June 13, 1961 H. H. ZABEL 2,988,722

HIGH VOLTAGE RESISTOR

Filed Aug. 16, 1960

2 Sheets-Sheet 1

Fig. 1

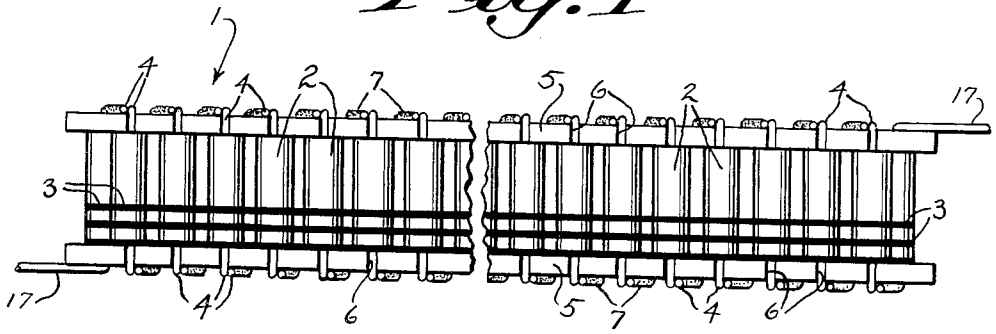


Fig. 2

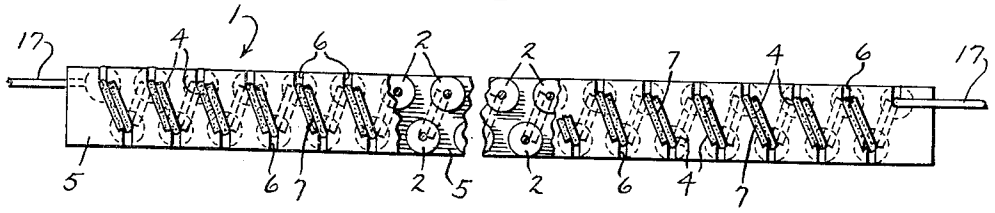
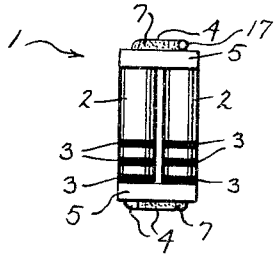


Fig. 3



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2 Sheets-Sheet 2

Fig. 4

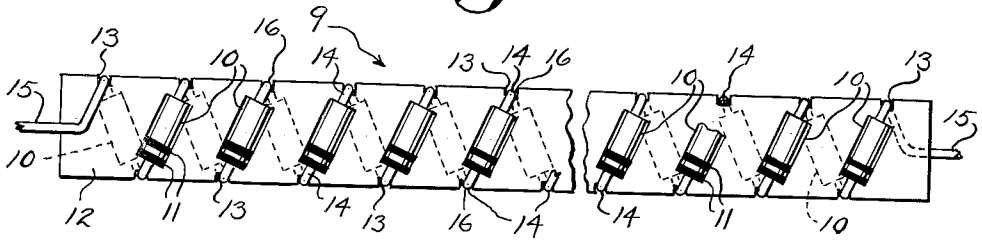


Fig. 5

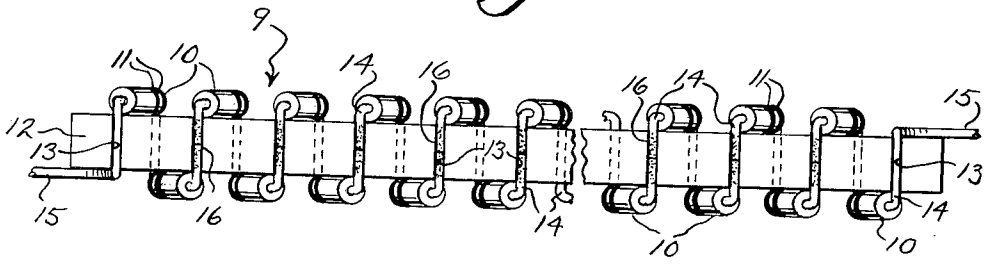
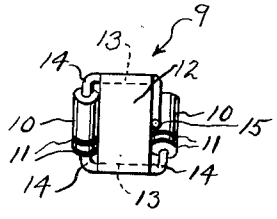


Fig. 6



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2,988,722

HIGH VOLTAGE RESISTOR

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Filed Aug. 16, 1960, Ser. No. 50,032
10 Claims. (Cl. 338—239)

This invention relates to resistors for high voltage application and it more particularly resides in a resistor comprising a large number of individual composition resistor components of relatively low individual voltage rating that are securely held in a space conserving array along a mounting board with series connections whereby each resistor component has a voltage drop that is a minor fracton of the potential across the entire resistor.

The design of many high voltage devices, such as X-ray machines and Van de Graaff electrostatic generators, calls for the use of resistors connected across points of large potential difference, and such resistors must occupy a minimum of space while also being of sufficient size to attain the necessary high voltage ratings. In addition to having a high voltage rating and being of small size, such resistors must be extremely dependable since in some of the equipment in which they are used it may be an unduly expensive procedure to shut down the operation and enter the equipment for maintenance purposes.

One form of high voltage resistor that has been employed in X-ray machines comprises many spaced turns of small diameter wire. The spacing of the turns results in an elongated form, and due to the necessarily small cross section of the wire required for achieving a large resistance such resistors are quite fragile and are prone to open circuit failure. Upon such a failure the very high potential of the circuit is impressed across the opening to cause arcing and vaporization of the adjacent material. These resistances of coiled wire also exhibit marked inductance which may be deleterious in some circuit arrangements.

Other high voltage resistors have taken the form of composition resistors rated and operated at high voltages per resistor unit. Such composition resistors consist of carbon particles dispersed and held within a molded insulating binder to form a resistance path comprised of a number of meandering paths defined by the random dispersion of the carbon particles. The continuity of the paths is dependent, in part, upon the applied voltage and hence the voltage resistance characteristic is such that when subjected to large voltage values the resistance decreases substantially. This voltage characteristic is particularly large for resistor units of high resistance, wherein the carbon paticles are more sparse and probably do not afford as stable a continuity for the current path. With a lack of stability the permissible maximum voltage may vary with age and use, whereby failure may become quite likely. Also, maximum voltage ratings must be conservative, to the point that size must be unduly increased so as to materially reduce the desirability of this form of resistor.

Another disadvantage of the composition resistor as heretofore employed occurs when they are utilized in serially connected groups. Each of the resistor units must operate at or near its maxium voltage rating, so that space requirements can be met, and should one of the elements fail by an excessive decrease in resistance the redistributed voltage on the remaining elements might well exceed their capacity. For example, should one of ten 5000 volt units in a 50,000 volt ressistor fail, the remaining nine must each accommodate 5,555.5 volts, or an increase of 11.1%. This increase may be an overload upon the remaining nine leading to an additional failure

of one of the remaining resistors, and hence a self-aggravating condition is quite likely to occur.

Another disadvantage in the use of a small number of resistor units is the large potential gradients that appear across short distances, which in strong electric fields may contribute to arcing and breakdown through or along insulation, or in the ambient air. Also, it is sometimes desirable to calibrate or adjust resistors to match conditions of use, and an individual composition resistor does not lend itself to any such procedure, nor do a few units connected to one another since shorting one element results in a relatively great change in resistance and thus makes accurate adjustment impossible.

A preferred construction for the present invention utilizes a large number of hot molded resistor components that have much smaller individual voltage ratings than the resistors of the foregoing paragraphs. These components are mounted in a manner that they are firmly secured in place with proper spacing between lead wires. The mounting also provides for a space saving arrangement of the many individual components whereby the large plurality of components is confined within a space as small as that occupied by previous high voltage resistors. The resistor of the invention is not subject to a catastrophic open circuit failure or to the instabilities discussed above with respect to other constructions heretofore employed. It is therefore apparent that a high voltage resistor utilizing a relatively large number of resistor components each of relatively low resistance will prove superior to either wire wound resistors or the older composition element resistors, and it is an object of this invention to provide an improved high voltage resistor unlikely to open circuit, substantially non-inductive, of relatively constant resistance upon change of voltage, capable of withstanding voltage redistribution upon failure of one or more elements, not generally subject to voltage breakdown, accurately adjustable, and inexpensive.

Although the invention herein contemplates the use of resistor components of any of a number of common types, it is especially effective when "hot molded" resistor components are used. The term "hot-molded" as used herein refers to a composition resistor comprising finely divided carbon particles dispersed within an organic thermal setting resin, such as a phenol formaldehyde, and a filler wherein the ingredients are first mixed with the resin in a partially cured granulated state, the mixture is then molded into a small unit under heat and pressure, and the resin is further advanced in cure after molding. This method precludes further flow of the resin, that would be accompanied by realignment of the carbon particles and a change in resistance value, upon subsequent use. It is in the nature of hot molded resistors to decrease in resistance rather than to have an open circuit failure, and thus an open circuit within an accompanying destruction of adjacent material becomes a near impossibility. Due to the large number of resistor elements employed in the invention herein, loss of resistance by one element will not materially affect the overall value of the resistor. Accordingly, it is another object of this invention to provide an improved high voltage resistor especially adapted to utilize hot molded resistor components.

Although the superior electrical characteristics of the multi-element resistor of this invention are apparent from the foregoing, further problems arise since it is necessary that the components be mounted within a given space. Obviously, it is necessary that the components be arranged and held in a space saving relation. It is also necessary that the leads of the components be held so that they may be easily connected by soldering or

other means. At the same time, however, since the connections must be made close to the bodies of the components to conserve space, it is necessary that some means be provided to prevent the heat of soldering or welding from impairing the resistor bodies. Further, it is necessary that the connected leads be held rigidly at a minimum distance one from the other to preclude electrical breakdown which may otherwise occur when used in very large electric fields as frequently encountered in high voltage devices. Thus, it is a further object of this invention to provide mounting board means to overcome the above difficulties which are themselves not costly and which allow for simple, inexpensive mounting of the resistor elements.

Further objects and advantages of the invention will appear in the description to follow. In the description, reference is made to the accompanying drawings, forming a part hereof, in which there are shown, by way of illustration and not of limitation, two specific embodiments of the invention.

In the drawings:

FIG. 1 is a fragmentary side view in elevation of one embodiment of the invention,

FIG. 2 is a fragmentary top view with parts broken away of the embodiment of FIG. 1,

FIG. 3 is an end view in elevation of the embodiment of FIG. 1,

FIG. 4 is a fragmentary side view in elevation of a second embodiment of the invention,

FIG. 5 is a fragmentary top view of the embodiment of FIG. 2, and

FIG. 6 is an end view in elevation of the embodiment of FIG. 2.

Referring now to FIGS. 1 through 3, there is shown one embodiment of a high voltage resistor formed according to the invention and designated generally by the reference numeral 1. The resistor 1 comprises a plurality of composition resistor components 2 that are formed with circular cylindrical bodies. The components 2 are preferably of the hot molded type hereinbefore described, and color bands 3 on the components 2 serve to identify their individual resistance values in conformance with a generally accepted code. It must be noted, however, that it is preferable to avoid the use of color bands of a metallic paint since the high electric fields in which the resistor may be operated may sometimes accumulate charges on these bands so as to have an undesirable capacitative effect. The resistor components 2 are preferably arranged in two staggered facing rows, each row being comprised of a plurality of closely spaced substantially parallel resistor components 2. The lengthwise dimension of the component bodies lies transversely of the run of the resistor, and by staggering the components in one row with respect to those in the other row the two rows are brought close to one another. Each resistor component 2 has projecting from each end an electrically conducting lead wire 4. Capping the staggered rows of components 2 are a pair of elongated ribbon-like mounting boards 5 formed of any suitably rigid insulating composition material and arranged in substantially parallel facing relation. The mounting boards 5 are each provided with a plurality of longitudinally spaced notches 6 along each of their longitudinal edges, said notches 6 being of sufficient size to accommodate the leads 4 which project therethrough. The notches 6 may also take the form of small holes of a diameter large enough to receive lead wires with a fairly snug fit. As will be apparent, the notches or holes function as wire receiving guide openings that retain the lead wires 4 in spaced relation.

The upper lead 4 of each component 2 is bent over the outer face of the upper mounting board 5 to lie adjacent a lead 4 of a resistor component 2 in the opposite row. Thus, as viewed in FIG. 2 the upper lead 4 of a component 2 in the row at the bottom of the figure is adjacent the lead 4 of the component 2 in the upper row that is at its left. The lower lead 4 of each component 2 is bent over the outer face of the lower mounting board 5 to lie adjacent the lead of the component 2 in the opposite row that is at its other side, so that the components 2 will be connected in series. Solder connections 7 serve to connect the adjacent leads 4 to have good electrical contact and for holding both leads and component bodies securely in proper spaced relation. One of the leads 4 of each of the end most resistor components 2 in the resistor 1 must, of course, remain unconnected and these extend outwardly to provide a pair of free leads 17 which serve to connect the resistor as a whole into any desired circuit.

It will be seen that the staggered row arrangement of resistor components 2 shown herein allows a near maximum number of components to be arranged within a limited space. Further, the mounting board means, together with the mounting notches 6, serve to securely hold the components 2 in the desired arrangement. Since the adjacent leads 4 are exposed on the outer faces of the mounting boards 5, solder or weld connections therebetween may be simply made. In addition, the insulating composition of the boards 5 serves to protect the resistor components 2 against damage by the heat due to soldering or welding. Further, it is apparent that the completed connections 7 are easily accessible in order that one or more of the resistor components 2 may be shorted out to calibrate or adjust the overall resistance of the resistor 1.

Referring now to the embodiment of the invention shown in FIGS. 4 through 6, there is again shown a high voltage resistor designated in this case generally by the numeral 9. The resistor 9 comprises a plurality of hot molded resistor components 10 color coded by bands 11. In this embodiment of the invention the resistor components 10 are arranged in two parallel facing rows, in which each row comprises a plurality of parallel, preferably angularly disposed, resistor components, and the components 10 in one row are angularly offset from the components in the other row. Interposed between the rows of resistor components 10 and substantially coextensive therewith, is a rod-like mounting board 12, preferably of square or rectangular cross-section, formed of any suitably rigid insulating material. The board 12 is provided along both its top and bottom with a series of longitudinally spaced transverse notches 13, each being of a size and depth sufficient to accommodate a pair of resistor leads 14 that are disposed in end to end abutting relation. The leads 14 of each resistor component 10 are bent across the mounting board 12 so as to lie within a notch 13 in the top and a notch 13 in the bottom. The leads 14 of a resistor component 10 are thereby disposed in said end to end abutting relation with leads from the preceding and succeeding components 10 in the opposite row, whereby the elements 10 are as a whole connected in an electrical series relation. The endmost leads are again unconnected and project outwardly to form terminals 15 for incorporation of the resistor into a circuit. Solder connections 16 serve to securely hold the components 10 and the leads 14 in place, and as clearly shown in FIGS. 4 and 5 the lead wire connection from one component 10 to the next presents a smooth surfaced electric path without sharp points or edges. The elimination of sharp edges reduces points of potential or field intensity which might possibly contribute to breakdown. This abutting of lead wires with a smooth solder surface, of course, may be used in the embodiment of FIGS. 1–3.

It can be seen that the mounting board means and notches of this second embodiment of the invention serve to hold the resistor components 10 in place in addition to holding the leads 14 in an accessible position for soldering or other connection. The insulating characteristics of the mounting board 12 serve to protect the bodies of

the resistor components 10 against the heat of soldering, and the connected leads are exposed to allow calibration.

The actual number of resistor components 10 which must be used in any given application to provide the advantages herein is, of course, determined to a great extent by the voltage and resistance requirements of the circuit into which the resistor is to be incorporated. It is preferred however, to provide a sufficient number of components such that each must accommodate no more than 2% of the total voltage applied across the resistor. Then the components may be operated at close to rated maximum continuous voltage and if one of the elements should fail, the remaining elements will be required to accommodate a voltage increase only of the order of 2%.

For illustrative purposes, a resistor suitable for incorporation into a 50,000 volt circuit may be considered. In such a case, if an old form of resistor utilizing 10 resistors each rated and operated at 5,000 volts is employed, then each individual resistor element must accommodate 10% of the total voltage, and if one of the elements should fail the remainder must each carry 11.1% of the voltage. In other words, each initially must accommodate 5000 volts but, should one of the resistors fail, the remaining resistors must each accommodate 5555.5 volts, a change of 555.5 volts or 11.1%. This increase will overload the ramining resistors to the point of further failure, whereby complete breakdown will follow. In contrast, the following table represents corresponding information for several 50,000 volt resistors formed according to the invention herein. In each case, there are shown the number of components, their voltage rating, the percentage of the initial voltage each component will carry when they are operated near the voltage rating, the percentage of the voltage each remaining element must carry should one element fail, the initial voltage each element must accommodate, the voltage each remaining element must accommodate should one fail, and the percent of increase in voltage which must be accommodated by each remaining element should one fail.

Although the following table indicates that the remaining elements are sometimes forced to accommodate a voltage somewhat in excess of their normal rated capacity, it will be obvious that the safety factor used in establishing such normal ratings will be more than sufficient to allow for accommodation of the higher voltage.

No. of Resistors	Individual Voltage Rating	Percent of Initial Voltage	Percent of Voltage on Failure	Initial Voltage	Voltage on Failure	Percent of Increase
67	750	1.49	1.51	746.27	757.57	1.5
100	500	1.00	1.01	500	505.0	1.00
143	350	0.7	0.704	349.7	352.1	0.69
200	250	0.5	0.503	250	251.26	0.504

It is a particular teaching of the invention that the use of a large number of individual resistor components with attendent reduction in resistance for the individual components provides an improved high voltage resistor having greater stability. The voltage characteristic will be stabilized since the carbon particle dispersion in the components will have a density that gives greater circuit continuity, wherefore the curent path provided by the resistor is more definitive and not as subject to variation in applied voltage. The performance of the complete resistor will also be improved by use of hot molded components that are stable in nature and have minimal drifts in resistance value. This invention also provides a particular arrangement of components in rows through the use of insulating mounting board means which add only a minimal amount of volume to the overall resistor, wherefore it is made possible to utilize a large number of components without sacrificing space requirements.

It is apparent that several electrical and mechanical variations have been shown each of which will provide a new and improved high voltage resistor. It is desired that it be understood that the invention is not to be limited to the exact form and arrangement of parts shown herein except insofar as such limitations are contained in the following claims.

I claim:

1. In a high voltage resistor the combination comprising: narrow elongated mounting board means having two rows of longiudinally spaced transverse lead wire receiving guide openings along opposite sides thereof; a plurality of composition resistor components each having a pair of lead wires projecting therefrom, said components being arranged in two parallel rows along said mounting board means in which rows the components lie transversely of the run of said mounting board means and are in a closely spaced parallel relation to one another, said lead wires lying across and transversely of said mounting board means and being disposed within said openings with the lead wires of each component being adjacent the lead wires of successive components in the opposite row of components; and connections between the adjacent lead wires whereby said components are secured along said mounting board means in an electrical series relation.

2. A high voltage resistor according to claim 1 wherein the resistor components are hot molded composition resistors.

3. In a high voltage resistor to accommodate a given voltage the combination comprising: narrow elongated mounting board means having two rows of longitudinally spaced transverse notches along opposite sides thereof; a plurality of composition resistor components each having a pair of lead wires projecting therefrom, said components being arranged in a pair of parallel rows along said mounting board means in which rows the components lie transversely of the run of said mounting board means and are in a closely spaced substantially parallel relation to one another, said lead wires lying transversely across said mounting board means and being disposed within said notches with the lead wires of each component being adjacent the lead wires of successive components in the opposite row of components; and connections between the adjacent lead wires whereby said components are secured along said mounting board means in an electrical series relation, said components being sufficient in number such that each component accommodates no more than 2% of said given voltage.

4. In a high voltage resistor the combination comprising: a pair of elongated ribbon-like mounting boards of insulating material arranged in a spaced, substantially parallel facing relation, each of said mounting boards having a series of longitudinally spaced notches cut into each of its longitudinal edges; a plurality of composition resistor components each having a body portion and a pair of leads extending therefrom, said body portions being arranged intermediate said mounting board means in two facing substantially parallel rows, the components in each row being in a closely spaced substantially parallel relationship and lying transversely of the run of said mounting boards, the leads of said components passing through said notches and being bent across the outer faces of said mounting boards to lie transversely of the run of said mounting boards, the leads of each component being adjacent the leads of successive components in the opposite row; and connections between said adjacent leads whereby the components are secured between the mounting boards in an electrical series relation.

5. A high voltage resistor according to claim 4 wherein the resistor components are hot molded composition resistors.

6. In a high voltage resistor the combination comprising: a pair of elongated ribbon-like mounting boards of insulating material arranged in a spaced substantially parallel facing relation, each of said mounting boards hav-

ing a series of longitudinally spaced notches cut into each of its longitudinal edges, the notches along one edge of each mounting board being offset from the notches in the other edge thereof, and the notches on corresponding edges of said mounting boards being aligned with one another; a plurality of composition resistor components each having a body portion and a pair of leads extending therefrom, said body portions being arranged intermediate said mounting boards in two staggered facing substantially parallel rows, the components in each row being in a closely spaced substantially parallel relation transversely of the run of said mounting boards, the leads of said components passing through said notches and being bent across the outer faces of said mounting boards to lie transversely of the run of said mounting boards, the leads of each component being adjacent the leads of said successive components in the opposite row; and connections between said adjacent leads whereby the components are secured between the mounting board in an electrical series relation.

7. In a high voltage resistor to accommodate a given voltage the combination comprising: a pair of elongated ribbon-like mounting boards arranged in a spaced substantially parallel facing relation, each of said mounting boards having a series of longitudinally spaced notches cut into each of its longitudinal edges; a plurality of composition resistor components having leads projecting therefrom, said components being arranged intermediate said mounting boards in two facing substantially parallel rows, the components in each row being in a closely spaced substantially parallel relationship transversely of the run of said mounting boards, the leads of each component passing through said notches and being bent across the outer faces of said mounting boards to lie transversely of the run of said mounting boards, the leads of each component being adjacent the leads of successive components in opposite rows; and connections between said adjacent leads whereby the components are held between the mounting boards in electrical series relation, the number of said components being sufficient such that each component accommodates less than 2% of said given voltage.

8. In a high voltage resistor the combination comprising: elongated rod-like mounting board means having two rows of longitudinally spaced notches along opposite sides thereof; a plurality of composition resistor components each having a pair of lead wires projecting therefrom, said components being arranged in two parallel rows along said mounting board means in which rows the components lie substantially transversely of the run of said means and are in a closely spaced substantially parallel relation to one another; said lead wires lying across and transversely of said mounting board means and being disposed within said notches with the lead wires of each component being positioned adjacent the lead wires of successive components in the opposite row of components; and connections between the adjacent leads whereby said components are held along said mounting board means in an electrical series relation.

9. A high voltage resistor according to claim 8 wherein said components are sufficient in number such that each component accommodates no more than 2% of the total voltage across the resistor.

10. In a high voltage resistor the combination comprising: narrow elongated mounting board means; a plurality of composition resistor components each having a pair of lead wires projecting therefrom, said components being arranged in two parallel rows along said mounting board means in which rows the components lie transversely of the run of said mounting board means and are in a closely spaced parallel relation to one another, said lead wires being wrapped about said mounting board means to have the components and their leads encircle said mounting board means with the leads lying transversely across said mounting board means so that the lead wires of each component are adjacent the lead wires of successsive components in the opposite row of components; and connections between the adjacent lead wires whereby said components are secured along said mounting board means in an electrical series relation.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,988,722 June 13, 1961

Harold H. Zabel

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 56, for "within an" read -- with an --; column 5, line 28, for "ramining" read -- remaining --; line 64, for "current" read -- current --.

Signed and sealed this 14th day of November 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

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Commissioner of Patents

USCOMM-DC

UNITED STATES PATENT OFFICE

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