

Sept. 7, 1965

F. J. McCABE

3,204,548

DAMPER CONSTRUCTION

Filed Nov. 29, 1963

5 Sheets-Sheet 1

FIG. 1

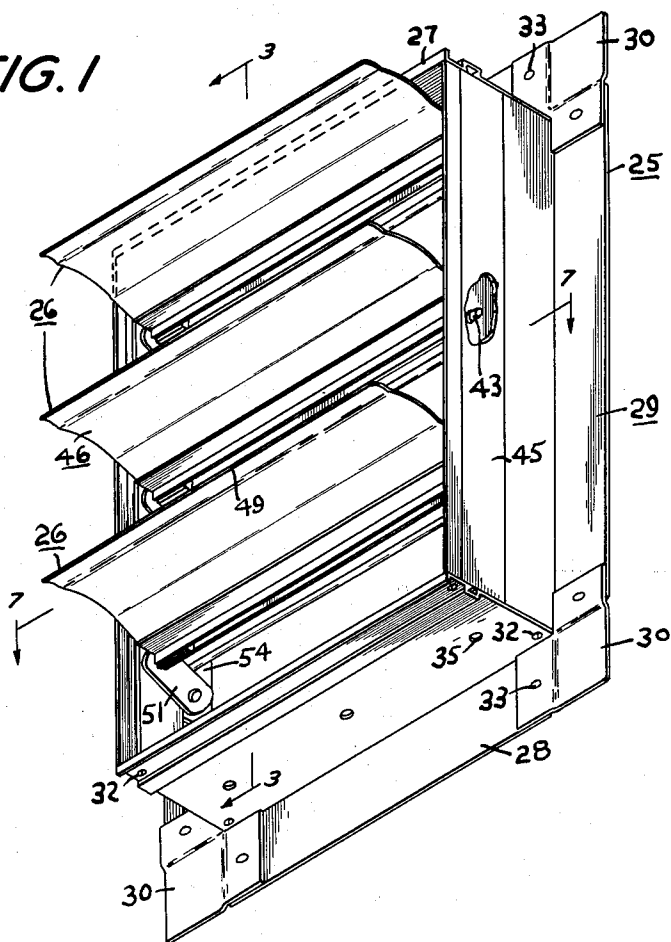
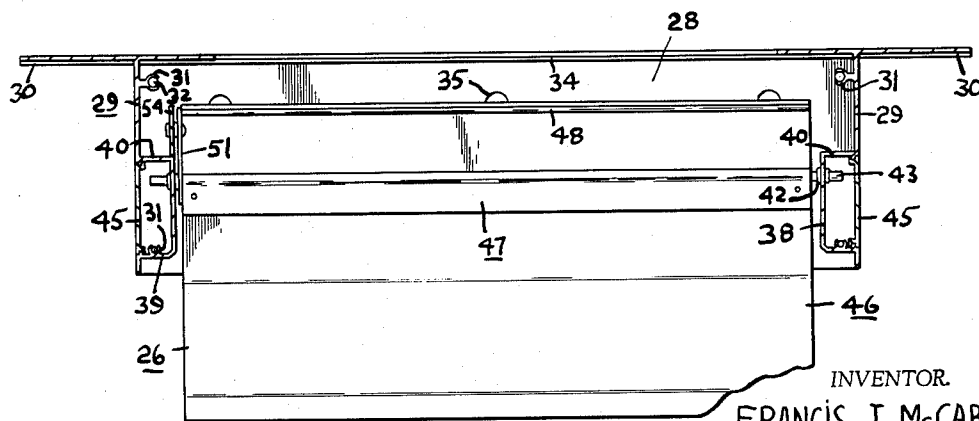


FIG. 7

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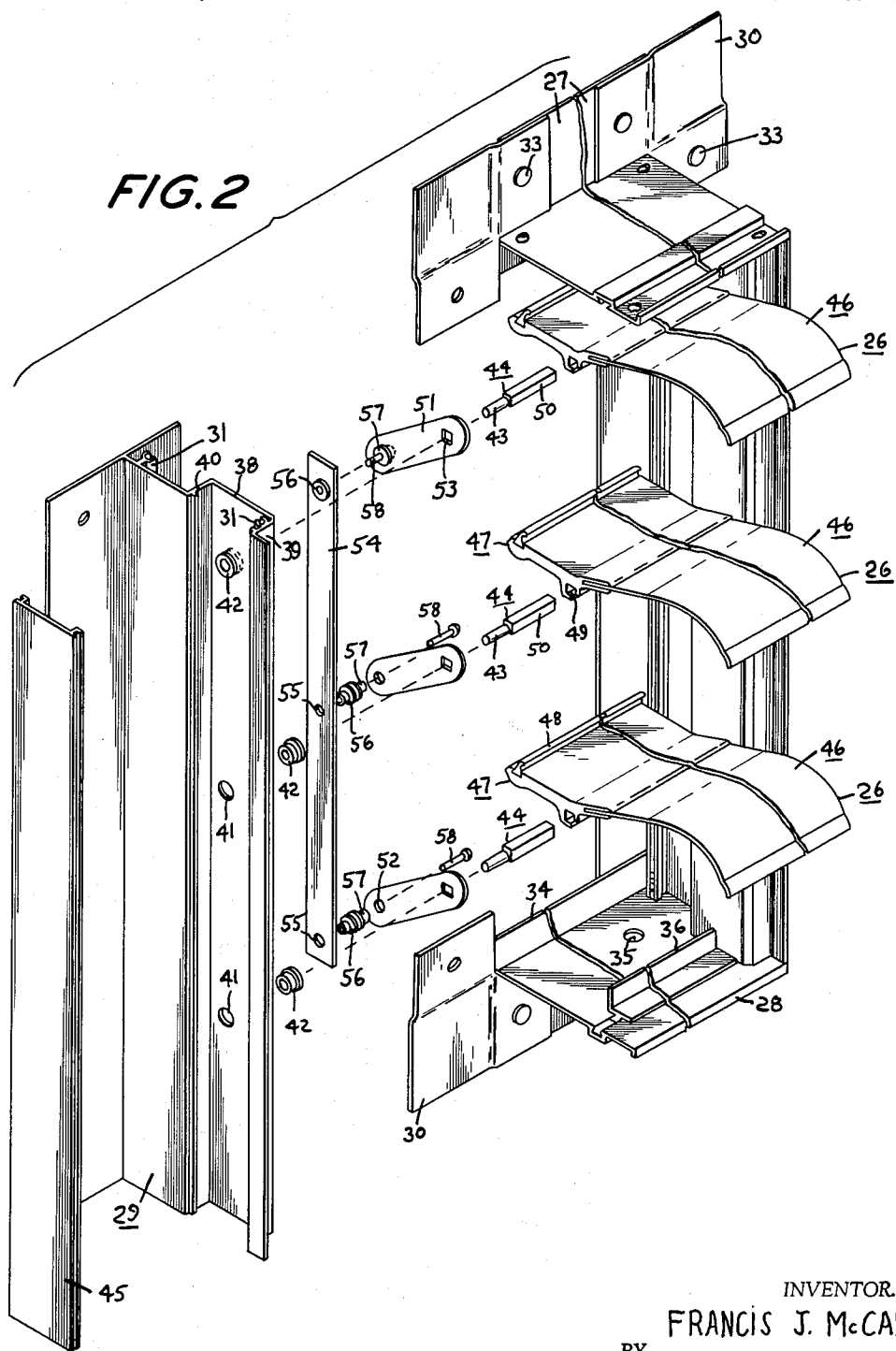
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DAMPER CONSTRUCTION

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FIG. 2



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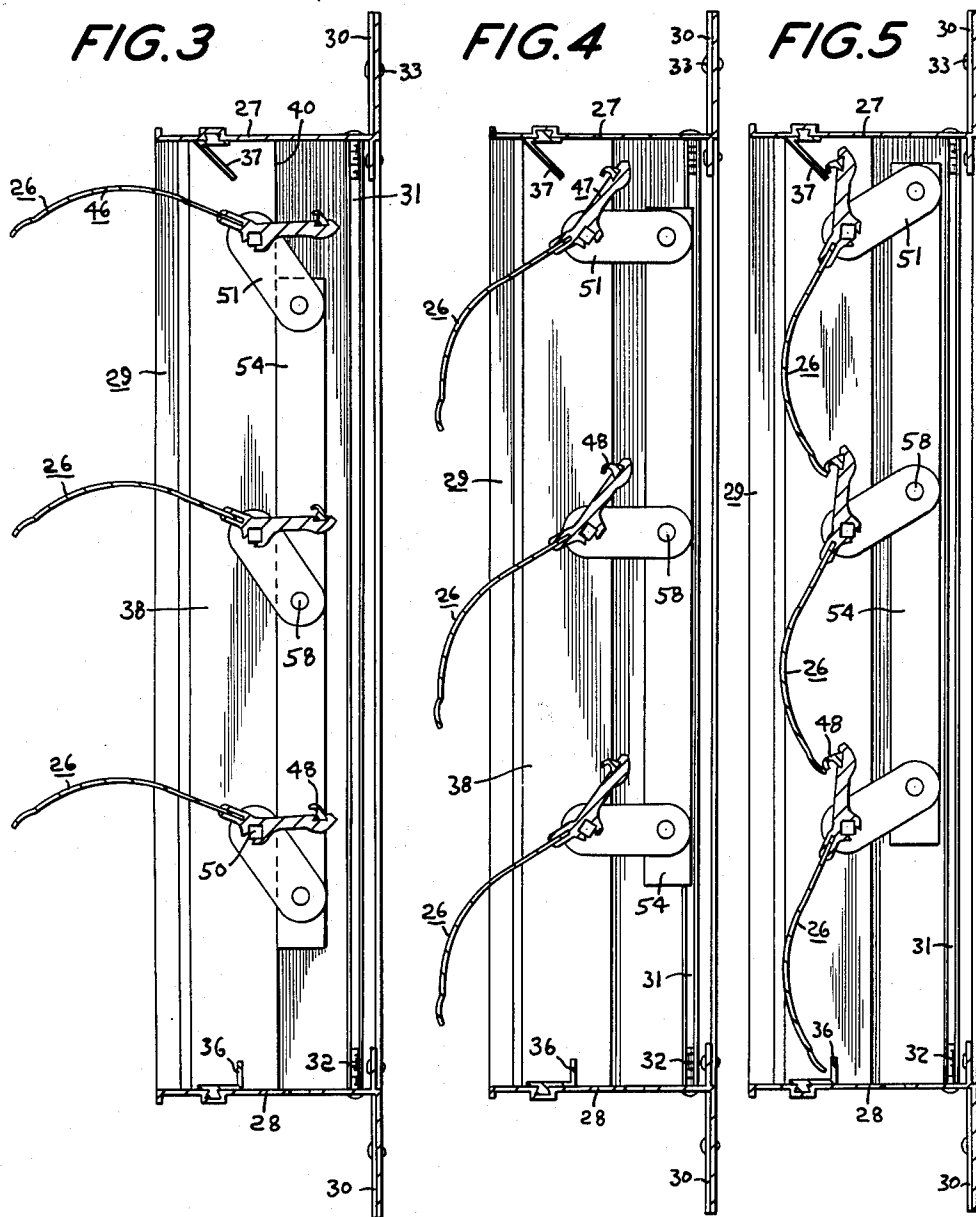
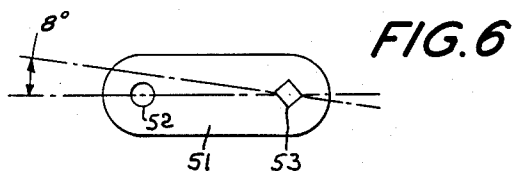
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FIG. 8

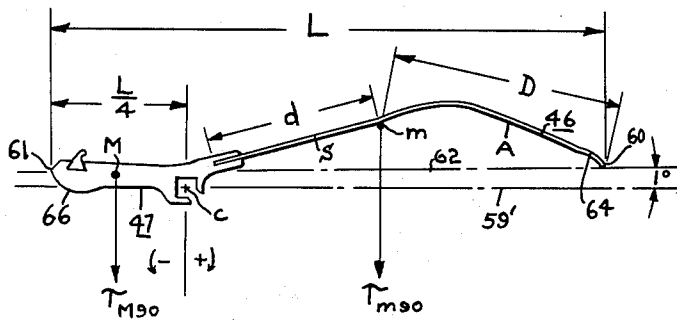


FIG. 9

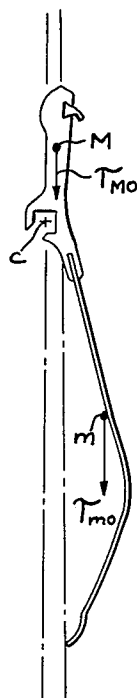
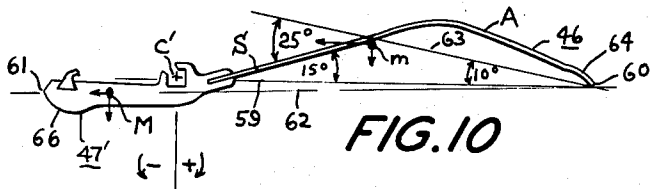


FIG. 10

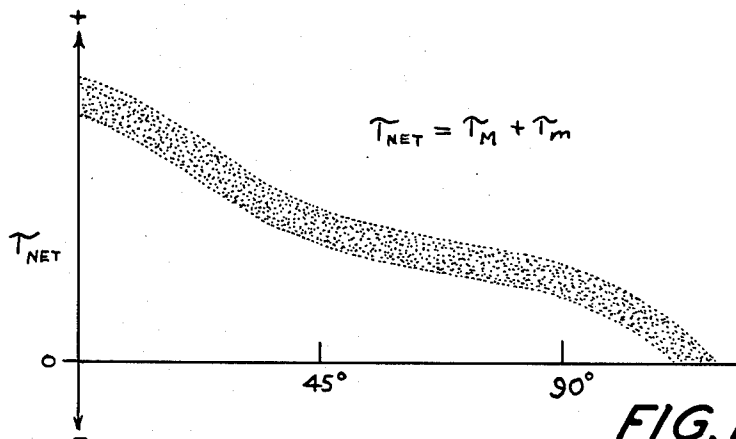


FIG. 11

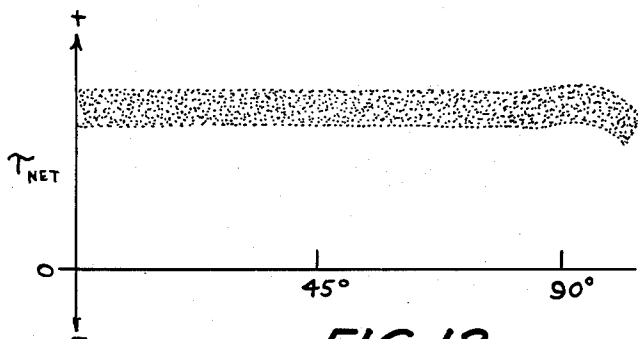


FIG. 12

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DAMPER CONSTRUCTION

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FIG. 13

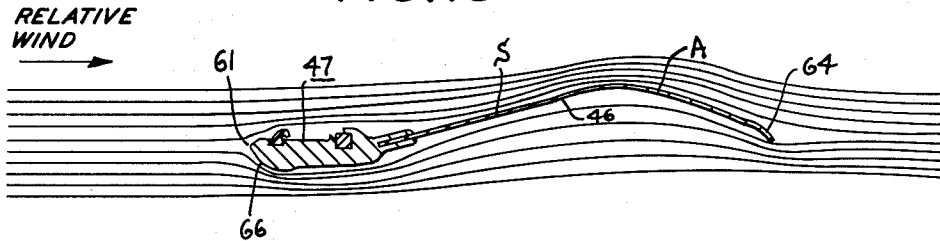


FIG. 14

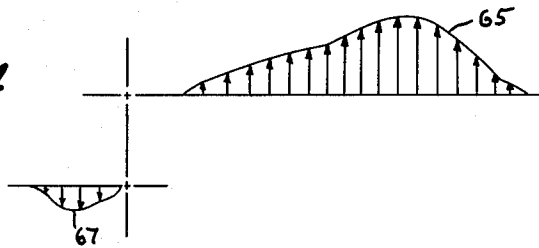
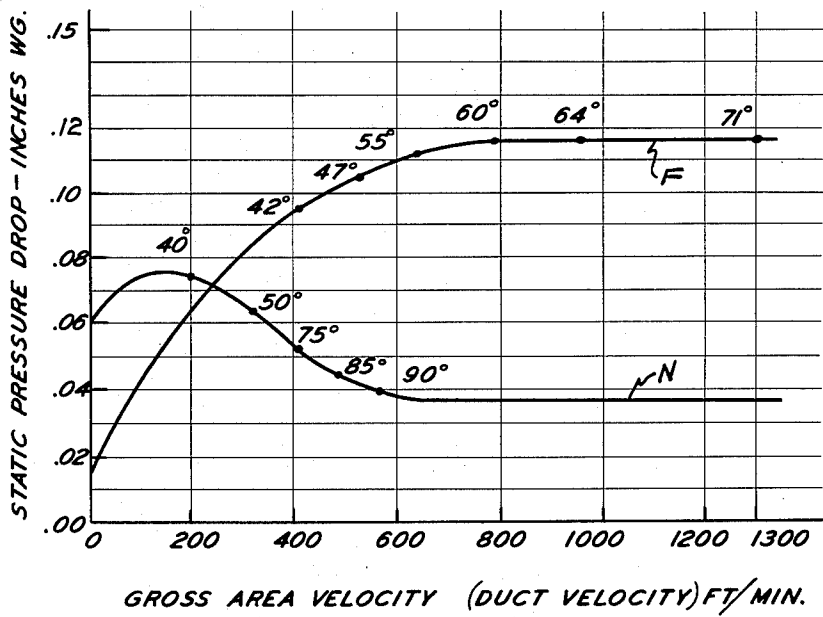


FIG. 15

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DAMPER CONSTRUCTION

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Filed Nov. 29, 1963, Ser. No. 326,759

10 Claims. (Cl. 98—119)

This invention relates generally to backdraft dampers or shutter devices which are adapted for use with fans and blowers employed in air circulating and venting systems, the damper closing the air exhaust opening when the blower is inoperative and opening automatically when the fan or blower is placed in operation. More particularly, this invention relates to a backdraft damper which utilizes pivoted damper blades or vanes of a unique design based upon aerodynamic principles which results in a construction of damper which exhibits radically improved operating characteristics by comparison with previously known devices of this type.

Backdraft dampers are not per se new, such devices having been in use for many years. In general, the blades of such dampers are normally gravity positioned substantially perpendicularly to the path of blower produced air flow when the damper is closed, the blades turning about their pivot shafts into more or less open position when subjected to the impact of air directed thereupon from operation of the associated fan or blower. The damper blades are usually pivoted substantially at the leading edge so that the blade opening force exerted by the air stream upon the damper blade, and which tends to align the blades more nearly with the air flow to reduce the air resistance of the blade, is progressively offset by a blade closing counterforce resulting from the offset of the blade center of mass with respect to the supporting pivot.

In the case of a vertically disposed damper structure in which the blades are driven by impact air from a vertically oriented closure position toward a horizontal open position, the known types of damper blades achieve a maximum open position at high air velocities which is on the order of twenty degrees below the horizontal, at low air velocities the angle being as much as 45 degrees below the horizontal. The partially closed positions of the blades acts as a constriction in the air flow path and thus requires considerably more fan or blower power to drive the air at a given velocity than would be required if the damper blades were fully open. Moreover, since the angle assumed by the damper blade is dependent upon the velocity of the air stream, variations in the air stream velocity cause the damper blades to rise and fall. Such air stream velocity variations result from a number of factors, as for example the opening and closing of doors into the region from which the air is being drawn, or outside backdrafts and cross winds. However, regardless of the source of variation, the damper blades are caused to flutter, resulting in objectionable rattle and vibration.

These obviously undesirable characteristics have caused considerable concern in the industry and numerous attempts have been made to eliminate the flutter problem and to achieve substantially horizontal blade positioning. One such solution utilizes an electric motor coupled to the blade for rotating the blade into fully open position, this solution being obviously an expensive one. Other attempts have included the use of complicated springs and counterbalance devices which cannot be made completely effective because they would prevent closure of the damper when the air flow was terminated, these devices also adding to the costs and maintenance of a damper.

The damper according to the invention is not so limited in that the utilization of a novel design of aerodynamically operated blade results in a damper in which the blades

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open to a full 90° without employing springs or motors or other mechanical attachments, the damper also incorporating therein a positive stop device which prevents the opening of the blades beyond the desired point and thereby eliminates blade flutter, rattle, and vibration by virtue of the fact that the aerodynamic forces exerted upon the damper blades maintain the latter positively against their stop for air stream velocities above a predetermined minimum value. Designs have been worked out for backdraft dampers intended for horizontal and vertical installation, as will be shown hereinafter.

Additionally, the backdraft dampers according to the invention are characterized by the requirement of a higher than usual initial opening pressure which then rapidly decreases to a static pressure drop across the damper which is considerably lower than that of any heretofore known unit, the relatively high initial opening pressure requirement being deliberately incorporated to preclude parasitic partial opening of the damper blade due to outside cross winds during those times when the associated fan or blower is inoperative. Thus, the objectionable shutter rattle which is common to other dampers under normal wind conditions is eliminated. Accordingly, it is a primary object of my invention to provide a novel damper blade construction according to aerodynamic principles which in a first form includes an airfoil structure positioned at the trailing edge of the damper blade and substantially downwind of the pivotal axis of the blade, and which in a second form includes an airfoil of unique design extending from the pivotal axis to the trailing edge of the blade.

Another principal object of my invention is to provide a novel damper blade constructed according to aerodynamic principles in which the leading edge of the blade is positioned upwind of the blade pivotal axis and is so shaped that it proportionally divides the relative wind for rearward flow above and below the airfoil to produce a condition of maximum aerodynamic lift on the airfoil, the above described first form of blade also including a relative wind guiding section between the leading edge of the blade and the effective leading edge of the airfoil positioned at the trailing edge of the blade which insures the optimal angle of attack of the airfoil with respect to the relative wind.

Yet another object of my invention is to provide a novel damper blade construction as aforesaid in which the pivotal blade axis is so positioned with respect to the mass of the blade that a net mass controlled closing torque is always exerted on the damper blade within the operating 90° rotational range of the blade when installed in a complete damper device.

A still further object of my invention is to provide a novel backdraft damper structure which incorporates therein pivoted blades of the aforesaid type and which as a consequence open to a full 90° position with a complete absence of blade flutter, a minimum of wind noise and a minimum static pressure drop across the damper structure.

A further object of my invention is to provide a novel backdraft damper construction as aforesaid which incorporates therein a positive stop mechanism which permits the damper blade to fully open into the air stream and then provides a positive stop to prevent further rotation of the damper blade beyond the desired position.

The foregoing and other objects of my invention will become clear from a reading of the following specification in conjunction with examination of the appended drawings, wherein:

FIGURE 1 is a front perspective view of a damper construction according to the invention as would be seen when looking upward to the left from the bottom

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right front corner with the damper blades fully open and with the blade linkage system in its stop position;

FIGURE 2 is an exploded view on an enlarged scale of the damper of FIGURE 1 viewed downward to the right from the upper left corner illustrating various constructional details of the damper;

FIGURE 3 is a vertical sectional view taken through the damper structure of FIGURE 1 as indicated by the line 3—3 on FIGURE 1;

FIGURES 4 and 5 are vertical sectional views through the damper taken as shown in FIGURE 3 with the exception that the damper blades are shown in intermediate and fully closed position, the three sectional views of FIGURES 3, 4 and 5 also illustrating operation of the blade linkage system;

FIGURE 6 is an enlarged plan view of one of the lever arms which couple the damper blade pivot shaft to the connecting rod of the blade linkage system;

FIGURE 7 is a horizontal sectional view through the damper structure of FIGURE 1 looking downward as would be seen when viewed along the line 7—7 of FIGURE 1;

FIGURE 8 is a side view of the novel blade structure according to the invention intended for use in a damper designed for orientation in a vertical plane, FIGURE 8 illustrating the horizontal or open position of the blade;

FIGURE 9 illustrates the blade of FIGURE 8 in its closed or vertical position;

FIGURE 10 illustrates a damper blade according to the invention which is similar to that of FIGURE 8 but which is intended for use in a damper designed for orientation in a horizontal plane;

FIGURES 11 and 12 are typical mass-torque graphs for damper blades of constructions shown respectively in FIGURES 8 and 10;

FIGURE 13 is a representational diagram of the novel blade according to the invention when disposed in its fully open position within the airstream passing through the plane of a damper;

FIGURE 14 is a diagrammatic showing of the forces exerted on the blade structure of FIGURE 13 resulting from aerodynamic pressures, these forces producing blade opening torques about the pivot shaft; and

FIGURE 15 is a comparison of the static pressure drop across a damper structure as a function of duct air velocity for a typical flat blade design of damper blade and for the design of damper blade according to the present invention.

In the figures, like elements are denoted by like reference characters.

Consider first the showings of FIGURES 1 through 7 for an understanding of the structural arrangement of the various parts which together form a typical damper structure. The damper structure consists of a mounting frame designated generally as 25, a plurality of damper blades each designated generally as 26, and a blade support and linkage structure including parts to be subsequently described.

The mounting frame 25 includes a head 27, sill 28 and a pair of opposite spaced apart side jambs 29. The head, sill and side jambs may be typically made of extruded aluminum sections and are of the shapes best seen in the exploded view of FIGURE 2. The side jambs 29 are formed with inwardly projecting vertically extending channel formations 31 adapted to receive screws 32 threaded thereinto through aligned holes in the head 27 and sill 28 to secure the head, sill and side jambs into a rigid unit. As is best seen in FIGURES 1 and 2, each of the head 27, sill 28 and side jambs 29 is formed with a laterally extending flange portion and these flange portions are also rigidly intersecured at their corners by tie plates 30 and rivets 33. As best seen in FIGURE 2, the sill 28 is formed with an upturned rear flange 34 which provides a water stop for back driven rain, for example, the trapped water running out through the weep holes 35. Extending upward from the sill 28 trans-

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versely between the side jambs 29 and abutting the latter is a sill stop 36 which, as best seen in FIGURE 5, functions as a blade stop for the bottom edge of the lower damper blade 26, the head 27 being similarly provided with a head stop 37 which is more clearly observed in operative position in the showing of FIGURE 5.

As best seen in the showings of FIGURES 2 and 7, the side jambs 29 are of generally T-shape in horizontal section with the front-to-rear extending stem of the T including an inwardly offset channel or U-shaped portion having a wall 38 perpendicular to the plane of the damper device, and front and rear connecting walls 39 and 40 respectively which join the inwardly offset wall 38 to the main stem side wall portions of the T-shaped side jambs 29. The inwardly offset jamb wall 38 is apertured as at 41 at vertically spaced intervals along the length of the jamb to receive metal grommets 42 which when secured within the apertures 41 act as bearings for the cylindrical shaft portions 43 of the damper blade pivot pins designed generally as 44. When the damper blade assembly has been installed in the mounting frame the cover plates 45 are snapped into the side jamb opening between the outer ends of the front and rear channel walls 39 and 40 to cover the exposed ends of the pivot pins and provide a continuous side wall surface as best seen in FIGURES 1 and 7.

Each of the damper blades 26 includes a vane portion 46 which constitutes the major structure of the damper blade located downwind of the pivotal axis, and a lead section 47 to which the vane 46 and pivot pins 44 are secured and which extends upwind of the damper blade pivotal axis. The lead section 47 may also be extrusion formed of aluminum and is observed to be of a thicker cross section than that of the blade vanes 46 to provide a counterbalancing mass effect to be described in more detail subsequently herein. The upper surface of the lead section proximate the forward edge is formed to receive a soft vinyl gasket 48 which provides an inter-blade seal when the damper is closed, in the manner best seen in the showing of FIGURE 5. The trailing edge of the lead section 47 is initially of open V formation so that the forward edge of the vane 46 may be inserted therewithin and fixed rigidly thereto by pressure applied to the V forming wall portions to clamp the same tightly about the front edge of the vane 46. Finally, the lead section 47 is formed with a transversely extending substantially rectangular passage 49 adapted to receive by forced fitting a complementally shaped rectangular cross section axial extension 50 of the cylindrical pivot shaft 43 of pivot pin 44.

Referring now principally to FIGURES 2 through 6 there is seen a flat plate elongated lever arm 51 provided at one end thereof with a circular aperture 52 therethrough, and provided at the opposite end with a rectangular aperture 53. The rectangular aperture 53 is so oriented that a diagonal thereof makes an angle of approximately 8° with the center line of the arm 51, this particular angle being most suitable for the illustrated damper geometry. Each of the damper blades 26 has one of the lever arms 51 rigidly affixed thereto by means of the rectangular section 50 of the pivot pin 44 which is forced through the rectangular aperture 53 and into the rectangular passage 49 of the lead section 47. Disposed on the jamb side of the lever arms 51 is a vertically extending connecting rod 54 apertured as at 55 at vertically spaced intervals along the length thereof, which spacing intervals are the same as the intervals between the apertures 41 in the jamb wall 38. Secured within each of the connecting rod apertures 55 is a metal grommet 56, and similarly secured within each of the lever arm apertures 52 is a metal grommet 57. A rivet 58 is passed freely through the metal grommets 56 and 57 and secured so that the lever arms 51 are all freely pivotally secured to the connecting rod 54.

From FIGURES 1, 3 and 7 it is clear that the length

of the lever arms 51 is so chosen that when the damper blades 26 are in their completely open position the front edge of the connecting rod 54 abuts the rear surface of transversely extending wall 40 of the side jamb 29. From the showings of FIGURES 4 and 5 it is clear that movement of the damper blade 26 downward toward closing position causes the connecting rod 54 to move rearward and upward out of engagement with the wall 40. The positive stop provided by engagement of the connecting rod 54 with the wall 40 of the side jamb prevents the damper blades 26 from rising beyond the fully open position illustrated in FIGURE 3, the design of the damper blades according to the invention being such that it is possible to cause the blades to rotate to approximately 60° beyond the fully open position illustrated at air speeds above about approximately eight hundred feet per minute. It is this capacity for rotation beyond the fully open position which when restrained by the stop action of the connecting rod provides the positive force upon the damper blades that prevents flutter and rattle.

Turn now to a consideration of FIGURES 8 and 9 which illustrate a profile of a damper blade 26 of the type illustrated in the previously described figures for use in a damper structure intended to be mounted in a vertical plane. The pivotal axis of the damper blade is located in the rectangular passage of the lead section 47 and is designated by the letter C. The mass of the lead section 47 which lies to the left of the pivotal axis C is shown as being concentrated at the dot designated M and produces a torque τ_M which is observed to be counterclockwise and designated as τ_{M90} in FIGURE 8 while being designated as τ_{M0} and being clockwise in the showing of FIGURE 9. The τ_{M90} designation of FIGURE 8 designates that this is the torque resulting from the mass M of the lead section 47 when the damper blade is in its 90° or fully open position, which is of course the positional orientation shown in FIGURE 8. Similarly, in FIGURE 9 the τ_{M0} designation indicates the torque produced by the mass M of the lead section 47 when the damper blade is in its zero degree or fully closed position.

In similar fashion, the mass of the vane 46 and that part of the lead section 47 lying to the right of the pivotal axis C is designated as m and is indicated as being located to produce the clockwise torque designated as τ_{m90} in FIGURE 8 while also producing a clockwise but smaller torque τ_{m0} in the showing of FIGURE 9. The graph of FIGURE 11 gives a general picture of the mass controlled net torque function for the damper blades of FIGURES 8 and 9, the net torque being the sum of the torques τ_M and τ_m and being illustrated for a range of blade rotation from 0° to more than 90°. It should be noted that a 90° and somewhat beyond the net torque function is positive, that is, clockwise for the orientations illustrated in FIGURES 8 and 9 so that when the damper blades are in full open position and the driving fan or blower is shut down there is a positive torque operative upon the blade which causes it to return to its closed position. The net torque at its closed position is observed to be substantially higher than that at the 90° position because, as is seen in FIGURE 9, both τ_{M0} and τ_{m0} are producing clockwise torques, whereas in the full open position τ_{M90} is offset to a large degree by τ_{M90} .

The torque characteristic of FIGURE 11 is of course the result of proper selection of the masses M and m and their location relative to the center of rotation C. The mass M of the lead section 47 thus functions as a counterbalance once the blade has opened to a certain degree sufficient to throw the center of mass M to the left of the center of rotation C. On the other hand, the relative positioning of the center of mass M relative to the rotational axis C when the damper blade is closed aids in producing the relatively high-torque initial opening condition that prevents the rattle caused by backdraft and crosswinds and permits the damper to open only un-

der sustained air pressure produced by the actuation of an associated fan or blower.

Consider now FIGURE 10 in conjunction with the showing of FIGURE 8 from which it will be observed that the identical vane 46 is utilized but that the lead section 47' of FIGURE 10 differs from the lead section 47 of FIGURE 8 in that the axis of rotation C' has been shifted vertically relative to the axis of rotation C seen in the lead section 47 of FIGURE 8, the masses M and m being the same in both structures. The blade configuration of FIGURE 10 differs from that of FIGURE 8 because it is intended for use in a damper structure oriented for disposition in a horizontal plane such that the damper blades are in closed position when horizontal, this condition being shown in FIGURE 10, and are rotated into their fully open vertical position so that they appear as would be seen by rotating FIGURE 10 counterclockwise by 90°. With FIGURE 10 held in a 90° counterclockwise rotated position it will be seen that the mass M of the lead section 47' produces a clockwise torque while the mass m produces a counterclockwise torque, the net torque about the axis of rotation C' being positive or clockwise at the 90° position as is seen from the graph of FIGURE 12 so that it is clear that the damper blade of FIGURE 10 will also automatically close itself upon shut down of the associated fan or blower.

While still holding FIGURE 10 in the 90° counterclockwise rotated position it is instructive to consider FIGURE 8 because it will be immediately recognized that the masses M and m are so positioned relative to the axis of rotation C that they both produce counterclockwise torques. Hence the configuration of FIGURE 8 could not be used in a horizontally mounted damper device because the damper blade having been once opened would remain in such position when the driving fan or blower were turned off. This would of course be completely unsatisfactory, one solution to this problem being that illustrated by the configuration of FIGURE 10 which merely involves a shifting of the axis of rotation of the damper blade.

FIGURE 12 is a general plot of the mass produced net torque function of the structure of FIGURE 10 due to the masses M and m for a range of blade rotation somewhat greater than 90°. The net torque function of FIGURE 12 differs considerably from that of FIGURE 11 because of the previously described change in configuration of FIGURE 10 and the changed orientation of the damper blades. While the net torque functions are shown for a freely pivoted blade so that characteristics beyond 90° rotation are observed, the blades of the damper structures in fact do not rotate beyond their fully opened positions because of the previously described positive stop mechanism afforded by the connecting rod 54.

Turning now to a consideration of the airfoil effects resulting from the configuration of the novel damper blade, consider FIGURES 8 and 10 which illustrate the design factors involved in the evolution of the novel blade structure. The vane 46 appears in the showing of FIGURE 8 to be basically composed of two sections which merge with one another, one section being an airfoil section designated by the letter A and having a chord length designated by the letter D while the other section is the web section S which joins the leading edge of the airfoil A to the trailing end of the lead section 47 and is of a length designated by the letter d . Alternatively, the vane 46 can be considered to be an airfoil in its entirety since the web S also produces aerodynamic lift. The vane when so considered is of unique design effective to shift the center of maximum lift toward the trailing edge of the vane to maximize the length of the moment arm thereof about the pivotal axis. In actuality, that part of the lead section 47 which extends between the pivotal axis and the front edge of the connecting web S functions as part of the web and should be so considered. The blade geometry is established by first drawing a

horizontal reference line designated as 59 in the showing of FIGURE 10 and as 59' in the showing of FIGURE 8, these reference lines passing through the center of rotation of the illustrated blade. Next, the blade structure is rotated about its pivotal axis until a straight line extending between the trailing edge 60 of the vane and nose 61 of the lead section makes a 1° angle with the reference line 59, this extended line being designated as 62 in both figures. In this connection, it is to be noted that the 1° angle is so oriented that the trailing edge 60 is positioned vertically higher than the nose 61. For purposes of analysis and description the vane 46 will be hereafter considered as though it were the combination of an airfoil section A and a web section S although as previously pointed out it is in reality also an airfoil of unique design in its entirety.

With the blade so oriented the airfoil chord line 63 which passes through the leading and trailing edges of the airfoil section A is observed to be inclined at an angle of 10° above the horizontal reference line 59 and the inclination of the connecting web S is observed to make an angle of 15° above the same horizontal reference line 59. It thus follows that the angle between the airfoil chord line 63 and the plane of the connecting Web S is 25°. This 25° angle of the airfoil section A with respect to the web S is very important because an airfoil functions as such when its chord line is disposed within an angular range to the relative wind between approximately -27° and +4°, the 27° limitation representing the stall angle. Moreover, the effectiveness of the airfoil in producing lift increases continuously as the angle of attack approaches the limiting value of the stall angle.

The foregoing considerations should be kept in mind while now referring also to the diagram of FIGURE 13 which illustrates the damper blade according to the invention disposed in an air stream at what corresponds to the fully open orientation of such a blade in a complete damper structure. The relative wind is divided by the lead section nose 61 so that part flows upward above the airfoil blade structure and part flows downward below. It is observed that the direction of flow of the relative wind flowing over the upper surface of the blade is altered by the angular inclination of the web section S so that the relative wind is at a 25° angle to the chord line of airfoil section A even though the chord line of the airfoil section A is only at a 10° angle to the direction of flow of the relative wind before the latter reaches the blade structure.

The connecting web S is thus seen to be an airflow direction control device which causes the airfoil section A to be optimally oriented with respect to the relative wind regardless of the initial direction of the relative wind before encountering the blade structure. For example, if the blade were rotated downward through an angle of say 30° the web section S would be inclined downward at an angle of approximately 15° below the horizontal, but the incoming horizontally moving air flow is turned by the blade structure to flow downward along the web section so that the relative wind still encounters the airfoil section A at substantially the optimal angle. The ability of the blade according to the invention to thus align the relative wind with respect to the airfoil section extends the angular limits within which the blade structure functions as an aerodynamic system, a blade of the illustrated design being aerodynamically functional between approximately -45° and +60° with respect to the horizontal.

While the airfoil section A, illustrated as being of the geometric type, could be constructed to include a bottom straight surface which would generally follow the chord line 63 as shown in FIGURE 10, two distinct advantages are realized by the omission of such structure. As a first matter, the omission of the chordally extending bottom surface of the airfoil section A materially simplifies the

construction of the vane 46 and permits its fabrication from a single press-formed piece of material such as aluminum. Additionally, and very important, is the fact that the omission of the chordally extending bottom surface of the airfoil section A creates a cavity or a chamber beneath the curved upper airfoil portion which acts as a plenum to slow the velocity of the air stream traveling beneath the blade and thus create an even greater pressure differential across the airfoil which further increases the generated lift. The trailing edge of the airfoil section A is inflected during forming to provide a simulated flap 64 at the trailing marginal edge of the airfoil, the flap providing a certain amount of additional lift and also strengthening the edge of the blade.

The envelope of the lift forces operating on the vane 46 of FIGURE 13 is illustrated in the diagrammatic showing of FIGURE 14 at 65. It will be noted that the maximum lift forces are generated, as would be expected, at the airfoil structure A, but it should be also noted that effective lift is produced by the web S due to the type of air flow above and below the connecting web. While one of the main functions of the lead section 47 is that of providing a mass counterbalance, as has already been described in connection with the showings of FIGURES 8 through 12, another important function of the lead section is that of dividing the relative wind to cause the proper amount of air to flow above and below the airfoil to thereby maximize the available lift.

As is best seen in FIGURE 13 the lead section contour 66 below the nose 61 increases the air velocity on the underside of the lead section between the nose 61 and the pivotal axis of the damper blade so that a certain degree of aerodynamic lift force is also produced on the lead section, the forces being as indicated by the lead section lift envelope 67 shown in FIGURE 14. The lift is of course in such direction as to produce a torque about the blade rotational axis which aids the lift produced by the airfoil section. The length of the lead section between the nose 61 and the pivotal axis is also of importance in that it provides a transition section allowing for the establishment of relatively streamlined flow of the relative wind by the time the latter reaches the connecting web S so that the connecting web is enabled to effectively control the air flow to the airfoil section A. For a damper blade of length L, as shown in FIGURE 8, it has been found that the length of the lead section between the nose 61 and the pivotal axis of the blade should be about L/4 or 25% of the total blade length, this length L/4 being sufficient to provide effective air flow control and also satisfy the mass counterbalance requirements.

From the foregoing it should be now clear that the design of a novel damper blade constructed in accordance with the present invention involves considerations relating to the total length of the blade profile L, the chord length D of the airfoil section A, and the length of the web section S as well as the ratio of the masses M and m. The airfoil section A has been placed at the rear end of the damper blade in order to maximize the aerodynamically produced torque by providing the longest possible moment arm for the lift forces. It has been found that the chordal length D of the airfoil section A may be held constant while the length of the connecting web S designated by the letter d may be varied within limits to provide damper blades having profiles of different lengths. For example, for a blade profile having lengths ranging between approximately 3½" and 5½" the airfoil chord length D may be maintained fixed at substantially 1¾" while the length d of the web section S may vary in length between approximately ¾" and 2".

The airfoil section A may also be of the symmetric type provided that a non-zero angle of attack is always maintained because symmetric airfoils produce no lift at zero angle of attack and only negligible lift at small attack angles in air streams having velocities below several thousand feet per minute, such velocities being substantially

higher than those encountered in applications for which backdraft dampers are usually employed, as for example is shown by the normal range of air speeds designated in the showing of FIGURE 15 to which reference will be subsequently made.

It should be also noted that an aerodynamically operated damper blade capable of full opening can be constructed according to the foregoing design considerations even when the lead section 47 is omitted, so that the leading edge of the blade is substantially at the pivotal axis. In such case the mass counterbalance effect of the lead section is of course lost, and the generated lift must be sufficient to control the entire blade mass. The fully open position of the blade will therefore require a somewhat higher minimum airstream velocity.

The graph of FIGURE 15 illustrates the measured pressure drop across damper units embodying two types of blade structure as a function of the air velocity through the duct cross section of a wind tunnel test device, the curve designated as F being that for a flat blade type of design while the curve designated N is for a damper incorporating blades fabricated according to the teachings of the present invention. Throughout the usual range of air velocities, between about 550 feet per minute and 1200 to 1300 feet per minute, it is evident that the pressure drop across the damper employing blades according to the invention is approximately only 35% or less of the pressure drop across a damper employing the flat type of blade construction. The presence of the aerodynamic lift forces is clearly evident from a comparison of the curves of FIGURE 15 at given air flow velocities. For example, at about 500 feet per minute the damper blades in the damper structure according to the invention are seen from curve N to be open approximately 86° while the blades of the flat blade damper are seen from curve F to be open only about 45°. Similarly, it is seen from curve N that the damper blades of the invention are fully open at air velocities below 600 feet and remain so thereafter while the flat blade design of curve F shows that the blades are only open at 71° at air velocities as high as 1300 feet per minute.

The other fact of significance which is disclosed by the graph of FIGURE 15 is revealed at the very low velocity region around and slightly above zero where it is observed that curve N exhibits an initially high static pressure drop characteristic while the conventional flat blade design exhibits a very low static pressure characteristic. The very low pressure at zero velocity characteristic of curve F makes dampers so characterized highly susceptible to rattle caused by backdrafts and cross winds, whereas the initially high static pressure characteristic of curve N at zero velocity requires a slight positive pressure build-up before permitting the blades of the damper to open. This initially high static pressure characteristic of course then drops quickly until in the regions of usual interest above 450 or 500 feet per minute of air velocity the pressure drop is quite small compared to that of the flat blade damper structures typified by the pressure curve F.

Having now described my invention in connection with a particularly illustrated embodiment thereof, it will be understood that modifications and variations of my invention may now occur from time to time to those persons normally skilled in the art without departing from the essential spirit and scope of my invention, and accordingly it is intended to claim the same broadly as well as specifically as indicated by the appended claims.

What is claimed as new and useful is:

1. An aerodynamically operated pivoted damper blade having a leading edge and a trailing edge for use in a damper structure which is intended for disposition in the air flow path of a blower device effective to close the path when the blower is inoperative and effective to open under air pressure when the blower becomes operative, said

damper blade having a pivotal axis and comprising in combination,

(a) an airfoil section having a definable leading edge and a trailing edge, said airfoil section being convex up and concave down to form a plenum under the airfoil and being spaced downwind from the pivotal axis of the blade when the blade is operatively disposed in the airstream, and

(b) airstream guiding means extending from said pivotal axis to said airfoil section and fixedly positioning the airfoil section for revolving movement about said pivotal axis,

said airstream guiding means being shaped to divide the airstream to cause separate portions of the latter to flow respectively above and below said guiding means and being effective to direct the airstream toward the leading edge of said airfoil section at a non-zero angle of attack less than the stall angle of the airfoil section when the damper blade has rotated to a position which is at least half open in the airstream, the maximum depth of said plenum under said airfoil occurring at a point closer to the trailing edge of said blade than to the leading edge of said blade

2. An aerodynamically operated pivoted damper blade for use in a damper structure which is intended for disposition in the air flow path of a blower device effective to close the path when the blower is inoperative and effective to open under air pressure when the blower becomes operative, said damper blade having a pivotal axis and comprising in combination,

(a) a lead section having a free forward leading edge extending upwind for a distance from the pivotal axis of the blade when the blade is operatively disposed in the airstream,

(b) an airfoil section having a leading edge and a trailing edge, said airfoil section being convex up and concave down to form a plenum under the airfoil and being spaced downwind from the pivotal axis of the blade when the blade is operatively disposed in the airstream, and,

(c) airstream guiding means extending between and fixedly coupling said lead section to said airfoil section,

said lead section being shaped to divide the airstream to cause separate portions of the latter to flow respectively above and below the lead section to the said airstream guiding means, said guiding means being effective to direct the airstream toward the leading edge of said airfoil section at an angle of attack less than the stall angle of the airfoil section when the damper blade has rotated to a position which is at least half open in the airstream, the maximum depth of said plenum under said airfoil section occurring at a point closer to the trailing edge of said blade than to the leading edge of said blade, the upwind extent of said lead section from the blade pivotal axis being substantially less than the downwind spacing of the trailing edge of said airfoil from the blade pivotal axis, the mass of said lead section and the mass of the downwind blade structure being so proportioned in magnitude and being so positioned relative to the pivotal axis of the blade that the net mass-controlled rotational torque about the blade pivotal axis throughout the permissible range of blade rotation is always in such sense as to tend to close the damper.

3. A damper structure for disposition in the air flow path of a blower device effective to close the path when the blower is inoperative and effective to open under air pressure when the blower becomes operative, comprising in combination, at least one pivoted damper blade having a leading edge and a trailing edge, a mounting frame, means pivotally mounting said blade within said frame, and stop means carried by said pivoted damper blade effective by engagement of said stop means with said damper mounting frame to positively prevent blade ro-

tation beyond a predetermined angle and independent of airstream velocity, said damper blade including,

- (a) an airfoil section having a definable leading edge and a trailing edge, said airfoil section being convex up and concave down to form a plenum under the airfoil and being spaced downwind from the pivotal axis of the blade when the blade is operatively disposed in the airstream, and
- (b) airstream guiding means extending from said pivotal axis to said airfoil section and fixedly positioning the airfoil section for revolving movement about said pivotal axis,

said airstream guiding means being shaped to divide the airstream to cause separate portions of the latter to flow respectively above and below said guiding means and being effective to direct the airstream toward the leading edge of said airfoil section at a non-zero angle of attack less than the stall angle of the airfoil section when the damper blade has rotated to a position which is at least half open in the airstream, the maximum depth of said plenum under said airfoil section occurring at a point closer to the trailing edge of said blade than to the leading edge of said blade.

4. An aerodynamically operated pivoted damper blade for use in a damper structure which is intended for disposition in the air flow path of a blower device effective to close the path when the blower is inoperative and effective to open under air pressure when the blower becomes operative, said damper blade having a pivotal axis and comprising in combination,

- (a) a lead section extending upwind for a distance from the pivotal axis of the blade when the blade is operatively disposed in the airstream,
- (b) an airfoil section contour-formed of substantially constant thickness rigid material to provide an airfoil curvature that is generally convex up and concave down to thereby form a plenum under the airfoil, said airfoil having leading and trailing edges and being spaced downwind from the pivotal axis of the blade when the blade is operatively disposed in the airstream, and
- (c) airstream guiding means extending between and fixedly coupling said lead section to said airfoil section,

said lead section being shaped to divide the airstream to cause separate portions of the latter to flow respectively above and below the lead section to the said airstream guiding means, said guiding means being effective to direct the airstream toward the leading edge of said airfoil section at an angle of attack less than the stall angle of the airfoil section when the damper blade has rotated to a position which is at least half open in the airstream, the maximum depth of said plenum under said airfoil section occurring at a point closer to the trailing edge of said blade than to the leading edge of said blade.

5. An aerodynamically operated pivoted damper blade for use in a damper structure which is intended for disposition in the air flow path of a blower device effective to close the path when the blower is inoperative and effective to open under air pressure when the blower becomes operative, said damper blade having a pivotal axis and comprising an airfoil section contour-formed of substantially constant thickness rigid material to provide an airfoil curvature that is generally convex up and concave down to thereby form a plenum under the airfoil, said airfoil having leading and trailing edges with the leading edges substantially at the pivotal axis of the blade, said leading edge being shaped to divide the airstream to cause separate portions of the latter to flow respectively above and below said airfoil section when the damper blade has rotated to a position which is at least half open in the airstream, the maximum depth of said plenum under said airfoil occurring at a point closer to the trailing edge of said blade than to the leading edge of said blade.

6. The damper blade structure as set forth in claim 5 wherein the radius of curvature of said airfoil is sharply reduced at the trailing edge of said airfoil to provide a simulated flap.

7. An aerodynamically operated pivoted damper blade for use in a damper structure intended for disposition in the air flow path of a blower device effective to close the path when the blower is inoperative and effective to open under sustained air pressure when the blower becomes operative, said damper blade comprising in combination a lead section and a vane section fixedly related to one another, the rotational axis of the blade extending transversely horizontally through the damper blade so that when the blade is operatively disposed within the airstream the lead section and vane section extend respectively upwind and downwind of the blade rotational axis, said lead section extending forward from the blade pivotal axis to a free forward leading edge, said vane section including,

- (a) a geometric airfoil section contour-formed of substantially constant thickness rigid material to provide an airfoil curvature that is generally convex up and concave down to thereby form a plenum under the airfoil, said airfoil having a leading edge and a trailing edge,
- (b) a straight planar connecting section extending forward from the leading edge of the airfoil section and merging with the lead section proximate to the pivotal axis,

said lead section leading edge being shaped to divide the relative wind to thereby cause a portion to flow above and a portion to flow beneath the lead section toward the said vane section, the chord line of the said airfoil section being inclined at an angle to the plane of the said connecting section, and the plane of the said connecting section being inclined at an angle to the plane of the lead section such that the relative wind portion flowing toward the connecting section above the lead section is caused to approach the airfoil section chord line at an angle of attack less than the stall angle of the airfoil section when the damper blade has rotated to a position which is at least half open in the airstream.

8. The damper blade structure as set forth in claim 7 wherein the angle made by the airfoil chord line with the plane of the connecting section is substantially 25°.

9. An aerodynamically operated pivoted damper blade for use in a damper structure intended for disposition with its plane vertically oriented in the air flow path of a blower device effective to close the path when the blower is inoperative and effective to open under sustained air pressure when the blower becomes operative, said damper blade comprising in combination a lead section and a vane section fixedly related to one another, the rotational axis of the blade extending transversely horizontally through the damper blade so that when the blade is operatively disposed within the airstream the lead section and vane section extend respectively upwind and downwind of the blade rotational axis, said lead section extending forward from the blade pivotal axis to a free forward leading edge, said vane section including,

- (a) a geometric airfoil section contour-formed of substantially constant thickness rigid material to provide an airfoil curvature that is generally convex up and concave down to thereby form a plenum under the airfoil, said airfoil having a leading edge and a trailing edge,
- (b) a straight planar connecting section extending forward from the leading edge of the airfoil section and merging with the lead section proximate to the pivotal axis,

said lead section leading edge being shaped to divide the relative wind to thereby cause a portion to flow above and a portion to flow beneath the lead section toward the said vane section, the chord line of the said airfoil section being inclined at an angle to the plane of the said con-

necting section, and the plane of the said connecting section being inclined at an angle to the plane of the lead section such that the relative wind portion flowing toward the connecting section above the lead section is caused to approach the airfoil section chord line at an angle of attack less than the stall angle of the airfoil section when the damper blade has rotated to a position which is at least half open in the airstream, the centers of mass of the lead section and vane section being so located relative to the pivotal axis of the blade that the torques produced thereby about the pivotal axis are both in blade closing direction when the blade is vertically oriented substantially in its closed position in a damper structure and become counter to one another when the blade is open beyond at least a predetermined minimum amount.

10. An aerodynamically operated pivoted damper blade for use in a damper structure intended for disposition with its plane horizontally oriented in the air flow path of a blower device effective to close the path when the blower is inoperative and effective to open under sustained air pressure when the blower becomes operative, said damper blade comprising in combination a lead section and a vane section fixedly related to one another, the rotational axis of the blade extending transversely horizontally through the damper blade so that when the blade is operatively disposed within the airstream the lead section and vane section extend respectively upwind and downwind of the blade rotational axis, said lead section extending forward from the blade pivotal axis to a free forward leading edge, said vane section including,

(a) a geometric airfoil section contour-formed of substantially constant thickness rigid material to provide an airfoil curvature that is generally convex up and concave down to thereby form a plenum under the airfoil, said airfoil having a leading edge and a trailing edge,

(b) a straight planar connecting section extending forward from the leading edge of the airfoil section and merging with the lead section proximate to the pivotal axis,

5 said lead section leading edge being shaped to divide the relative wind to thereby cause a portion to flow above and a portion to flow beneath the lead section toward the said vane section, the chord line of the said airfoil section being inclined at an angle to the plane of the said connecting section, and the plane of the said connecting section being inclined at an angle to the plane of the lead section such that the relative wind portion flowing toward the connecting section above the lead section is caused to approach the airfoil section chord line at an angle of attack less than the stall angle of the airfoil section when the damper blade has rotated to a position which is at least half open in the airstream, the centers of mass of the lead section and vane section being so located relative to the pivotal axis of the blade that the torques produced thereby about the pivotal axis are counter to one another when the blade is fully open and fully closed, and the net mass-controlled torque operative on the blade is always in blade closing direction.

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