Feb. 11, 1941. E. W. BALLENTINE 2,231,746

AIR CONTROL FOR CIRCULATING SYSTEMS AND THE LIKE

Filed Feb. 14, 1939 3 Sheets-Sheet 1

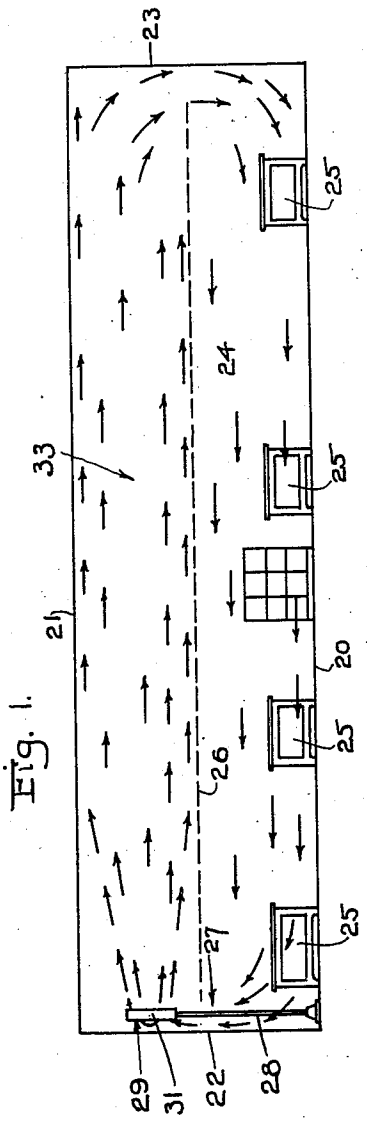


Fig. 1.

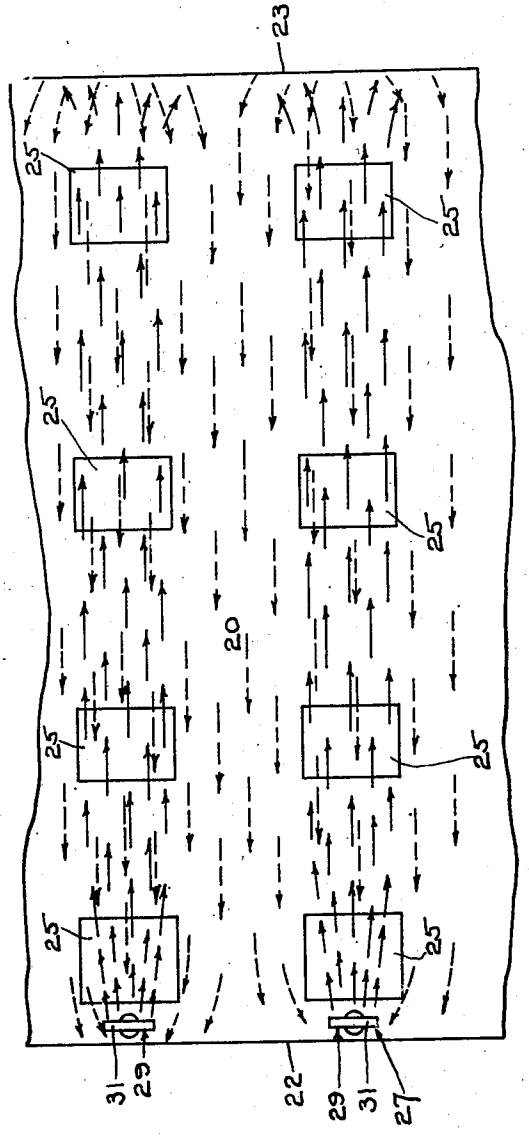


Fig. 2.

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AIR CONTROL FOR CIRCULATING SYSTEMS AND THE LIKE

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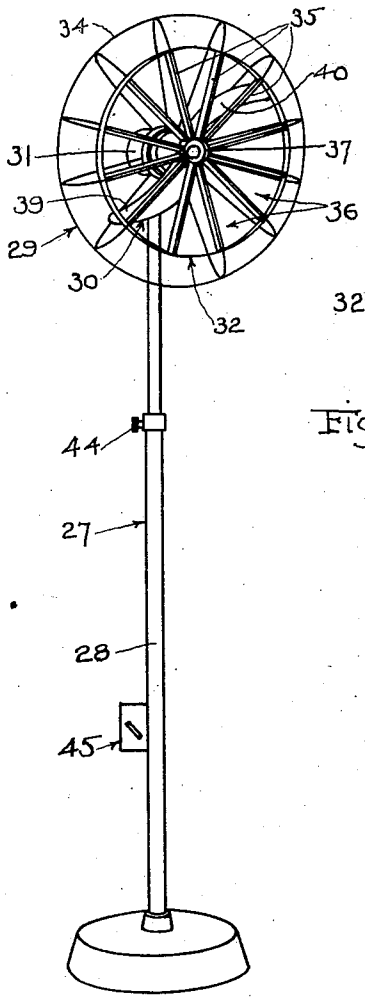


Fig. 3.

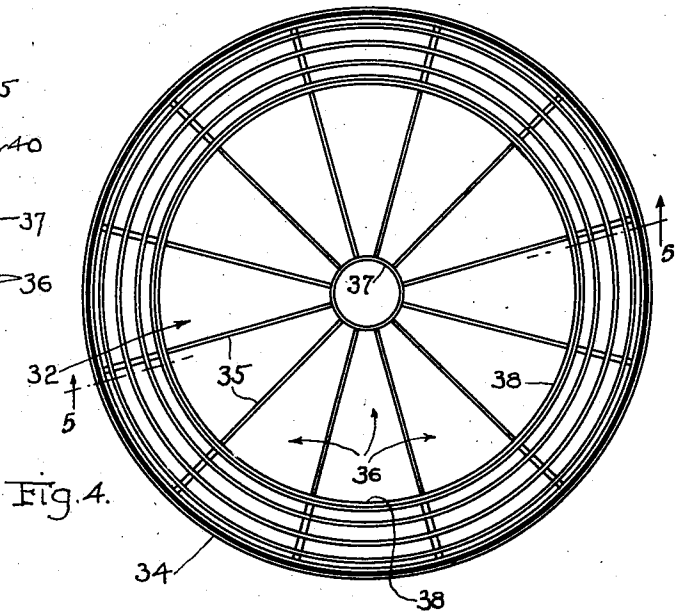


Fig. 4.

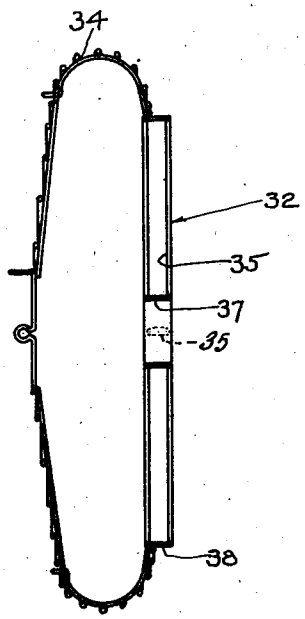


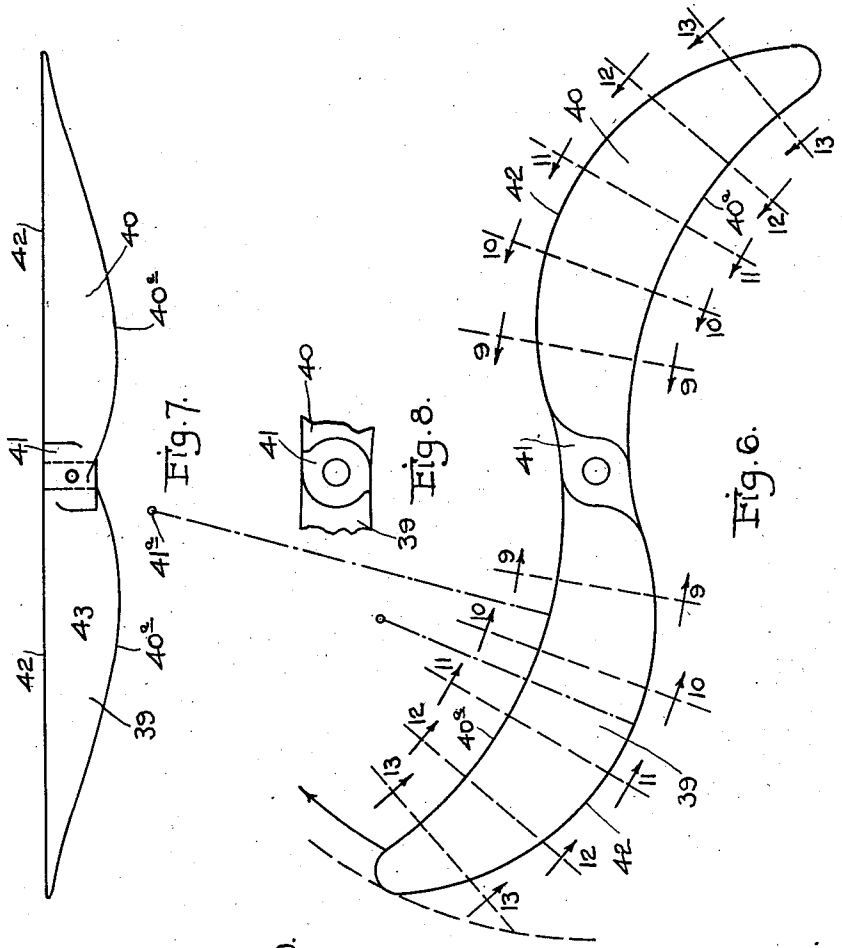
Fig. 5.

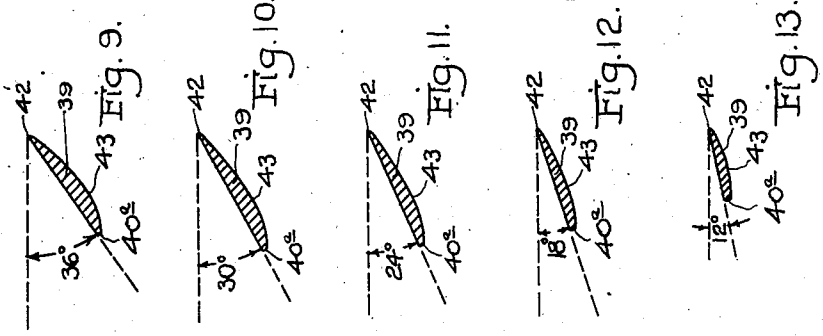
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AIR CONTROL FOR CIRCULATING SYSTEMS AND THE LIKE

Filed Feb. 14, 1939 3 Sheets-Sheet 3





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UNITED STATES PATENT OFFICE

2,231,746

AIR CONTROL FOR CIRCULATING SYSTEMS AND THE LIKE

Earle W. Ballentine, Wilmette, Ill., assignor, by mesne assignments, to Russell Electric Corporation, a corporation of Illinois

Application February 14, 1939, Serial No. 256,397

3 Claims. (Cl. 230—274)

The present invention relates to an improved air control and means for causing and directing the circulation of air in an air circulating system, and also to the air circulating system making use of such air control feature especially in connection with an air conditioning system. The improved air control herein disclosed is usable in connection with various forms and types of circulating systems, but it has been devised with especial reference to the conditions existing in cooling systems in which primary reliance is placed on the circulation of the air in a room or other enclosure, but is not limited to such use. In order that the features of the invention may be better understood I shall mention certain of the factors governing cooling systems in relation to the cooling effects produced and governed by such factors.

The cooling effect may be effected either by reducing the relative humidity of the air, or by reducing the absolute temperature of the air, or by circulating the air in the room or other enclosure wherein the cooling effect is desired; and by the term "cooling effect" I mean the effective temperature which is felt by the observer or occupant of such room. The amount of power necessary to produce a given cooling effect in a given space and for a given number of occupants of such space is a maximum when such cooling effect is produced solely by reduction of relative humidity by mechanical means; is less when such cooling effect is producer solely by actual lowering of absolute temperature; and is a minimum when such cooling effect is produced solely by air motion in the space in question; and of course the desired cooling effect may be produced by a combination of two or more of such means, with corresponding effect on total power consumption. Nevertheless the air motion system is the most economical of the several schemes above defined, and greatly to be desired. This is especially true of relatively large enclosures, such as auditoriums, meeting places, large office rooms, and similar places. The rate of air motion therein must, however, not be excessive, especially in the "zone of occupancy" or levels where people are accommodated. Generally speaking, there is a reduction of the "effective temperature" amounting to about 1.20 degrees F. for each hundred feet per minute of air flow in such zone.

In large enclosures it is of course desired to obtain the desired rate of air flow uniformly over the entire zone of occupancy, so that no occupied portion of such zone will be subjected to excessive rate of flow, and also to ensure sufficient flow at all portions of such zone to produce the desired cooling effect therein.

In order to produce the desired air flow in such large enclosures it is also desirable to make use of relatively large fan units, both in order to reduce first cost thereof, and also on account of the higher total efficiency thereby obtainable. Prior to the present invention it has been impossible to provide such large fan units of design suitable for placement directly in the enclosures to be cooled, since it has not been possible heretofore to secure with such units the desired uniformity of flow over the entire zone to be cooled; and neither has it been possible to produce the desired carrying effect with such fans to cause the air to carry to the far portions of the enclosure, so that such far portions especially have been starved of the cooling effect, and a very uneven cooling effect has been produced over such large enclosures. As a result it has heretofore been necessary to make use of an excessive number of such fan units, placed at various locations within the enclosure, with attendant high cost of installation, relatively smaller size of each such fan unit, and corresponding lowered efficiency of operation. Furthermore, when using several such fan units placed at various locations within the enclosure, such units will frequently produce air currents flowing at cross flows, so that the distribution and cooling effect are thereby greatly impaired.

In the type of circulating system herein referred to it is customary to direct the air flow from the fan located near one end or the enclosure along an upper zone of the enclosure and above the zone of occupancy, towards the opposite end of the enclosure, so that the air draft thus flowed towards such opposite end will strike such opposite end of the enclosure and flow downwardly to the zone of occupancy; thence the air current will flow backwardly along the zone of occupancy to the fan, producing the cooling effect during such backward flow, in the zone of occupancy. Heretofore it has been found that there has been a very definite limit to the distance through which the air would carry from the fan without such diffusion of the air stream that the more distant locations would receive no benefit therefrom, and this limitation has been such that a carrying effect for more than possibly fifty feet could not be depended on from a single fan.

The above mentioned limit for carrying effect of the air stream has been due to the tendency of the stream of air from the fan to become diffused

or distributed over a rapidly increasing cross-sectional area (measured at right angles to the direction of air flow from the fan), so that the air stream has rapidly enlarged as it moved away from the fan, with corresponding reduction of rate of flow and loss of carrying power, as well as uncertainty as to distribution of the circulation at various portions of the enclosure.

It is to be noted that if the outwardly flowing stream from the fan reaches the opposite wall of the enclosure its flow will thereby be positively arrested, and the stream will be caused to flow in the only direction it can go, namely, down to the zone of occupancy, and due to contact with such far end wall there will be at that location a diffusion or distribution of the so-downwardly turned stream of air, so that during the return movement it will flow at relatively slow speed and over the entire cross-sectional area of the zone of occupancy. By this means it is possible to direct the outwardly flowing stream at a higher rate than is desirable for the stream in the zone of occupancy, such outwardly flowing stream occupying a relatively small cross-sectional area clear to the far end wall; and at the same time the returning stream in the zone of occupancy will flow at the desired rate in such occupied zone, and over the entire cross-section of such occupied zone.

The main object of my present invention is to greatly increase the carrying power of the stream of air coming off the fan unit, by reduction of the diffusion action of the air in such stream, thereby ensuring delivery of a stream which will flow for a great distance from the fan unit with little increase of its cross-sectional area, so that the effective carrying power of such stream will be greatly increased, and the great benefits of such improvement may be realized in such systems as above discussed, as well as in other uses of the fan units.

I have discovered that the diffusion action in the air stream coming off the fan is due almost entirely to the rotary component of motion delivered to the air coming off the fan blades. In this connection it is noted that the motion of the air moving off the blades includes both the forward component and also a rotary component; and such rotary component depends in large measure on the angle or pitch of the blades, but is a component which cannot be entirely avoided in conventional forms of fans. Such rotary component of air motion in the stream tends to cause a spiraling movement of the air flowing away from the fan, and this spiral or rotary movement necessarily produces a centrifugal action in the air particles of the stream, so that as the air particles move away from the fan unit they not only move forward, but also are thrown outwardly from the true axis of the stream, and a diffusion or enlargement of the stream occurs. This enlarging action is progressive on an increasing rate as the air flows away from the fan unit; and the carrying power of the air stream rapidly falls due to the lowered rate of air movement along the axis of the stream, as well as to the fact that the enlargement of the stream is accompanied by a picking up of additional air (not coming from the fan unit), the momentum of which additional air must be produced by the air particles of the "true stream", with a consequent great reduction of stream velocity, and a very rapid loss of stream carrying power.

I have found that by removing the rotary component of movement of the air immediately after the air leaves the fan blades, so that the air stream flows directly away from the fan unit substantially without rotary component of motion I am enabled to increase the "carrying power" of the air stream to several times its previous carrying power, so that I am enabled to throw the air stream from the fan several times as far as has formerly been possible, substantially without enlargement or diffusion of such stream, thus making it possible to satisfactorily circulate the air body within an enclosure correspondingly larger than has formerly been possible. Furthermore, it will be noted that when the outgoing air stream becomes seriously diffused or enlarged before reaching the far end wall, portions of such stream reach down into the path of the returning current in the zone of occupancy, with corresponding interference with the return current in the zone of occupancy; which effect is also obviated by the practice of the present invention.

Now the rotary component created in a particle of air coming off the fan blade depends largely on the angle or pitch of the blade at the location of such air particle; and it is customary to design the blades with a maximum pitch or angle close to the hub. Air particles coming off of portions of the blade at successively greater radii measured from the hub have successively smaller rotary components of motion. I have therefore provided means for removing the rotary components of motion from all particles of the air coming from all radial positions measured along the blades, in such manner that all particles of the air stream are equally and completely relieved of the rotary components of motion, and the entire air stream, throughout its entire diameter is substantially freed of any such rotary component of motion.

In connection with the foregoing it may be noted that a radial fin, placed with its surface parallel to the axis of the air stream, and extending radially outwardly from the axis of the fan, will present a surface normal to the rotary component of motion, and that a series of such fins extending radially outwards from the axis of the air stream will present a series of air passages between them, said air passages having side surfaces normal to the axis of the stream, and the sizes of said passages will increase, measured outwardly from the axis of the stream towards its outer limit. It is here noted that in order to completely remove the rotary component of motion the distance or dimensions of such fins measured in the direction of the stream axis should be greater, in comparison to the distance between the fins, at points where the radial component is greater, than at points where such radial component is lesser—that is, the ratio of fin length, parallel to the axis, compared to distance between fins, across the air stream, should be a maximum close to the hub, and may then reduce as one moves away from the axis of the stream and towards its outer limit. It is now noted that by using fins of uniform dimension measured in the direction of the axis, and placed radially from the axis, and at uniform spacing around the circle, and with their surfaces parallel to the direction of the air stream, I have provided an air controller of ideal design and arrangement, and one which will remove the rotary component of motion from all portions of the body of the air stream equally; and it is noted that the dimensions of such

fins parallel to the direction of air flow may be quite small and still accomplish the result of complete removal of the rotary component of motion at all locations across the diameter of the air stream.

A further feature of the present invention relates to an improved design of the fan blades themselves, for the purpose of increasing the efficiency of the fan as a translator of energy, and also for the purpose of silencing the action thereof. The efficiency of the fan to translate energy is measured by comparison of the kinetic energy of the entire air stream moved away from the fan, with the energy input to the fan, taking account, of course, of the volume of air moved at different radial positions along the air stream. I have found that an angular pitch of the blades close to the hub, amounting to substantially thirty-six (36) degrees, (measured from the plane normal to the axis), and tapering regularly to an angular pitch of substantially eight (8) degrees, at the tips of the blades will give a maximum efficiency of air movement over the entire radial dimension of the blades, and in fact efficiencies as high as eighteen percent (18%) of the total energy input may be attained with such designs. These angular pitches are much lower than have heretofore been generally accepted as the best for fan designs, but I have determined the correctness of this design for maximum efficiency by a great number of experiments and with many blade designs.

In connection with the foregoing, it is also noted that the rotary component of motion of the air flowing away from the fan blades depends largely on the angular pitch of the blades, and of course lowering of said pitch therefore results in lowering of such rotary component of motion. It is therefore to be observed that such low angular pitch blades lend themselves admirably to use in connection with the means for ensuring projection of an air stream substantially free of any rotary component of motion, all as hereinbefore set forth, and therefore a double benefit is secured by using such low angular pitch blades in the present connection.

I have discovered that the noise generated by the action of the air on the blades may be greatly lessened or even eliminated by curving the blades into an arcuate form measured about a center displaced angularly from the position of each blade, so that each blade curves about a center located in or near the plane of the blade but angularly displaced from the radial position of the blade. By this arrangement each blade presents a tip which will lead or trail depending on the direction of rotation. This results in an action wherein the air wave generated by the blade moves progressively along the length of the blade instead of being concentrated at one time on the entire length of the blade, and a corresponding lessening of air noise is the result. Generally I prefer to curve the blades so that the tips lead in the direction of rotation.

Furthermore, I prefer to so form the blades that the delivery edge of each blade lies within a plane normal to the axis of rotation, the leading edge of such blade lying within a warped plane. In this connection it is noted that a convenient manufacturing operation for making these fans consists in casting them, and afterwards buffing or polishing them. During these operations the blades frequently become bent out of line or form, so that they must be bent or formed back into proper curvature as intended. By designing the blades so that one edge of each blade, generally the delivery edge, lies in a plane, it is possible to set the fan down on a flat surface after it has been buffed or polished, and if it is out of form such fact will appear from the existence of parts of such edge which do not lie in contact with such surface. It is then a very easy matter to bend the blade back into form which result is evidenced by the contacting of the entire edge with such flat surface.

Other objects and uses of the invention will appear from a detailed description of the same, which consists in the features of construction and combinations of parts hereinafter described and claimed.

In the drawings:

Figure 1 shows diagrammatically a large room or enclosure having therein a number of desks located in the cooling zone of occupancy, the figure showing a vertical longitudinal section through such room, and the circulating fan being mounted on a post at one end of the room to throw the outflowing air stream to the far end of the room above the zone of occupancy, the air stream then striking the far wall and moving down to the zone of occupancy and returning in said zone to the beginning end of the room for recirculation;

Figure 2 shows a plan view corresponding to Figure 1, looking down onto the portion of the room treated by such fan;

Figure 3 shows a vertical elevation of a typical fan unit embodying the features of the present invention, including the air director for removing the rotary component of motion;

Figure 4 shows a face view of the air director for removing the rotary component of motion from the air stream;

Figure 5 shows a cross-section on the line 5—5 of Figure 4, looking in the direction of the arrows;

Figure 6 shows a plan or face view of a typical fan blade embodying the features of the present invention, being a two blade unit;

Figure 7 shows an edge view corresponding to Figure 6;

Figure 8 shows a fragmentary face view of the hub portion of the unit of Figure 6, looking at the other face thereof as compared to Figure 6; and

Figures 9, 10, 11, 12, and 13 show cross-sections through one of the blades taken on the lines 9—9, 10—10, 11—11, 12—12 and 13 of Figure 6, looking in the directions of the arrows;

Referring first to Figures 1 and 2, the enclosure therein shown includes the floor 20, ceiling 21, near end wall 22 and far end wall 23. The side walls may be assumed to be at 24 (for the far side) and cut away (for the near side). A number of desks or other work units are shown at 25, and these are of course all in the lower or zone of occupancy of the room, namely, below the dotted line 26 which extends horizontally along the room somewhat above the normal elevation of the occupants of the room. The fan circulating unit is shown close to the wall 22, and is designated by the numeral 27. It includes the stand 28 which holds the fan above the zone of occupancy and in line with the delivery zone, the fan unit proper 29 being carried by said stand and in line with the delivery zone. This fan unit proper includes a fan 30 and motor 31, together with the air director 32; and the details of the fan and air director are shown in Figures 4 to 13, inclusive, and will be described hereinafter.

Referring again to Figures 1 and 2, the current of air delivered by the fan flows horizontally along the upper portion of the room and above the zone of occupancy as shown by the air stream 33, and it will be noted that this stream continues substantially without diffusion clear from the fan unit to the opposite end wall 23, so that the delivered air current flows somewhat in the form of a tubular body of air clear to the far end wall. There is shown in Figures 1 and 2 a slight widening of this stream of air after it leaves the fan unit, but this is due to the viscosity of the air and not to any rotary component of motion; and due to the removal of the rotary component by the means hereinafter enlarged upon I have secured a very great increase of the "carrying power" of the air stream, so that a full and definite stream of controlled air may be delivered to great distances, as much as one hundred fifty or two hundred feet, substantially without diffusion.

At the far end this delivered air stream strikes the wall 23 and is immediately diverted thereby, so that it becomes widened (until it strikes side walls or other like streams of air from other units), and then this stream flows towards the only location where it may be accommodated, namely, downwardly to the lower portion of the room, and to a location beneath the outwardly flowing stream; and then the so-lowered stream flows backwardly along the zone of occupancy towards the point of beginning, and then upwardly back to the fan unit. It is then again recirculated, following this circuit time after time. Now it is noted that the original outwardly flowing stream is of comparatively small cross-sectional size, and does not occupy more than a portion of the width of the room (normal to the drawings of Figures 1 and 2), whereas the returning stream in the zone of occupancy fills the entire width of the room or the space to adjacent similar streams circulated by other similar fan units, so that the velocity of the returning air in the zone of occupancy may be much less than the outgoing stream. Or, to put the matter another way, the outgoing stream may be delivered at a much higher velocity than can be comfortably borne by the human body, thereby ensuring a great carrying power to reach a distant end wall, and then the returning stream in the zone of occupancy may still flow at a velocity which is as great as may be properly used in such zone. Thus the advantages of high velocity and great carrying power in the delivery stream are combined with the provision of a proper and comfortable velocity in the zone of occupancy.

Referring now to Figure 3 the fan unit includes the motor 31 driving the fan 30, which is generally mounted directly on the motor shaft. A guard 34 of wire or the like is placed around the fan proper; but the front face of said guard is either modified or eliminated to form and provide for an air director 32. This air director is shown in detail in Figures 4 and 5. It includes a series of radially placed plates or slats 35, located at uniform angular positions and extending outwardly radially from the axis of the fan, which is also the axis of the air stream. These plates lie in planes parallel to the axis of the air stream and the axis of the fan, and are of such width (or distance along the direction of air flow) as to provide the desired corrective action. It will be noted that these plates, therefore stand in position to receive the rotary component of air movement normally against the faces of the plates, so that such component is received by the plates and (disregarding friction losses) will be converted into an additive component of movement in the direction of the axis of the stream. Therefore, the rotary component will theoretically actually serve to increase the velocity of the stream. As a matter of fact this additive component of movement will serve to counterbalance any frictional loss due to the flow of the air stream through the air director, so that a full delivery velocity will still be ensured, and no loss of stream velocity will be occasioned.

Now it is noted that a single such directive plate would not properly perform its function, so a suitable number of such plates is provided; and thereby there are established the angular shaped openings 36 between said plates. Each of these openings increases in width from the axis towards the periphery of the director. (Generally a ring 37 is placed at the center of the director, and in front of the fan hub since there is little air delivery coming directly therefrom, and the inner ends of the plates 35 are connected thereto and supported thereby.) The outer ends of the plate 35 are suitably connected to and supported by the guard, as by a ring 38.

Examination of Figure 5 shows that the plates 35 are of uniform width (distance along the axis of stream flow) throughout their radial dimension. The rotary component of the air movement is greatest close to the axis of the air stream, where the blades have the maximum pitch, and is least at the tips of the blades. The axial length (width) of the plates 35 should be in direct ratio to the rotary component of movement to be removed from the air stream at any given point, measured radially from the axis of the stream, so that, as far as this factor alone is concerned the plates 35 should taper in axial dimension (width) from a maximum at their inner ends, to a minimum at their outer ends, at the ring 38. On the other hand, the axial dimension of said plates should be, at each radial position measured from the stream axis, in proportion to the amount of air volume flowing at such position; and since the plates 35 spread apart from the center towards the outer periphery, so that the air volumes of successive radial increments increase proportionately, it follows that the plates 35 should be of uniform axial dimension (width), as shown in Figure 5. Therefore, the use of plates 35 of uniform axial dimension provides an air director which responds to all requirements, as far as fully removing the rotary component of the air movement is concerned. Furthermore, such plates require no special forming or cutting, but can be made from strip of uniform width.

The edges of the plates 35 should be rounded or streamlined so as to interfere the least amount with the air flow through the director. Also, said plates should be as thin as is consistent with proper rigidity and strength.

The diameter of the air director should approximate that of the fan, and the director should be placed as close as possible to the fan, consistent with proper clearances. Thereby there will be assurance that all portions of the air stream will be properly treated by the director, and that such treatment will be accorded before the centrifugal action of the rotary component of air movement has had time to effect any appreciable dispersing action on the air stream.

Thereby the full body of the air stream will leave the fan unit substantially without any motion except straight ahead, so that a maximum carrying effect will be available. Tests over extended periods of time, and under severe operating conditions have definitely established the fact that the carrying effect and power of the air stream from relatively large fans (meaning such fans intended for circulation in rooms and other similar enclosures as for example 22 inches in diameter) can be more than doubled by such an air director, with all the attendant advantages.

The details of the fan itself are shown in Figures 6 to 13 inclusive. Therein is shown a two blade fan, having the blades 39 and 40 carried by the hub 41. These blades are, of course identical and placed at uniform angular separations. Each blade is formed with a twist of its propelling surface (seen in Figure 6), commencing with a pitch of substantially 36 degrees close to the hub (see Figure 9), and tapering to a twist of substantially 8 degrees at the tip. (Figures 9, 10, 11, 12 and 13 are sections at successive radial positions along the blade, and the section 13—13 is not at the extreme tip.) It will be noted that the pitches at the successive sections increase uniformly measured backwardly from the tip towards the hub, as is evident from comparison of Figures 9, 10, 11, 12 and 13 with each other.

Examination of Figures 9 to 13 inclusive also shows that the propellant surface of the blade (tops of Figures 6, 9, 10, 11, 12 and 13) is so formed that all the sections show said top surface as being a straight line. In other words, this surface is generated by the movement of a straight line outwardly from the hub to the tip, and at the same time altering the angle of tilt of such line (measured from the plane normal to the axis of rotation), with a uniform rate of change of such angle, so that, in effect, the propellant surface of the blade is a true warped surface.

It is also noted that each of the sections 9 to 13 inclusive is taken on a plane at right angles to the entering edge 40a of the blade, (the direction of rotation is shown by the arrow), so the warping of said surface takes place with a movement of the generating line radially around the center of curvature of the entering edge of the blade, and with a movement of the pivoting point of said generating line along a line drawn through the center of curvature 41a of the entering edge of the blade.

The trailing edge 42 of the blade may be curved to suit, but the form shown is one in which said trailing edge lies within a plane lying at right angles or normal to the axis of fan rotation, as evident from Figure 7, and for reasons which have already been explained herein. It is noted that by this formation of the blade there is also produced a blade having its width increasing from the hub to a position about half way to the maximum radial dimension, and then again reducing in width to the tip. Thereby there is produced a blade having its propellant surface at all radial locations substantially in proportion to the amount of air to be moved at such location (taking into account the propellant speed of the blade at such point). Generally the extreme tip of the blade should be curved as shown in Figure 6; and generally, also the curvature of the entering edge 40 should be concave towards the direction of blade movement, but not necessarily so.

The back surface 43 of the blade should be streamlined as well shown in Figures 9 to 13 inclusive and of generally air foil design as well shown in said figures.

Now it is noted that the pitch angles shown at the various sections are much less than have heretofore been generally accepted as suitable for this type of fan; but I have already mentioned that I have found from a large number of comprehensive tests and studies that the angles herein shown give a maximum efficiency of air movement, meaning thereby a comparison of the kinetic energy of the entire volume of the air stream with the energy input to the fan itself. In fact, for fans of substantially 22 inches diameter I have been able to secure efficiencies as high as eighteen percent of the total input, delivered as kinetic energy of the stream. This is far above the efficiencies which it has heretofore been possible to secure in such devices.

Moreover, it is noted that the low pitch angles herein disclosed produce a much lowered rotary component of air movement as the air at any given section leaves the blade, so that the work to be performed by the air director is correspondingly reduced, and the size of such air director may be correspondingly reduced. Therefore the combination of such a fan blade with the air director herein disclosed is ideal for production of an air stream which is substantially free of any rotary component of motion, and therefore best adapted for great carrying power; and therefore best adapted for the circulation of air in large enclosures, and according to the system of cooling by air circulation as herein set out.

It may be noted that the guard 34 placed around the fan may be of conventional design, comprising a series of wire rings of successively differing diameters, connected together by a series of more or less radial wire ties, as well shown in Figures 3, 4 and 5; and as there shown, said guard may be carried around the back side of the fan, the air director being located at the front of said guard; or, as shown, within an opening in the front of said guard. In such case the ring 38 of the air director may be suitably secured to the front of the guard, or to the edge of an opening in the front of the guard, as shown in Figures 4 and 5.

Furthermore, the fan unit is conveniently carried by a stand 28 of telescoping tubular form, having the set screw 44 whereby the elevation of the fan proper may be adjusted to ensure delivery of the outgoing air stream at the proper elevation in the room. Also, suitable means (not shown in detail) may be provided for making it possible to adjust the angle of tilt of the fan so that the outgoing air stream will travel in the proper direction.

It may be noted that the removal of the rotary component of motion from the air stream is in some respects similar to single polarization of light, in the sense that the air motion in one component has been removed. I therefore sometimes speak of my air director herein disclosed as an "air polarizer," it being understood that this term is purely arbitrary, and in no sense a limitation of the invention as such.

It is noted that the cooling effect should be adjusted from time to time by variation of fan speed with consequent variation of rate of air circulation and flow. If the outgoing air stream were to contain a rotary component of motion

the dispersion or diffusion of with stream would vary with changes of rate of circulation so that the diffusion would be much different for some rates of air circulation than for other rates. By removing the rotary component from the motion of the air stream I am able to change the rate of circulation from time to time through wide limits of variation and still maintain in all cases a stream flow in the outgoing stream of substantially linear form and substantially free of diffusion or dispersion. Any suitable speed adjustment may be used, such as a rheostat or autotransformer 45.

It is to be noted that a stream of air of linear form and free of rotary component, such as herein contemplated, will flow linearly through the enclosing envelope of stationary air, somewhat after the manner of flowage of such stream along a tube; and it is also to be noted that air has viscosity. Therefore, the linearly flowing stream, free of rotary component will have exerted on its marginal portion a drag, due to contact with the enclosing envelope. This drag, and also the natural viscosity of the flowing air stream, will cause a gradual widening of the outflowing stream, as shown by the arrangement of the full line arrows in Figure 2; but such widening is very much less than would have been caused by a rotary component of motion, and is due to an entirely different physical action than that due to rotary component of motion, and is to be very clearly distinguished therefrom. The two actions are not to be confused in aerodynamics.

While I have herein shown and described only one embodiment of the features of my present invention, still I do not intend to limit myself thereto, except as I may do so in the claims to follow.

I claim:

1. Means to produce an air stream substantially free of any spiralling motion, comprising a fan having a series of blades each having a propellant surface in the form of a warped surface generated by movement of a straight line outwardly from the hub commencing with a pitch of substantially thirty-six degrees with respect to a plane normal to the axis of fan rotation, close to the fan hub, and ending with a pitch of substantially eight degrees with respect to said plane at the tips of the blades, to thereby obtain high efficiency of the fan combined with low rotary motion of the delivered air, together with means to remove rotary component of motion from the air delivered by said fan, comprising an air director placed close to the fan at the delivery side thereof and including a series of plates located in a plane normal to the axis of the air stream, said plates having their surfaces parallel to the air stream, and said plates extending outwardly radially with respect to the axis of the air stream, whereby any rotary component of motion of air delivered by said fan is removed from the air stream immediately after leaving the fan blades, by contact of the spiralling air with the surfaces of the air director, substantially as described.

2. Means to generate an air stream by means of a blade fan and substantially free of rotary component of motion comprising a fan unit including a blade fan and an air director in close proximity to the delivery side of said fan, said blade fan having blades of relatively low pitch angle on their propellant surfaces with consequent generation of a relatively small amount of rotary component of motion in the delivered air stream, and the air director being located in close proximity to said delivery side of the fan and including a series of plates located in the air stream and having surfaces normal to the rotary component of air motion, said surfaces being parallel to the axis of the air stream, and each such surface of the air director having a dimension parallel to the axis of the air stream at every point proportional to the product of the fan blade pitch at such point multiplied by the distance between plates at such point, substantially as described.

3. Means to generate an air stream by means of a blade fan and substantially free of rotary component of motion comprising a fan unit including a blade fan and an air director in close proximity to the delivery side of said fan, said blade fan having blades of relatively low pitch angle on their propellant surfaces with consequent generation of a relatively small amount of rotary component of motion in the delivered air stream, and the air director including a series of plates having their surfaces at right angles to the rotary component of motion and at all points substantially in surface area proportional to the amount of rotary component of the air in proximity to each point multiplied by the air space between plates at such point, substantially as described.

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