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3,550,058

ELECTRICAL RESISTOR STRUCTURE

Filed May 29, 1968

2 Sheets-Sheet 1

FIG. 1

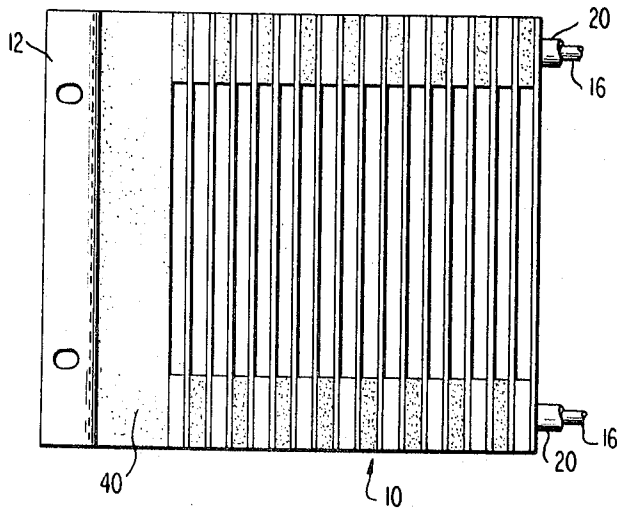


FIG. 3

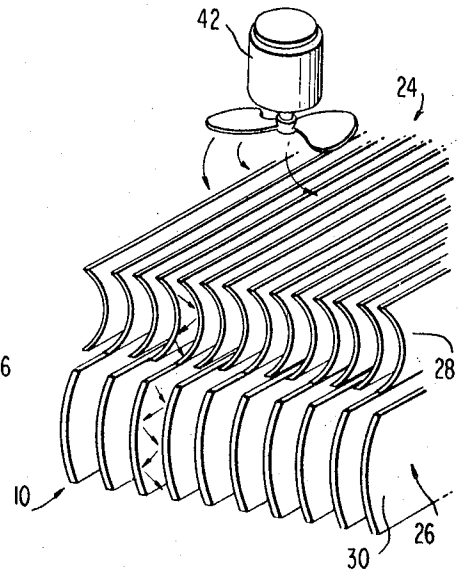
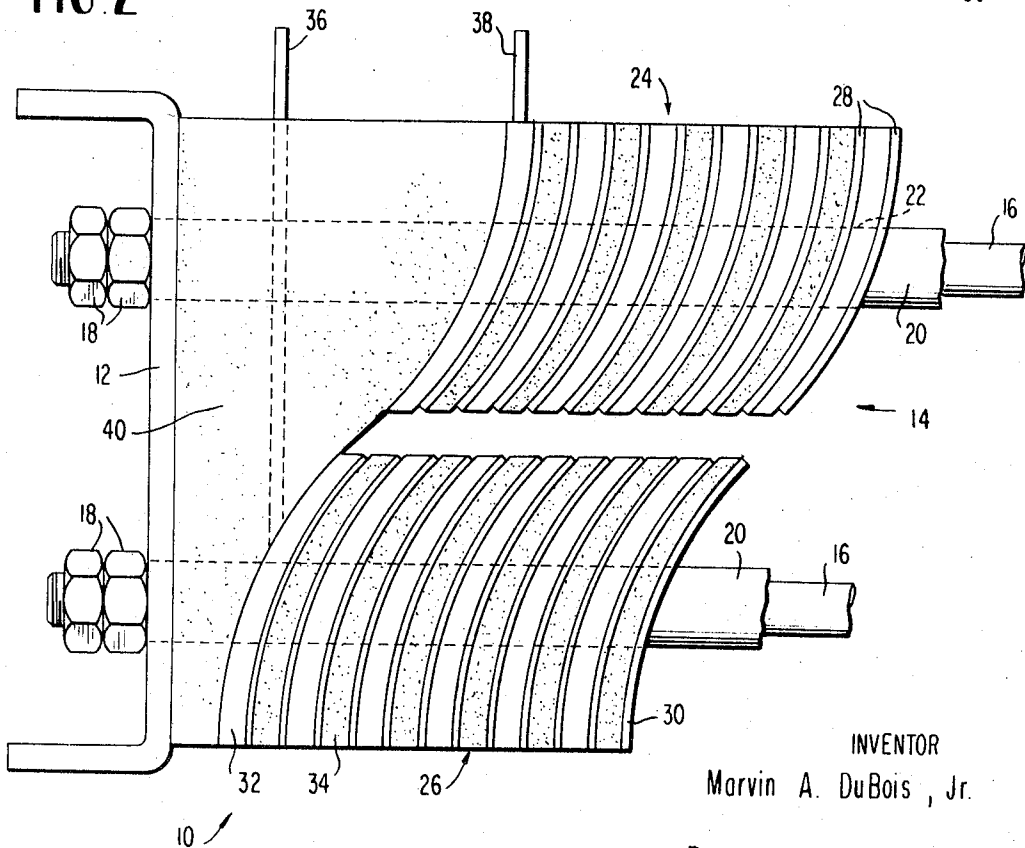


FIG. 2



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FIG. 4

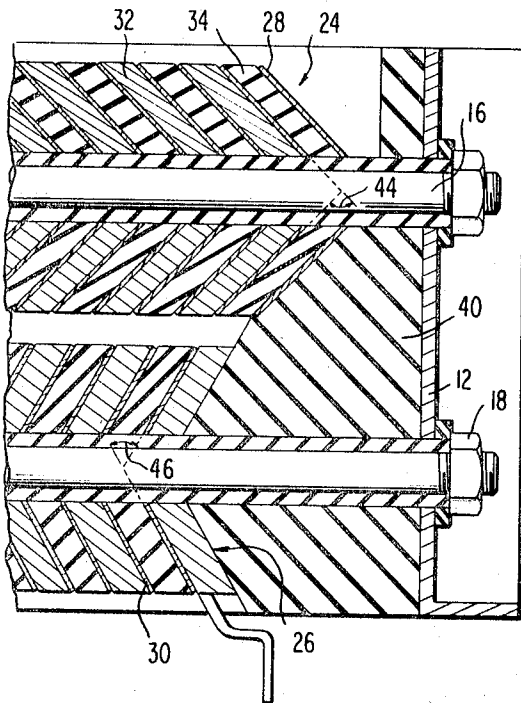
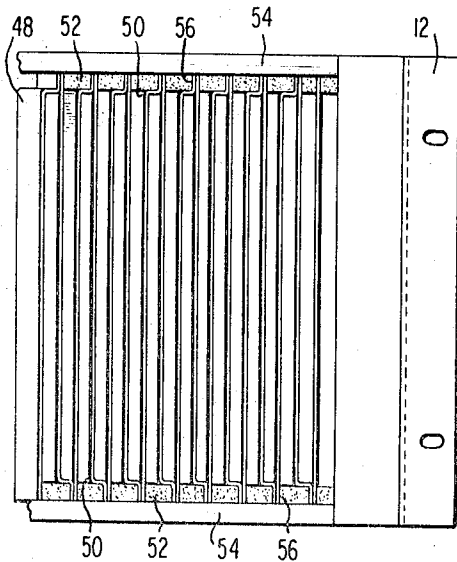


FIG. 6

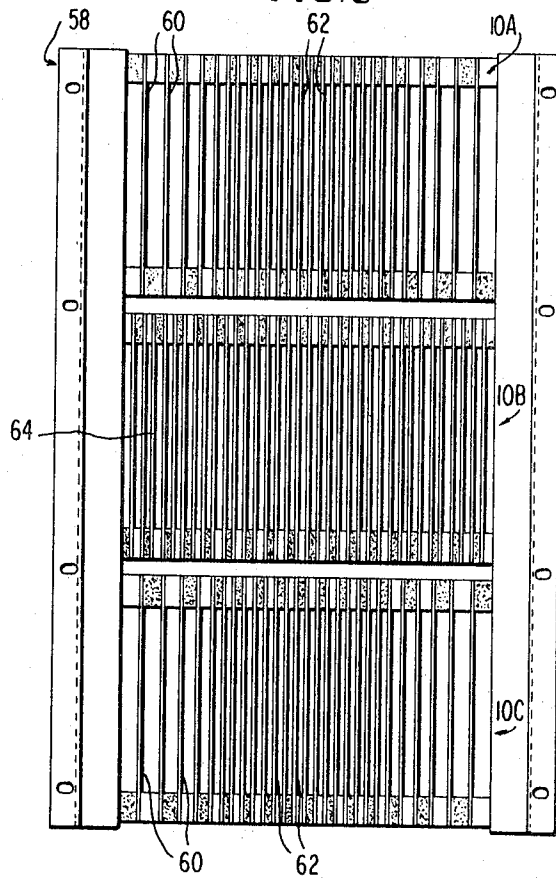
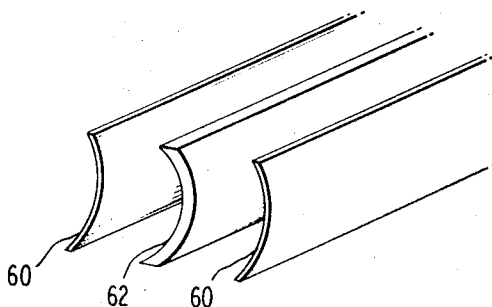


FIG. 5

FIG. 7



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ABSTRACT OF THE DISCLOSURE

A heavy duty electrical resistor is formed by combining a ventilation source to create a moving stream of forced air with a resistor grid structure designed to create maximum air turbulence within the resistor bank. Individual resistor grids on the entrant end of the bank are inclined in a direction opposite to the direction of air flow and the grid spacing and configuration is set to create internal reversals of flow direction with increased air turbulence within the bank.

BACKGROUND

This invention relates to resistor structures generally, and more particularly to a novel and improved heavy duty ventilated resistor structure.

Large, heavy duty resistance banks are presently required for a variety of high voltage applications, such as for example in starting and regulating devices on electrically driven vehicles, large electrically operated dynamic braking systems for vehicles, and similar applications necessitating the effective resistance control of extremely high electrical currents. Generally resistor structures capable of handling currents of this magnitude include a plurality of interconnected resistor grids formed from a strip of thin metallic material which is shaped to form a number of U-shaped, substantially parallel convolutions. These multi-grid units are then stacked and electrically interconnected to form a complete resistor structure.

The capacity of such heavy duty high voltage resistor structures is limited by mechanical as well as electrical considerations. For example, although it is often desirable to limit the size and weight of a resistor bank to achieve economies in space and cost, limitations pertaining to the structural strength and electrical capacity of such resistors cannot be ignored. When a high current is applied to a thin, metallic, resistor grid, there is a tremendous mechanical shock which tends to deform the grid, and weaker grids which succumb to this mechanical shock often short circuit or otherwise damage the resistor. In many cases it is necessary to electrically parallel resistor sections to increase the electrical handling capacity of a resistor bank, and the mechanical shock on these individual parallel sections when a high current load is applied thereto can be great.

With any high current carrying resistor bank, resistor cooling becomes a prime consideration, and resistor design is subject to structural limitations required to facilitate adequate cooling of the bank. Recent trends in resistor design have been directed toward the development of high capacity resistor structures intended to facilitate grid cooling while increasing grid structural strength to withstand mechanical shock. With these goals in mind, curved resistor grids have been designed to replace the previously employed straight grids. These curved grid structures formed from thin metal strips inherently possess a greater mechanical strength than did the straight grids of thin metal tape previously employed, and consequently they exhibit greater resistance to deformation by the mechanical shock occurring when a high current is applied thereto. These grid structures, due to their increased rigidity,

also tend to resist external pressures applied by forced ventilation systems.

The design of a curved grid electrical resistor bank is particularly well illustrated by U.S. Patent 2,875,310 to Schoch. However, such previous curved grid designs have been exclusively directed toward an increase in the strength of the individual resistor grids within a bank while decreasing the size and space requirements for the bank. The heat transfer capabilities of such grids have not constituted a primary consideration in the design of curved grid banks. In fact known curved grid resistor units have been carefully oriented in such a way that when forced air cooling is applied thereto, the air flow between the grids will be completely laminar to eliminate eddy currents of air and turbulence. This philosophy of smooth, laminar airflow between equally spaced, curved grids with the elimination of air eddy currents and emphasis on the increased structural strength provided by a curved grid configuration has dominated presently known curved grid resistor design.

The enhanced structural strength achieved through the use of curved resistor grids permits the use of lighter weight grids or increases slightly the capacity of conventional weight grids. This increased capacity obtained through purely structural considerations results in some saving in weight and space, for the size of the resistor bank can be decreased by decreasing the number of individual resistor grids required to handle a specific current magnitude. However, when design is dictated solely by considerations of structural strength, the savings achieved are contributed only by the elimination of a few relatively inexpensive resistor grids and by decreasing somewhat the overall size of the resistor bank.

It is a primary object of the present invention to provide a novel and improved electrical resistor structure having a high current capacity.

Another object of this invention is to provide a novel and improved electrical resistor structure having a high current capacity which is adapted for rapid and economical manufacture.

A further object of this invention is to provide a novel and improved electrical resistor structure having a high current capacity which exhibits an enhanced heat dissipating capability combined with high structural strength.

Another object of this invention is to provide a heavy duty force ventilated resistor structure designed to create maximum cooling air turbulence within such structure.

A still further object of this invention is to provide a novel and improved force ventilated resistor structure incorporating novel grid spacing and design to equalize the distribution of back pressure in the cooling air to assure even cooling and an even distribution of heat in the air issuing from a grid bank.

These and other objects and details of the invention will be readily apparent upon a consideration of the following specification taken with the accompanying drawings in which:

FIG. 1 is a plan view of a section of the resistor unit of the present invention;

FIG. 2 is a partially sectioned view in side elevation of the resistor unit of FIG. 1;

FIG. 3 is a diagrammatic perspective view of the resistor unit of the present invention;

FIG. 4 is a plan view of a section of the resistor unit illustrating a grid structure embodiment of the present invention;

FIG. 5 is a partially sectioned view in side elevation of a resistor grid embodiment of the present invention;

FIG. 6 is a plan view of a section of resistor structure illustrating a grid bank configuration of the present invention; and

FIG. 7 is a diagrammatic perspective view of resistor grids employed in the grid bank of FIG. 6.

Referring now to FIGS. 1 and 2, a resistor section illustrated generally at 10 constructed in accordance with the present invention includes spaced vertical end plates 12 (one shown) which constitute the major support for a resistor grid assembly indicated generally at 14. Extending transversely between the spaced end plates are grid mounting bolts 16 which are secured to the end plates by lock nuts 18. The outer surface of each grid mounting bolt is encased in a tube of insulating material 20 which, for example, may constitute a mica insulating tube.

The mounting bolts 16 mount the resistor grid assembly 14 between the endplates 12 by extending through apertures, indicated in dotted lines in FIG. 2 at 22, provides in the resistor grids and the intervening grid spacers. Generally, two mounting bolts are employed for each rank of resistor grids to prevent the grids from rotating relative to the endplates. However, in some instances alternative grid mounting constructions can be employed as will be subsequently described.

The grid assembly 14 may constitute a number of superimposed ranks of resistor grids attached between the endplates 12, but for purposes of illustration in FIG. 2, the resistor section 10 will be shown as including two grid ranks; an upper grid rank 24 and a lower grid rank 26. Each of these grid ranks includes a plurality of curved resistor elements 28 and 30 which are mounted in spaced relationship upon the mounting bolts 16. These resistor elements may be formed from elongated strips of thin metal tape or other thin strips of resistor material.

The resistor elements 28 and 30 are maintained in a desired spaced relationship by intervening spacers mounted upon the mounting bolts 16, and such spacers constitute alternate conducting and non-conducting spacing units. Both the conductive spacing units indicated at 32 and the non-conductive or insulating spacing units indicated at 34 are curved to correspond with the curvature and shape of adjoining resistor elements. Also, as will be noted in FIG. 1, the conducting and insulating spacers on opposite sides of the resistor section 10 alternate, so that the individual resistor elements in each resistor rank are connected in series to form a sinuous grid. Thus electrical current fed into the resistor section 10 through a terminal 36 which is connected to a conductive spacer 32 in the lower grid rank 26 will, by means of the alternately positioned conductive spacers 32 on opposite sides of the resistor section, flow in a serpentine manner through sequential resistor elements 28 until current has passed through the lower grid rank. A conductive strip, not shown, at the far end of the lower grid rank from the terminal 36 is electrically connected to an adjacent end conductive spacer (not shown) in the upper grid rank 24, so that current continues to flow through the upper grid rank until it reaches an output terminal 38. This output terminal is electrically connected to the last conductive spacer in the upper grid rank.

The output terminal 38 may be connected to another resistor grid section similar to the resistor section 10, and a number of such resistor grid sections may be combined to form a complete resistor structure. It is obvious that any desired number of resistor sections can be electrically connected in series or in parallel to form a resistor grid bank.

The structure of the resistor section 10 is completed by the provision of an insulating block 40 positioned at either end of the resistor section between the endplate and the resistor elements. This insulating block serves a dual purpose in insulating electrically the resistor elements from ground, and in directing a cooling flow of air from a ventilating source onto the end resistor elements in the resistor section. For this purpose, the insulating block is curved to conform to the shape of the end resistor elements. Also, this insulator block permits the

resistor elements at the ends of the resistor section to be spaced closer together to facilitate the addition of more elements in the section, for the insulator block acts as a heat sink to draw additional heat by radiation from the end resistor elements. For this reason, these end elements often require less cooling air than the inside elements, and cooling by forced ventilation of the resistor section is thereby evenly distributed. It is often difficult to evenly distribute flow from a ventilating unit throughout the complete resistor section, particularly in the end portions thereof.

The resistor structure of this invention includes, as a combination, not only a grid bank formed from resistor sections of the type illustrated by the resistor section 10 of FIGS. 1 and 2, but also a source of forced ventilation indicated diagrammatically at 42 in FIG. 3. This ventilation source provides a spiraling or circularly moving stream of forced air for cooling the grid elements 28 of a resistor bank formed by a number of resistor sections. The diagrammatic representation of FIG. 3 includes an exaggerated showing of resistor element curvatures and spacings to better illustrate the manner in which the resistor sections of the remaining figures are internally formed for combination with a source of forced ventilation to accomplish the objects of this invention.

When considering the diagrammatic representation of FIG. 3, it is important to remember that a primary object of this invention is to create maximum turbulence in the cooling air as it passes through the resistor bank structure, for it has been noted that turbulent cooling air exerts a scrubbing effect upon the individual grids within a resistor bank to increase heat transfer. By judicious selection of the direction of curvature of the resistor grids in the upper and lower grid ranks 24 and 26, it is possible to utilize the flow of air from the air ventilation source 42 to obtain maximum turbulence in the flow between individual grids. This is achieved by arranging the upper grids 28 in the upper grid rank 24 so that the grids curve against the flow of air from the air source 42. This is directly contrary to the procedure normally followed to insure laminar airflow between curved resistor grids, for normally various baffles or other air diverting means are employed between the source of ventilation 42 and the adjacent grid section to alter the normal flow of air from the ventilation source and conform this flow to a path which will enable it to enter and flow between the resistor grids in a laminar manner with a minimum of turbulence.

In the present invention, as indicated by FIG. 3, the curved grids of the resistor section are positioned to curve into an obstruct the normal flow of air from the ventilation source 42. Thus, instead of operating in a conventional manner to receive all flow from a ventilation source and to continue to guide this airflow in a laminar manner, the resistor grid structure of the present invention is positioned so that the curved grids of the top rank 24 intercept and obstruct the flow of air from the ventilation source so that the air flow impinges directly against the curved surfaces of the grids 28 in the upper rank 24. The resistor grid structure of the present invention operates particularly well with axial fans which provide a spiral air flow and the grids of the upper rank are positioned to intercept and obstruct the normal course of the spiral flow.

The introduction of ventilating air between the resistor grids 28 of the upper rank 24 on a course which causes the air flow to impinge upon the surface of the grids creates maximum air turbulence between the grids. The reversals in direction of air flow between the grids caused by the reverse curvatures of individual grids in the upper and lower ranks 24 and 26 maintain this turbulence, and prevent the flow of ventilating air from adjusting itself into a laminar air flow as it passes through successive ranks of the resistor bank. Thus the resistor

grids 30 of the lower rank 26 are curved to meet and obstruct the normal flow of air issuing from the upper rank 24, so that this air flow impinges directly against the face of individual grids 30 in the lower rank.

Many curved resistor grid banks include a plurality of superimposed grid ranks formed by equally spaced resistor grids having the same curvature and the same resistance properties. The use of such resistor banks in conjunction with a source of forced ventilation does not provide maximum cooling efficiency, because the successive ranks of resistor grids are alike and no allowance is made for the expansion and consequent acceleration of cooling air or the increased temperature of the cooling air as it passes through subsequent layers in the grid bank structure.

Variation in the spacing, shape, thickness, and width of resistor grids in succeeding grid ranks in the ventilation air stream have a decided effect upon the effectiveness of heat dissipation from the resistor bank. Any one or a combination of these factors may be employed to control effective heat dissipation, and for illustrative purposes in FIG. 3, all of these factors are illustrated in combination.

Considering singly the structural heat control factors of FIG. 3, it is first most important to recognize that in a curved grid structure cooled by a turbulent air stream, the velocity and turbulence of the air stream increase as the cooling air progresses from the ventilation source through successive underlying ranks of resistor grids. Thus, in a curved grid bank, a primary factor in uniform heat dissipation is the spacing of grids in successive ranks progressing outwardly from the ventilation source. Referring to FIG. 3, heating causes the volume of air issuing from the upper rank 24 to be increased, thereby causing an increase in velocity as this air enters the lower rank 26. Thus, even though heat transfer would normally be diminished in the lower rank because of the higher air temperature, it is still possible to effect further heat transfer in successive ranks due to the increased velocity and turbulence of the cooling air passing through such ranks. When the grids in each successive rank are equal in spacing, shape, thickness, and width, as are the grids illustrated in FIG. 2, turbulent air flow still provides an increased cooling capacity. Through the use of turbulent air flow instead of laminar air flow, an equal volume of input air achieves greater dissipation of heat in all ranks of the resistor bank, achieves dissipation of equal amounts of heat in the same volume with lower issuing air temperatures, or permits the utilization of smaller volumes of air for the dissipation of equal amounts of heat.

To obtain greater efficiency in cooling, the grids in succeeding ranks of the resistor bank progressing outwardly from the ventilation source can be made wider in width or of greater thickness than the corresponding grids in overlying ranks within the bank of a combination of both. These grids would have decreased resistance to permit greater current flow through them, but the increasing air turbulence in these succeeding ranks provides effective heat dissipation.

As has been previously indicated, the velocity and turbulence, as well as the temperature of the cooling air increases as the air flows through successive grid ranks. To control the turbulence of the cooling air in individual grid ranks as well as to control the volume of air flow, the curvature of the resistor grids within individual grid ranks and also the spacing thereof may be varied. For example, as the velocity and turbulence of the cooling air increases, the back pressure opposing internal air flow within a resistor bank also increases and this back pressure tends to decrease the volume of cooling air. Therefore, it is advantageous to increase the spacing between grids in successive grid ranks to permit a greater volume of air flow therethrough while also decreasing the angle of curvature of the individual grids within the succes-

sive grid ranks. This decrease of grid curvature in successive ranks is permitted by the increased turbulence caused by increased air velocity, and therefore less grid curvature is required to maintain a turbulence equal to that in proceeding grid ranks.

Ideally, all of these control factors are incorporated in a resistor grid bank as illustrated diagrammatically in FIG. 3. Thus, the thickness and width of the individual resistor grids 28 in the upper rank 24 are less than the thickness and width of the individual grids 30 in the lower rank 26, while the curvature of the grids in the upper rank is greater than that of the grids in the lower rank. However, the spacing between the grids 30 is greater than the spacing between the grids 28. Therefore, back pressure is minimized, and air flow and turbulence controlled within the bank by the respective grid spacings and curvatures, and this, combined with a controlled variation in the respective thickness and width of the grids therein operates to provide maximum heat dissipation.

It must be recognized that the diagrammatic representation of the resistor bank of FIG. 3 and the control features in the structure of the resistor grid ranks of this bank are intended to be applied to resistor banks formed from any of the structures illustrated in the remaining figures of drawings.

The individual resistor grids in the upper and lower grid ranks may be formed to provide a multiplicity of curves or corrugations, or can be formed to provide sharper irregularity in cross section. For example, in FIG. 2, the resistor grids 28 of the upper grid rank 24 are formed so that the curvature thereof begins immediately at the air entrant side of the upper rank 24 and continues throughout the lower rank 26 so that air turbulence is generated continuously along the whole curve. However, other grid curvature designs may be employed, and for example, the individual grids of the upper and lower ranks of FIG. 2 might be formed so that the upper portions of the resistor grids 28 are straight and parallel while the lower portions of the resistor grids 30 are similarly straight and parallel. The lower portions of the upper grids 28 could then be curved and the upper portions of the lower grids 30 similarly curved as illustrated in FIG. 2 so that maximum air turbulence would occur at the innermost portion of the resistor bank while the air inlet and outlet sides of the resistor bank would be straight, thereby producing less turbulence.

In some instances, as indicated by FIG. 5, it may be desirable to provide sharper irregularities in the cross section of the resistor grids, and a multiplicity of chevron-shaped grids could be used. These chevron-shaped grids 28 and 30 operate in the same manner as the curved grids of FIGS. 2 and 3 to change the direction of cooling air as it flows through the resistor grid bank to cause maximum turbulence. It will be noted that the angle of inclination of the chevron-shaped grids 28 in the upper grid rank 24 of FIG. 5 is greater than the angle of inclination of the chevron-shaped grids 30 in the lower grid rank 26. As previously described, this allows for the increased velocity of the air leaving the upper rank and also causes this air stream to impinge upon the faces of the grids 30 in the lower rank to insure that laminar air flow does not result.

The angle of inclination of the resistor grids in FIGS. 2, 3 and 5 can become quite important, and for illustrative purposes FIG. 5 will be employed in the description of such angles, although this description also applies to the curved grids of FIGS. 2 and 3. It is necessary to form the resistor grids so that the change in direction of the cooling air flowing therebetween is not too abrupt, for abrupt changes in air flow create a back pressure which prevents the even flow of ventilating air throughout a resistor grid bank. It has been found that the resistor grids must be formed so that the change in cooling air flow does not exceed 90°, for otherwise the back pressure on

the ventilation source becomes excessive. In FIG. 5, the angle indicated at 44 of the chevron-shaped upper grids 28 is approximately 90° while the angle indicated at 46 for the lower resistor grids 30 is approximately 60°.

The mounting of the individual resistor grids within a grid rank can take several forms. One form includes the alternating insulating and conductive spacers 32 and 34 of FIG. 1, but these spacers may be eliminated by directly joining one end of a resistor grid to the deformed end of an adjacent grid as illustrated by FIG. 4. Each of the resistor grids indicated at 48 in FIG. 4 includes one deformed end 50 which is shaped in an L configuration to facilitate contact with the straight end of the subsequent adjacent grid to provide an electrically conductive path. The contacting ends of the two adjacent grids 48 are then inserted in slots formed in blocks of insulation 52 which are secured to side supports 54 extending between the end plates 12 of a resistor section 10. The slots 56 in the insulating blocks 52 are either curved or crescent shaped to conform to the shapes of the individual resistor grids 48. As will be noted from FIG. 4, the deformed ends 50 of successive adjacent grids are positioned on opposite sides of the resistor section 10 to form a continuous, sinuous, conductive path.

In constructing a resistor bank containing a plurality of resistor sections 10 of the types illustrated by FIGS. 1-5, it is possible to even out the distribution of back pressure on the ventilation source by varying the spacing between individual resistor grids in specific grid sections while also controlling the curvature, spacing, thickness, and width of grids within successive grid sections as previously described in connection with FIG. 3. Normally, a grid rank formed from a plurality of individual grid sections is square or rectangular in configuration, while the source of ventilation generally produces a spiral or substantially circular flow of air. This difference between the configuration of the grid rank and the air flow from the ventilation source plus the back pressure created by the resistor bank on the ventilation source tends to result in uneven ventilation flow distribution.

To assure even cooling of a resistor bank and an even distribution of heat in the issuing air, the back pressure presented by the resistor bank to the ventilation source must be equalized. This is accomplished by the structures of FIGS. 6 and 7 wherein, for illustrative purposes, three resistor grid sections 10A, 10B and 10C have been illustrated as forming each rank in a resistor bank indicated generally at 58. As an axial blower or similar ventilation source for providing a substantially circular flow of air will not provide air to the four corners of the resistor bank 58 which is equal in flow to that provided to the central sections of the bank, it is necessary to structurally compensate for this uneven flow. To reduce the back pressure created at the corners of the resistor bank, the two end resistor sections 10A and 10C are constructed so that the individual resistor grids 60 at the corners of the resistor bank are spaced further apart than the resistor grids 62 and 64 in the central portions of the bank. As will be noted, the spacing between the corner resistor grids 60 decreases progressively as the grids approach the central portion of the resistor sections 10A and 10C, while the grids 62 in the central portion of these resistor sections are equally spaced, one from another in close relationship. The spacing of the resistor grids 62 at the central portions of the resistor sections 10A and 10C is substantially equal to that of the equally spaced resistor grids 64 in the center section 10B. Also the thickness of the grids 62 and 64 may be greater than that of the grids 60.

In addition to increasing the spacing between the resistor grids 60 at the four corners of the resistor bank 58 to create less restriction to the flow of ventilating air, thereby decreasing back pressure at these corner portions, the curvature of the resistor grids 60 might also be decreased with respect to the curvature of the grids 62 and 64 to additionally decrease the back pressure at

the corners of the resistor bank. This decrease in curvature is illustrated in FIG. 7 wherein the grids 60 have a curvature which is less than that of the central grids 62. The curvature of the grids 62 is substantially equal to the curvature of the grids 64 in the center section 10B.

Thus, to evenly distribute cooling air through the resistor bank 58, the back pressure presented to the ventilation source is decreased in the four corners of the bank by increasing the spacing between the resistor grids 60 and/or decreasing the curvature of these grids with relation to the curvature of the grids 62 and 64. By this means, ventilation flow through the bank 58 is substantially equalized and the resistor ranks subsequent to the rank formed by the sections 10A, 10B and 10C may be formed both in accordance with the illustration of FIG. 6 and that of FIG. 3. Thus, a rank subsequent to that shown in FIG. 6 may include resistor grids which, as shown in FIG. 3, have less curvature than either the grids 60, 62 and 64, are spaced further apart than either the grids 60, 62 and 64, are of greater thickness and width than the grids 60, 62 and 64, and yet still include the differences in spacing and grid curvature illustrated by FIGS. 6 and 7.

It will be readily apparent to those skilled in the art that the present invention provides a heavy duty electrical resistor structure and method of ventilating such structure which will increase the transfer of heat per unit volume of ventilating air while providing a strong, self-supporting grid bank unit.

What is claimed is:

1. A heavy duty, force ventilated resistor assembly for use in combination with ventilation source means for creating a moving air stream comprising resistor structural means adapted to internally receive said air stream and create a turbulence therein, said resistor structural means including at least two resistor grid ranks relatively mounted to form a first rank adjacent to said ventilation source means to receive air directly therefrom and a second rank adjacent to said first rank to receive air discharged from said first rank, each such grid rank including a plurality of electrically interconnected, spaced, resistor grid means formed to receive and guide a flow of air therebetween in a first direction and to alter the direction of said airflow to a second direction before discharge from said rank, each said grid means including an input surface and an output surface extending angularly relative to the input surface, the input surfaces of the grid means of said second rank extending angularly relative to the plane of the discharge airflow from the output surfaces of the grid means of said first rank to cause air discharged from said first rank to angularly impinge against the input surfaces of said second rank to increase the turbulence thereof, and the input surfaces of the grid means of said first rank being mounted to extend angularly relative to the plane of the air flow from the ventilation source means to cause air received from said ventilation source means to angularly impinge against said first rank input surfaces.

2. The heavy duty force ventilated resistor assembly of claim 1 wherein each of said plurality of spaced resistor grid means forming said first and second ranks includes spaced resistance elements, the spacing between resistance elements in said first rank being less than the spacing between resistance elements in said second rank.

3. The heavy duty force ventilated resistor assembly of claim 1 wherein each of said plurality of spaced resistor grid means forming said first and second ranks includes a plurality of spaced resistance elements, the resistance elements in said second rank being of greater thickness than the resistance elements in said first rank.

4. The heavy duty force ventilated resistor assembly of claim 1 wherein each of said plurality of spaced resistor grid means forming said first and second ranks includes spaced resistance elements, the surface area of the resistance elements in said second rank being greater

than the surface area of the resistance elements in said first rank.

5. The heavy duty, force ventilated resistor structure of claim 1 wherein the angular relationship between the input and output surfaces of the resistor grid means of said first grid rank is different from the angular relationship between the input and output surfaces of the resistor grid means of said second grid rank, the spaced resistor grid means of said first grid rank being formed to alter the direction of air flow therethrough to a greater degree than are the resistor grid means of said second grid rank.

6. The heavy duty force ventilated resistor assembly of claim 5 wherein each of said plurality of said spaced resistor grid means forming said first and second ranks includes spaced curved resistance elements, the direction of curvature of the resistance elements in said first rank being opposite to the direction of curvature of the resistance elements in said second rank.

7. The heavy duty force ventilated resistor assembly of claim 6 wherein each of said plurality of spaced resistor grid means forming said first and second ranks includes a plurality of spaced resistance elements, the spacing between the resistance elements in said first rank being less than the spacing between the resistance elements in said second rank.

8. The heavy duty force ventilated resistor assembly of claim 7 wherein the thickness of the resistance elements in said second rank is greater than the thickness of the resistance elements in said first rank.

9. The heavy duty force ventilated resistor assembly of claim 8 wherein the surface area of the resistance elements in said second rank is greater than the surface area of the resistance elements in said first rank.

10. The heavy duty force ventilated resistor assembly of claim 6 wherein said resistor structural means includes mounting means for said electrically interconnected, spaced grid means, said mounting means including spaced end plates positioned at either end of said grid ranks outwardly of said resistor grid means, and an insulating block positioned between each of said end plates and said resistor grid means, said insulating block being formed to conform to the configuration of said resistor grid means.

11. The heavy duty force ventilated resistor assembly of claim 10 wherein said plurality of spaced resistor grid means forming said first and second ranks includes a plurality of elongated resistance elements relatively spaced by spacer units interposed between said resistance elements at either end thereof, said space units being formed to conform to the configuration of said resistance elements and including insulating and conductive spacer units alternately arranged to electrically connect said resistance elements in a serpentine series manner.

12. The heavy duty force ventilated resistor assembly of claim 5 wherein each of said plurality of spaced resistor grid means forming said first and second ranks in-

cludes a plurality of spaced, chevron-shaped resistance elements, the resistance elements of said first rank being oriented in a direction opposite to the resistance elements in said second rank.

13. A heavy duty resistor structure adapted to receive a flow of cooling air from a ventilation source comprising a plurality of spaced, electrically connected resistance elements curved to guide a flow of air therebetween in a first direction and to alter the direction of said air flow to a second direction before discharge, means for mounting said elements in a plurality of substantially parallel sections, the curvature of said resistance elements in the outermost of said sections progressively decreasing toward each end of such outermost sections.

14. A heavy duty resistor structure adapted to receive a flow of cooling air from a ventilation source comprising a plurality of spaced, electrically connected resistance elements, means for mounting said elements in a plurality of substantially parallel sections, the spacing between resistance elements in the outermost of the sections progressively increasing toward each end of such outermost sections.

15. The heavy duty resistor structure of claim 14 wherein said resistance elements are curved to guide a flow of air therebetween in a first direction and to alter the direction of said air flow to a second direction before discharge therefrom, the curvature of the resistance elements in the outermost of said sections progressively decreasing toward each end of such outermost sections.

16. The heavy duty resistor structure of claim 15 wherein the thickness of said resistance elements in the outermost of the sections progressively decreases toward each end of such outermost sections.

17. A heavy duty resistor structure adapted to receive a flow of cooling air from a ventilation source comprising a plurality of spaced, electrically connected resistance elements, means for mounting said elements in a plurality of substantially parallel sections, the thickness of such resistance elements in the outermost of the sections progressively decreasing toward each end of such outermost sections.

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RICHARD A. FARLEY, Primary Examiner

T. H. TUBBESING, Assistant Examiner

U.S. Cl. X.R.

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