

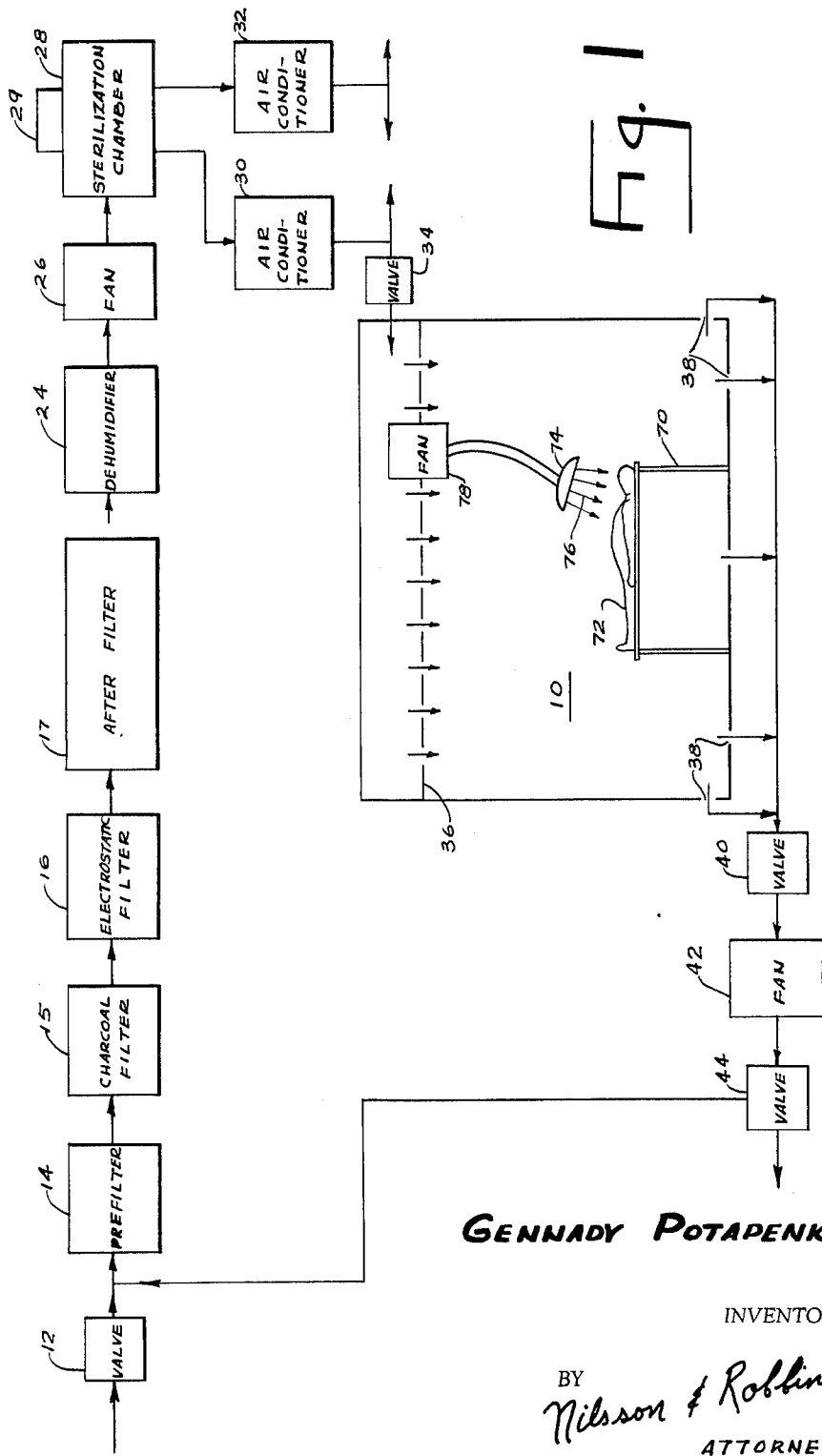
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G. POTAPENKO
ASEPTIC AIR SYSTEM

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2 Sheets-Sheet 1



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2 Sheets-Sheet 2

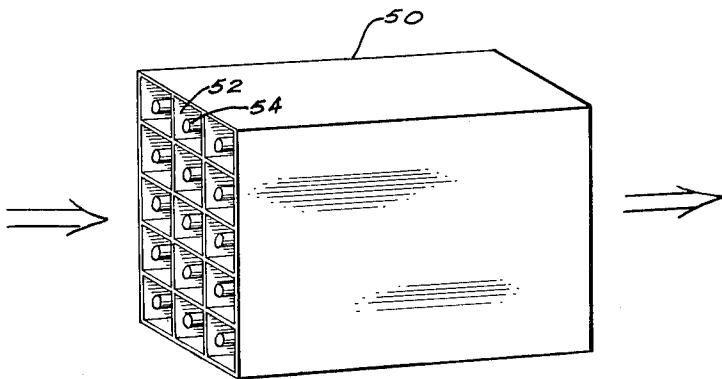


Fig. 2

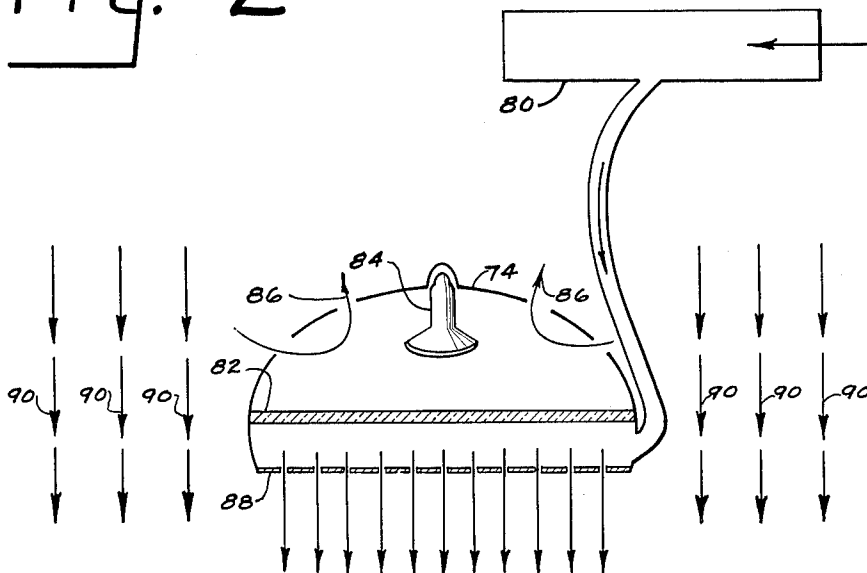


Fig. 3

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ASEPTIC AIR SYSTEM

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2 Claims. (Cl. 21-74)

This invention relates generally to the conditioning of air, and more particularly to a system and method for providing and maintaining an aseptically clean atmosphere in a given space, and which may effectively isolate the space from adjoining spaces.

In modern industry, research laboratories, and particularly in hospitals, it has become increasingly useful to be able to provide a given room or other space with aseptic sterile air. This requires that the air of the room be made sterile and, when the room includes sources, such as humans, for example, of micro-organisms, that the air in the room be repeatedly or continuously sterilized. In hospitals, particularly, in recent years the need for aseptic environments has become exceedingly acute. Certain strains of Staphylococcus bacteria have become highly resistant to antibiotics in hospital atmospheres where various antibiotics are used substantially continuously. The resistant species are deadly and are readily and commonly airborne and are transmitted from one person to another through such means as air conditioning systems, linens transferring, bath facilities, or door knobs.

Under ordinary conditions, the air in hospital rooms may contain up to 5 staphylococci per cubic foot, and right after the beds are made there may be from 20 to 30 staphylococci per cubic foot ("Hospital Sepsis: a Communicable Disease"; Johnson and Johnson, New Brunswick, N.J. 1960, p. 5).

The micro-organisms may be airborne indefinitely on moisture or dust nuclei. Many explosive epidemics have recently occurred in hospitals throughout the world; and every hospital, in spite of its practice of the most rigid conventional sterilization and isolation techniques, is in potential danger of a Staphylococcus epidemic. The disease frequently is not apparent until a patient has returned home. Thus, whole families or communities may be infected before the disease is detected.

The harmful bacteria are typically spread through hospitals by air currents and even by filtered air conditioning systems. Spot checking in the most careful of hospitals has shown that Staphylococcus bacteria was present in the very air being supplied to operating rooms where wounds must be opened to the room atmosphere and where typically the patient's resistance to such infection is exceedingly low.

Previous attempts to solve this problem have typically been directed toward isolating different patients in different rooms or on different floors in a hospital. However, such attempts have not been fully effective because of necessary or inherent communication between different parts of the hospital and have resulted in a waste of expensive and badly needed hospital space. Another attempt has been directed toward sterilizing the air in communicable disease wards or operating rooms by illuminating the space with germicidal radiation, such as ultraviolet light. However, ultraviolet light is effectively germicidal only if the micro-organisms are within a relatively short distance from the radiation source and only if the humidity of the air is within a certain range. Furthermore, the ultraviolet radiation is significantly harmful to other living organisms to which it is exposed. Some attempts have included a system for propelling the air past the germicidal lamp before its injection into the space to be maintained sterile, but such systems have typically stirred up, by air turbulence, more harmful

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micro-organisms, as from floor dust, than are killed by the germicidal action. Furthermore, such systems may leave stagnant air pockets as in room corners which act as micro-organism reservoirs from which the bacteria may later be disbursed to other areas.

One prior art attempt to provide adequately aseptic air is to draw in outside air from an atmosphere which happens to be at least relatively free of the harmful organisms. Such systems, however, rely to a dangerous degree on the lack of contamination of the outside air which obviously may change from factors such as wind velocity and direction and the proximity of sources or carriers of the harmful micro-organisms.

Further, these and most other prior art systems must "throw away" the air when it has been circulated merely once through a hospital space, such as an operating room. This procedure, required by governmental health or safety regulatory bodies, is extremely expensive because the conditioned air is wasted and because it must be discarded by means which is isolated from the input of the system in order to avoid recirculating or spreading any dangerous airborne micro-organisms.

It is therefore an object of this invention to provide a system for and method of supplying aseptic air to a given space which are not subject to these and other disadvantages of the prior art.

It is another object of this invention to provide such a system which maintains the air in a space such as an operating room at a level of sterilization such as to permit the treatment of patients as by surgery who would otherwise be below the permissible level of resistance to communicable diseases.

It is another object to provide such a system which germicidally irradiates the air without thereby exposing vulnerable objects and personnel to the radiation and which may automatically indicate any failure of the irradiating source.

It is another object to provide such a system which purifies and sterilizes the air adequately to permit recirculation of at least a large part of the air.

It is another object to provide such a system which continuously flushes the room or other space without creating turbulence or stagnant pockets in the room.

It is another object to provide such a system which effectively isolates a patient from his immediate surroundings and substantially precludes spreading of micro-organisms from the room to other spaces in a hospital.

Briefly, these and other objects and advantages are achieved in one example of the invention by an air supply system which includes a pre-filter for removing ordinary dust and contaminants from the air taken from the atmosphere. A subsequent electrostatic filter removes the finer particles and has an associated high quality after-filter for mechanically collecting any blow-off of particles from the elements of the electrostatic filter in the event of any electrical or mechanical failure of the electrostatic filter. The air is then passed through an activated carbon filter which removes odors and vaporous chemicals, such as flammable anesthetic gases. The air thus filtered is then humidity conditioned by removing water vapor if the air has a relative humidity of more than approximately sixty percent. The air is then ready for sterilization for example by the use of such means as efficient germicidal irradiation by ultraviolet lamps which are designed and disposed so that all of the air and any micro-organisms borne thereby must pass within a few inches of the lamps.

The aseptic air may then be temperature conditioned and further humidity conditioned for comfort by conventional air conditioning means.

The sterilized air thusly conditioned is then ducted to an inlet in or near the ceiling of a space, such as a

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hospital operating room. The room may be provided with distributed exit registers near the floor and with a false ceiling which forms a plenum for distributing air evenly across the room and directing it downwardly toward the exit registers at a low velocity to achieve a piston-like effect. In this manner, the room is continuously flushed with aseptic air. Furthermore, the downward current of air carries with it the bacteria and virus-laden dust particles and moisture droplets. The former may be stirred by motion within the room and the latter are exuded by the millions by surgeons, attendants and patients even though they may be wearing surgical masks. Thusly, the occupants of the room are effectively isolated from each other by a non-hindering, invisible curtain of aseptic air.

In accordance with one embodiment of the invention, the patient who may be particularly vulnerable because of open wounds or a lowered resistance to communicable diseases, may be further isolated by an additional column of aseptic air which is directed particularly over his wound or otherwise vulnerable area at a velocity and flux which substantially precludes the entry into the column of the germ-laden particles of droplets exuded at a higher level in the room by attending personnel. The additional column of air may be directed upon the patient through an air outlet affixed to the movable overhead surgical lamp in a manner such that when the light is directed upon the patient the invisible column of air is automatically directed upon the same area.

A large proportion of the exhaust air may be safely returned to the input of either the pre-filter or the electrostatic filter and recirculated through the humidity control and the sterilization means. The air thusly resterilized and conditioned may then be passed again through the room being flushed with aseptic air. This system has recently been approved by the governmental regulatory bodies of the State of California because the filtering and sterilization it provides is greater than 99.99 percent effective in purifying the air with respect to bacteria content and bacteria-laden particles or droplets.

The novel features of this invention, as well as other embodiments and examples thereof, and their principles of operation, will be more fully understood from a consideration of the following description of the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a system in accordance with one embodiment of the present invention;

FIG. 2 is a schematic view of a radiation sterilization chamber which may be utilized in the system of FIG. 1; and

FIG. 3 is a sectional schematic view of a surgical lamp which may be utilized in the system depicted in FIG. 1.

Referring to the figures in more detail, it is stressed that the details shown are by way of example only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles of the invention. The detailed showing is not to be taken as a limitation upon the scope of the invention which is to be measured by the appended claims forming a part of this specification.

In FIG. 1 there is shown a system for supplying and circulating aseptic air through an operating room 10. The space could as well be a room in a laboratory or a factory in which it is desired to supply aseptic air continuously through the room. Input air is supplied through a valve 12 from an external source (not shown) which may be outside atmosphere. The air is first passed through a pre-filter 14 which may contain a number of layers of porous filter material, such as felt, or fiberglass wool or any other appropriate, porous material. The function of the pre-filter is to remove the larger airborne particles which may be germ-laden. A charcoal filter 15, which may contain activated carbon, removes the air odors and any traces of volatile medical materials which the air may pick up while being circulated through a

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room or rooms in which such materials are exposed. The air then passes through an electrostatic filter 16, the purpose of which is to remove and retain those particles which are too small to be held by the pre-filter 14. Subsequent to the electrostatic filter 16 is shown an after-filter 17 for retaining any fine particles which may be blown through or off of the elements of the electrostatic filter 16 in the event of any failure associated therewith.

The air thusly filtered is passed through a de-humidifier 24, the purpose of which is to assure that the humidity of the air passing through it is approximately less than sixty percent relative. The de-humidifier 24 may contain coils over which the air is passed and which are heated by electricity or hot water. A fan 26 motivates or propels the air through the filters and on toward the operating room 10.

When the air has been filtered and humidity conditioned, it is passed through a sterilization chamber 23, the active element of which may be one or more ultraviolet lamps. Associated with the sterilization chamber 23 is a sterilizing lamp, a ballast, and a failure indicator 29. Further details of an example of such chambers are discussed in connection with FIG. 2 below. After the air has been sterilized by its passage through the sterilization chamber 23, it may be further humidity and temperature conditioned by a conventional air conditioner 30. For example, its temperature may be lowered to approximately 70 degrees and its humidity may be lowered from approximately fifty percent relative to a level more suitable for the comfort of the occupants of the operating room 10. The air conditioner 30 may be ducted to a plurality of additional spaces, such as wards or other operating rooms of the hospital. In addition, the sterilization chamber 23 may be ducted to additional air conditioners, such as air conditioner 32 so that one aseptic air supply system as above described may be utilized to supply aseptic air to a large number of separate spaces. A valve 34 may be interposed between the air conditioner 30 and the operating room 10.

The operating room 10 may be provided with a perforated false ceiling 36 near the actual ceiling thereby forming a plenum into which the air is applied from the valve 34 and released downwardly through the room over substantially its entire width. A relatively large body of air may thus be supplied through the room at a low velocity to continuously and effectively flush the room without creating turbulence and stagnant pockets. In this embodiment it may be seen that the action of the air is like a slowly moving piston from the ceiling of the room to the floor carrying with it any contaminated air. A distributed exit register 38 is provided in or near the floor of the room as shown for extracting the piston of air from the room. The exit air flows through a valve 40 and a fan 42.

The exhaust air from the fan 42 may be forced selectively by a valve 44 to an output (not shown) which may be the external atmosphere or back to the input of the pre-filter 14. Thus by the combined operation of the valves 12, 44 a proportion of the air may be recirculated through the filters and sterilization chamber for re-use. Such recirculation of the once conditioned air is highly desirable from an economic standpoint and is very safe due to the filtering and sterilization of the system as described.

As an additional safety precaution, it is frequently desirable to isolate, in effect, in a hospital a non-infectious space, such as the operating room 10, from adjoining rooms by maintaining a slightly positive pressure in the operating room 10 with respect to that of the adjoining spaces. A differential pressure of approximately $\frac{1}{100}$ of an inch of water in this regard has been found to be particularly appropriate. If the pressure differential is less than that or is negative, infected air may enter the space from adjoining corridors or other openings in the walls of the room. On the other hand, if the differential pres-

sure is much greater than $\frac{1}{100}$ of an inch of water, excessive turbulence and drafts in the room may result, thus unduly stirring dust from the floor and causing discomfort to the occupants of the room. The desired differential pressure may be readily maintained by the operation of the valves 34, 40 which may be controlled with a differential manometer (not shown). Another example wherein the achievement of isolation by such a slight positive differential pressure is desirable is a hospital nursery.

In some cases it may be desirable for a room which is supplied with aseptic air to be maintained at a slightly negative differential pressure with respect to other spaces. For example, when the room is an infectious ward or a single hospital room for a patient having an infection. In such cases the escape of air from the room may be precluded by maintaining the same magnitude of differential air pressure in the negative sense thus preventing any possible spread of the infection throughout the hospital. These differential pressures may also be controlled either wholly or in part by the operation of the fans 26, 42.

The germicidal effect of the sterilization chamber 28 on bacteria and other micro-organisms is a critical function of the relative humidity of the air on which they are borne. If the relative humidity of the air is allowed to become too great, then the germicidal effect of ultraviolet radiation on all micro-organisms begins to drop rapidly. For example, at fifty-six percent relative humidity, the germicidal effect decreases to approximately one-third of that at fifty percent relative humidity; and at sixty-five percent relative humidity, it decreases to less than twenty percent of that which is observed at fifty percent relative humidity (W. E. Wells, "Airborne Contagion and Air Hygiene"; Harvard University Press, Cambridge, Massachusetts, 1955; pp. 69 and 73). In practice, of course, at any point of time the dehumidifier 24 will be needed to assure that the relative humidity of the air entering the sterilization chamber 28 is below approximately sixty percent.

Another critical requirement for the efficient sterilization of air by ultraviolet irradiation is that the air must pass where the intensity of irradiation is high, preferably within a few inches of the presently available source of the ultraviolet light. To this end, the sterilization chamber 50 shown in FIG. 2 is provided with a plurality of longitudinal passageways 52, each of which contains an ultraviolet lamp 54. The cross-connection of the passageway 52 is such that air passing therethrough must at all times be within a few inches from the lamp 54. Obviously, there are other equivalent forms of ultraviolet radiation sterilization chambers and it is also to be noted that other types of germicidal radiation may be utilized, such as, for example, gamma or beta irradiation.

The amount of irradiating energy for effective sterilization in the type of ultraviolet sterilizers depicted generally by FIG. 2 is determined by the required rate of flow of the aseptic air. Assuming that the system is supplying aseptic air to one room, the rate of flow is determined by the volume of the room and the number of air exchanges per hour as required by building codes and other governmental safety regulations. For an operating room, the number of air exchanges per hour may be as high as ten while for wards or other rooms it is usually lower than ten per hour. The rate of flow of air is usually expressed in cubic feet per minute, hence the required flow is the product of the room volume and the number of air exchanges per hour divided by 60 (in cubic feet per minute). As an example, when a room is 20' x 20' x 8' and the number of air exchanges per hour is 10, the sterilizing chamber must supply 522 cubic feet per minute of aseptic air to the room. When the required flow has thus been determined, the power of ultraviolet radiation which must be supplied by the lamps of the sterilizing chamber can be determined from the following considerations. Practice and experimentation has shown that when the above described system is used without recirculation

and the input air is taken from the atmosphere of a densely populated area, such as a city, approximately 100 milli-watts of ultraviolet radiation for each cubic foot per minute passing through the sterilization chamber is required. Bacteriological tests have shown that under these conditions 99.99 percent of the bacteria in the incident air are killed; in other words, the system yields substantially sterile air even in the most unfavorable cases. In a location where the air at the intake of the system is more pure than in a densely populated area, the required ultraviolet power may be decreased by a factor of 2 or more. Further, when recirculation is permitted, the required amount of power is decreased even further. The permissible decrease in the required power of ultraviolet radiation is determined in each individual case separately by the bacteriological analysis of samples of air taken downstream from the sterilization chamber.

Referring again to FIG. 1, there is shown within the operating room 10 an operating table 70 and a patient 72. A surgical lamp 74 is disposed above the patient for illuminating that part of the patient which is to be treated as by surgery. The surgical lamp 74 is also a secondary source of aseptic air and projects a slightly diverging column 76 of aseptic air toward that portion of the patient which is to be treated. The column 76 of air provides additional isolation of the patient from the germ-laden dust particles and moisture droplets exuded by the attending personnel. The surgical lamp 74 is ducted to the distributing plenum above the false ceiling 36 and its flux of aseptic air may be assured by a fan 78 which takes air from within the plenum and supplies it to the surgical lamp 74. The flux of secondary column 76 of aseptic air including its velocity must be adequate to provide at least a slight divergence of the column 76 so that infected air cannot be drawn so far within it as to diminish the degree of desired isolation. On the other hand, the velocity of the air within the column 76 must not be so great as to cause turbulence and uncomfortable drafts by bouncing off the patient or his immediate surroundings including the hands of the surgeon or his instruments.

When the wattage of the ultraviolet radiation of the lamps in the sterilization chamber 28 is reduced significantly below 100 milli-watts per cubic foot per minute of air passing through it, it may become desirable to provide additional sterilization of the air which is supplied through the surgical lamp. To this end, the surgical lamp 74 illustrated in more detail in FIG. 3 is depicted in connection with the secondary sterilization chamber 80. The surgical lamp is preferably provided with two transparent lenses. The first is a lens 82 which transmits the light but holds back a substantial portion of the heat from a light source 84. The heat energy may be removed from the lamp 74 in the form of hot air by convection currents indicated by the arrows 86. The lens 82 and a perforated lens 88, as shown, may form a plenum for distributing and directing downwardly toward the patient the aseptic air from the chamber 80. The primary aseptic air moving downwardly from the perforated ceiling and having a slightly lower linear velocity is indicated by the arrows 90. It is stressed that although the primary aseptic air is provided and directed downwardly by the false ceiling plenum in the example described, and that this is an embodiment of the invention which presently is considered particularly advantageous and useful, it is not considered essential to the operation of the invention in its more basic form. It is also to be noted that the inclusion of each of the components in the circuit of the aseptic air in FIG. 1 as well as the particular sequence of the components, such as valves, filters, and fans is not essential and may be varied by one skilled in the art without departing from the scope and spirit of the invention.

What is claimed is:

1. A system for providing and continuously flushing a room with aseptic air and for substantially effectively

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isolating aseptically a smaller space within the said room, the system comprising:

- (a) air inlet duct means;
- (b) air treating means connected to said air inlet duct means; 5
- (c) air sterilizing means connected to said air treating means;
- (d) a plenum in said room defined by a false ceiling spaced from the ceiling of said room and coextensive therewith, said false ceiling having a plurality of openings therethrough and entering into said room, and said plenum being connected to said air sterilizing means; 10
- (e) distributed exit means disposed within said room for removing said air from said room; 15
- (f) first air motivating means operatively connected for moving air through said duct means, said air treating means, said air sterilizing means, said plenum, through said room out through said exit means; 20
- (g) lamp means in said room disposed below said false ceiling;
- (h) second air motivating means disposed in said plenum; and
- (i) air conducting means connected to said lamp means and said second air motivating means to provide a flow of aseptic air through said lamp means. 25

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2. A system as defined by claim 1 which further includes a second air sterilizing means interconnected between said air conducting means and said lamp means.

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MORRIS O. WOLK, *Primary Examiner*.