packages of masks (1), spacer support packages of masks (2),
cover (3) with radiant panel (4), a radiant panel support (5), unit of command and programming (6), supply cord, voltage 230 V.

Fig. 5. Equipment made as a prototype.

In Fig. 6, is presented the equipment loaded with packages of masks (600 pieces in 24 packages of 25 pieces), intended for sterilization or disinfection.

Fig. 6. The equipment loaded with the 600 sterilization masks.

The sterilization / disinfection case can be made in three variants, depending on the size of the materials / equipment to be sterilized / disinfected, namely : 660x560x150 mm, 970x670x150 mm and 1310x670x150 mm , the material used being stainless steel sheet.

Panels (I.R. radiation sources) are IP 65 [10] , and have the following technical characteristics: power variants: 2x250W; 2x500W; 2x700W; supply voltage: 230V ± 10 V, 50 Hz; consumption / cycle: 0.2 kw / h for 2x500 w source.

The general electrical diagram of the installation is given in Fig.7. The main components of this scheme are : radiant panels (1, 2) and control unit (3), comprising: a power cord for sources (4) ; power switch; timer cycle start button; time delay reduction button; timing increase button; emergency stop button; 3-digit LED display; timeout indicator LED; buzzer indicator of timeout. The technical characteristics are: supply voltage: 230V ± 10 V, 50 Hz. ; controlled load power: max. 1500 W; timing length: 30 ÷ 300 sec. in steps of 30 sec. , dimensions: 150x120x40 mm.

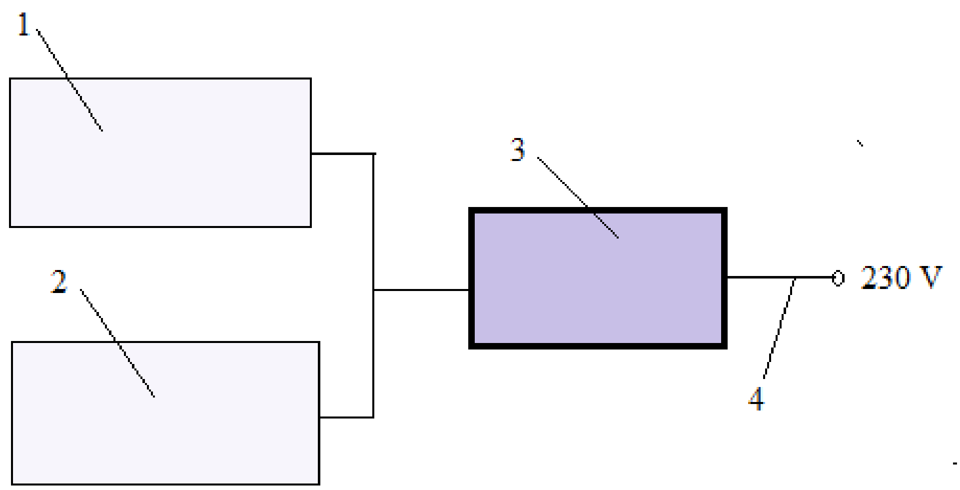


Fig. 7 . Schematic diagram of the equipment with radiant panels.

4.2.3. Testing

In order to verify the correct operation of the equipment several tests were conducted to establish the correlation between the time required to achieve the optimum temperature to ensure sterilization or disinfection. In Fig. 8 is given the time / temperature diagram drawn by following the operation of the tested equipment. Because according to current data the virus is destroyed in five minutes, at 75 gr. C [11] and in two minutes at 90 gr. C, the variant of increasing the temperature up to around 90-91 gr. C was adopted. It was found that the time required to reach this temperature when loading the equipment with 600 masks is about 30 minutes, according to the diagram in Fig. 8.

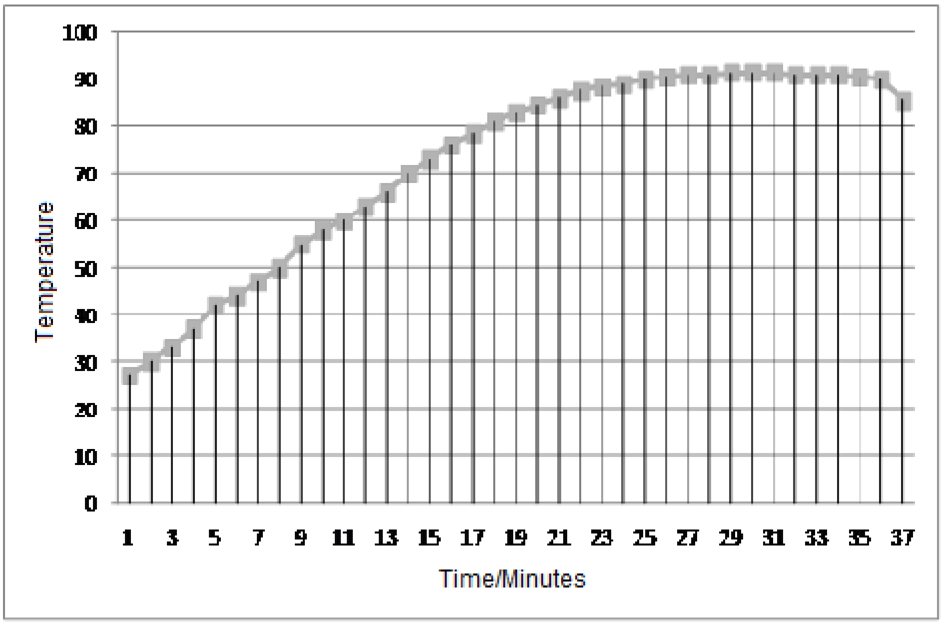


Fig. 8 . Temperature evolution graph depending on the operating time of the radiant panels for equipment of 970 x 670 x 150 mm.

Further, in Fig. 9, the working cycle of the equipment is represented. A duty cycle has the following phases: first open the lid of the equipment and remove the masks that have been subject to sterilization / disinfection in about 2 minutes, then load the equipment with the new batch of masks (600 pieces in packs of 25 pieces), in about 2 minutes, then close the lid and continue feeding the panels for two minutes after which the power supply stops for 1 minute, and then continue the pulsating supply : power 2 minutes, disconnect from the power of the radiant panels one minute until the temperature of 90-91 gr. C is reached, after about 30 minutes, for the case of treating 600 masks to obtain the required temperature throughout the mass of the masks (power is interrupted to avoid overheating of the radiant panels, but the process of raising the temperature in the mass of the masks continues). If the quantity of masks is smaller or much smaller, the time required is considerably reduced, for the desired quantity the necessary experimentation will be made, so that then the equipment can be adjusted according to the respective situation.

In addition to the above, it is also specified that sterilization / thermal disinfection, which includes the use of radiant panels, is regulated by the European standard EN 15883 [12], a rule that regulates the time and temperature of exposure that is to be sterilized / thermally disinfected. Thermal sterilization / disinfection with wet heat, based on the concept A0 (EN ISO 15883-1), is the most common method of sterilization / disinfection , to which we can add as well the method proposed in this paper.

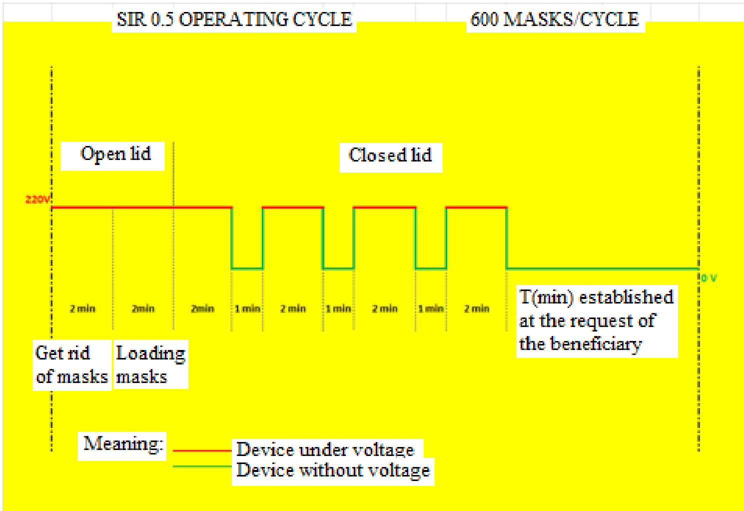


Fig. 9. Equipment duty cycle for 600 masks per cycle.

The A0 concept according to EN ISO 15 883-1 has been introduced to describe in more detail the performance of thermal sterilization / disinfection. The value A0 represents different combinations of temperature / time, but which result in the same effect. A0 only applies at temperatures above 65° C.
According to EN ISO 15883 and the recommendations of the Robert Koch Institute (European Authority for this topic), an A0 value of 600 is considered as the minimum standard for thermal sterilization / disinfection. An A0 value of 600 can be obtained by maintaining a temperature of 80° C for 10 minutes or 90° C for 1 minute or again, 75° C for 100 minutes.
As an example, if there are heat-resistant viruses, such as hepatitis B virus, the value of A0 must be at least 3000. This can be achieved by maintaining a temperature of 90 gr. C for 5 minutes. Thermal disinfection is generally recommended to be performed at a temperature above 90° C for at least 1 minute.
The time / temperature combination is shown below :

Time / minutes	**Temperature**	**Value A0**
10	80 ° C	600
1	90 ° C	600
100	75 ° C	600
50	80 ° C	3000
5	90 ° C	3000

4.2.4. Customization according to the objects subject to sterilization or disinfection

The equipment in the form made as a prototype, with the dimensions of 970 x 670 x 150 mm, can also be used for sterilization / disinfection of other objects such as protective gloves or gowns. In Fig. 10 a, the equipment loaded with protective gloves is shown and in Fig.10 b, the equipment loaded with protective gowns is shown.

a b

Fig. 10. (a)the equipment loaded with protective gloves; (b) equipment loaded with protective gowns.

4.2.5. Development perspectives

The equipment in question, which is the only one to date to use heat produced by IR radiation sources, can be used for thermal sterilization / disinfection of the following means of protection: protective masks of all types, gloves, visors, gowns, glasses, coveralls, etc.. They can also be used for thermal disinfection of medical utensils. For different types of objects subject to sterilization or disinfection, cases of appropriate sizes can be designed and made, using panels of suitable sizes, which will generally have the same main components as those described above. An interesting development is the production of variants for disinfecting the clothing of equipped people, in which case the panels are large and are arranged vertically, a development that is currently in the design phase.

5. Conclusions

Based on those presented in this paper, the following conclusions can be drawn:
- sterilization and disinfection of infected objects are very important activities that can be done with several technical solutions, some of which are precisely regulated;

- in this paper a sterilization / disinfection solution is presented with the use of radiant panels with infrared radiation;
- thermal disinfection by using IR radiation sources, is an absolute novelty, through the effects and performances achieved, it can be compared in terms of physical parameters, with wet thermal disinfection, a method regulated at European level;
- the equipment presented, which uses the heat produced by IR radiation sources, can be used for the thermal disinfection of the following means of protection: protective masks of all types, gloves, visors, gowns, glasses, coveralls, etc., being possible to be made in various types of dimensions and can be extended to the disinfection of persons equipped with protective equipment as well as for the thermal disinfection of medical utensils.

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