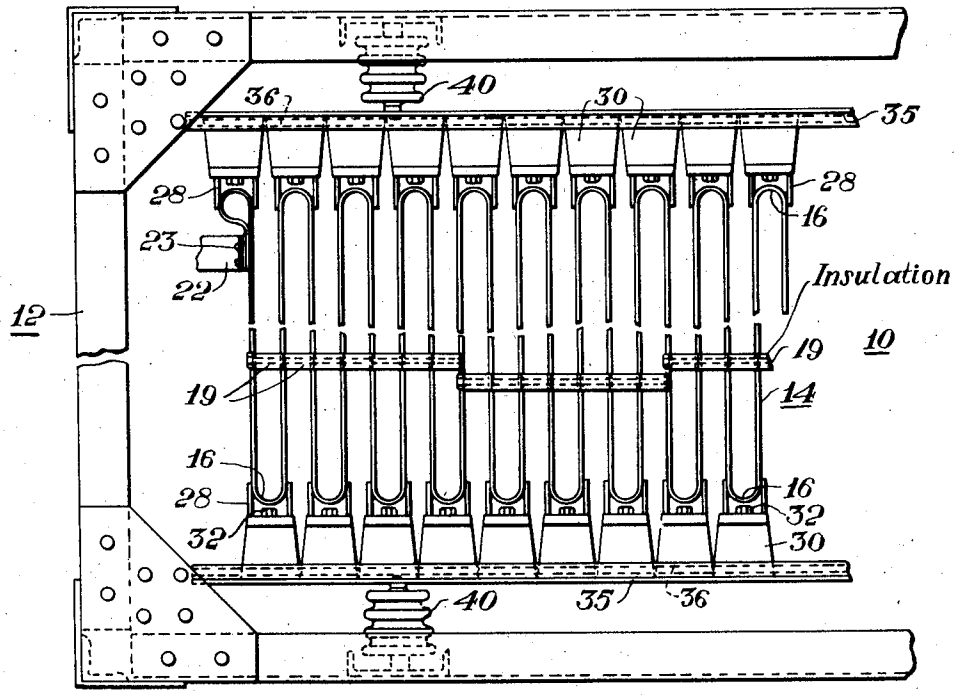
March 31, 1942. V. E. JOHNSON ET AL 2,277,912

RESISTOR

Filed Oct. 29, 1938 4 Sheets-Sheet 1

Fig. 1.



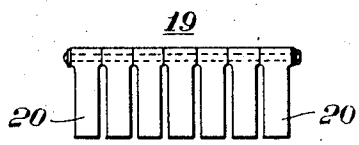


Fig. 2

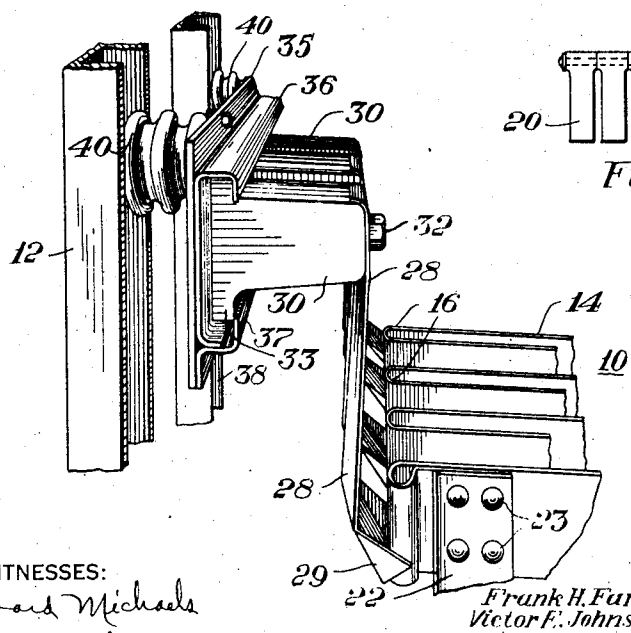


Fig. 3.

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RESISTOR

Filed Oct. 29, 1938 4 Sheets-Sheet 2

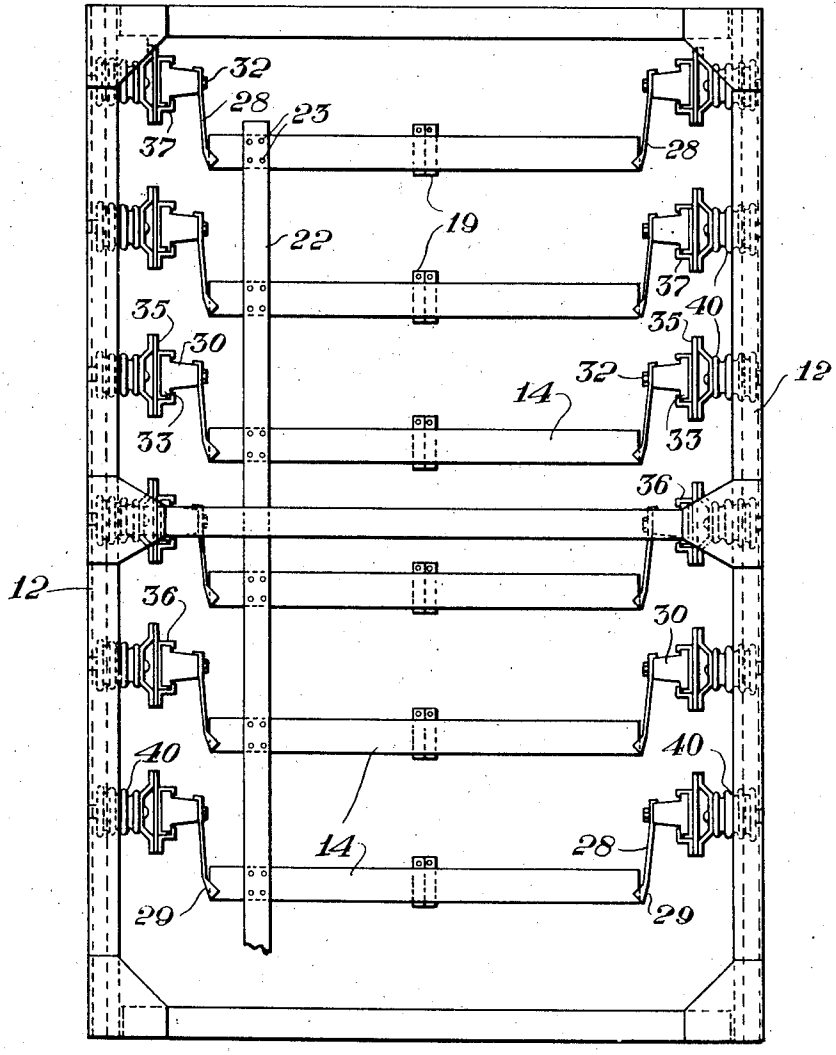


Fig. 4.

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RESISTOR

Filed Oct. 29, 1938 4 Sheets-Sheet 3

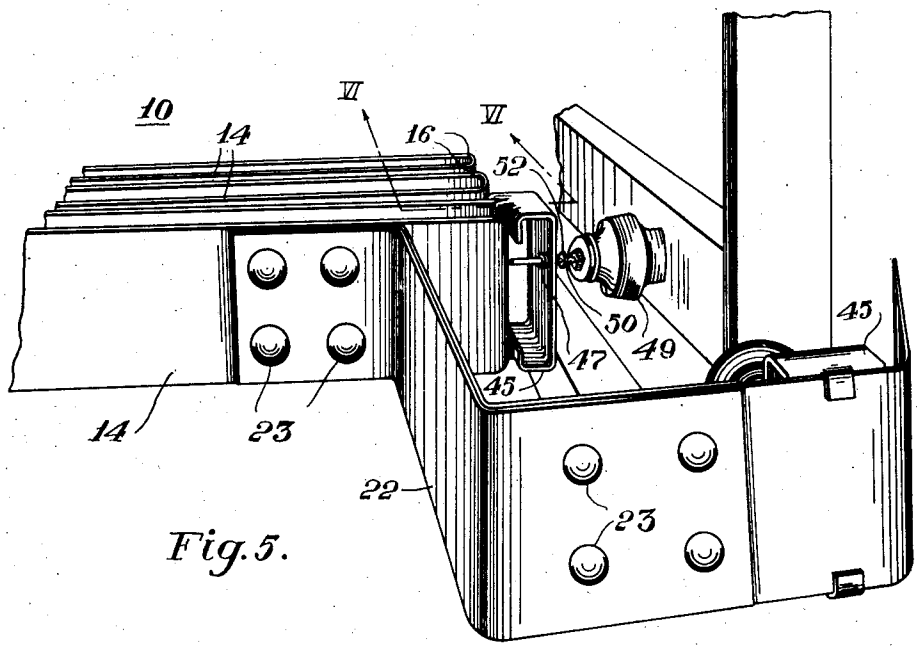


Fig. 5.

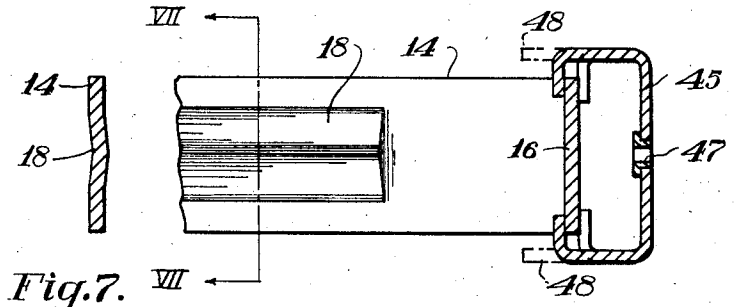


Fig. 7.

Fig. 6.

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RESISTOR

Filed Oct. 29, 1938 4 Sheets-Sheet 4

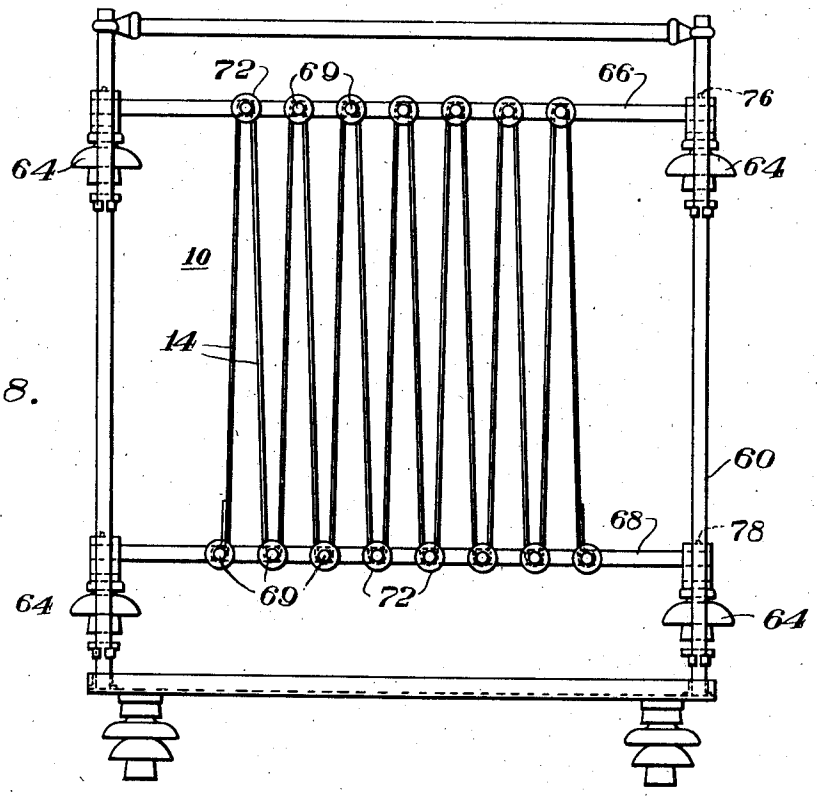


Fig. 8.

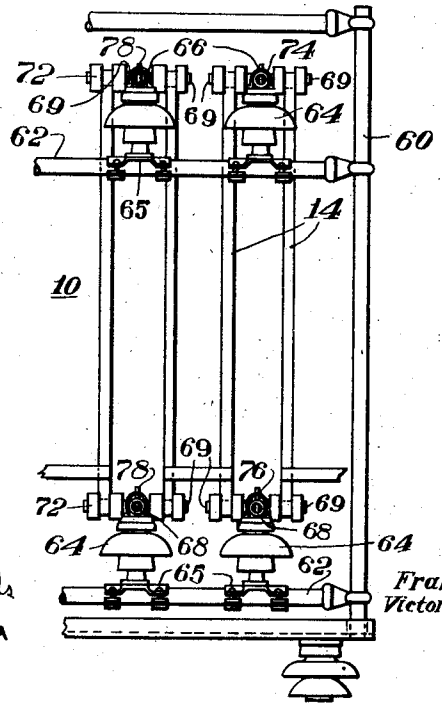


Fig. 9.

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UNITED STATES PATENT OFFICE

2,277,912

RESISTOR

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Application October 29, 1938, Serial No. 237,786

6 Claims. (Cl. 201—74)

Our invention relates generally to resistors, and it has reference, in particular, to an improved construction for neutral grounding resistors.

In large polyphase power distribution systems, it is usually desirable to provide a grounding resistor between the neutral wire of the system and the ground, for limiting the flow of fault current and assisting in stabilizing the system when a ground fault occurs therein. The duty imposed on neutral resistors is of a radically different nature than that imposed on ordinary control resistors, and while called upon to function at relatively rare intervals, they must at those times be able to handle unfailingly and without distress large currents for indefinite periods. Under normal conditions, the grounding resistor may carry current for only a very short period of time, while under abnormal conditions, exceedingly heavy currents must be carried by the grounding resistor for relatively long periods of time of from one minute to ten minutes in extreme cases before the system is disconnected from the source of power, or before the faulty section of the system is isolated. Since these grounding resistors are necessarily relatively large, owing to the peak currents and the extended periods of fault duration for which they must be designed, it is desirable to locate the resistors out of doors adjacent to the point of ground connection of the system, so as not to use up valuable space within the station, or require separate housings therefor. It may, therefore, be seen that in general it is desirable to provide a resistor which is not only capable of withstanding exceedingly heavy surges of current for extended periods without failure, but which is also unaffected by exposure to varied weather conditions.

Heretofore, it has been customary to utilize indoor mounted resistors comprising a plurality of cast iron grid sections rigidly mounted on supporting rods in a frame, for providing the necessary amount of resistance and the desired current carrying capacity. Resistors of this type were required to be thus protected as such construction necessarily involves a large number of joints between adjacent grids, which, if the grids are exposed to weather, often become a source of trouble, since corrosion of the grid surfaces tends to increase the contact resistance between the adjacent grids. This results in excessive heating at the joints, during the flow of fault current, so that the cast iron grids may become sufficiently overheated to melt. Failure of a neutral grounding resistor under such conditions, during the existence of a fault on the system, may result in serious system disturbances, disrupting the service at points quite remote from the source of the fault. Furthermore, resistor elements of this kind are inherently weak structurally and may become broken at any time, depriving the system of the ground protection the resistor is intended to afford, thus requiring constant vigilance and testing to eliminate the hazards of open circuits resulting from broken grids. A cast resistor is inherently a low-temperature device, and when rated at five or ten minutes, becomes abnormally large and expensive.

Therefore, the object of our invention, generally stated, is to provide an improved resistor of simple and rugged construction, which may be economically constructed and maintained, which is reliable in operation, and which will withstand continuous exposure to the weather and extreme heating and cooling cycles without deterioration or breakage.

A more specific object of our invention is to provide for utilizing, in a resistor, a non-corrosive continuous resistance element of a material which will resist deformation at high temperatures, and for yieldingly supporting the element in a frame to allow expansion and contraction of the element.

Another object of our invention is to provide for supporting or suspending a flexible strip resistance element in a rigid frame structure in such manner as to eliminate distortion thereof due to expansion and contraction.

A further object of our invention is to provide for resiliently suspending a continuous strip resistance element in a support frame without impairing the current carrying characteristics, or the ventilation thereof.

Another object of our invention is to provide for supporting or suspending a flexible strip resistance element formed in a zigzag shape in a supporting frame by utilizing insulating hangers connected to the reversely curved or bent portions of the element.

A further object of our invention is to provide for forming a resistance element of the above-described character in such manner that it may be suspended in a frame by supporting it at the reversely curved or bent portions only.

A still further object of our invention is to utilize a grounding resistor comprising a continuous stainless steel strip element in the neutral ground connection of a power system.

A further object of our invention is to utilize a plurality of yieldingly supported stainless steel

resistor elements in a resistor unit to provide a compact and durable neutral grounding resistor.

Other objects will, in part, be obvious, and will, in part, appear hereinafter.

In a preferred embodiment of our invention, the resistor may comprise, generally, a continuous strip resistance element which is disposed to be supported in a rigid frame so as to allow for expansion and contraction of the element without subjecting the parts thereof to undue stress. In order to safely withstand the heavy current surges to which the resistor may be subjected when utilized, for example, for grounding the neutral point of a power system or the like, the resistance element comprises preferably a strip of one of the nickel chromium alloy steels, commonly known as stainless steels, which is not only highly resistant to corrosion, but which also retains a relatively high degree of mechanical strength even at relatively high temperatures, so that the resistor may be safely operated at much higher temperatures than can cast iron grid resistors, thus permitting a marked reduction in the mass of the resistance element, and at the same time utilizing the greatly increased ohmic value of the resistance element at these higher temperatures for restricting the flow of fault current.

For a further understanding of the nature and scope of our invention, reference may be had to the following detailed description, taken in connection with the accompanying drawings, in which:

Figure 1 is a plan view of a portion of a resistor embodying a preferred form of our invention;

Fig. 2 is a side view of a spacer member used with the resistor of Fig. 1;

Fig. 3 is an enlarged perspective view of a portion of the resistor of Fig. 1;

Fig. 4 is a side elevation view of a resistor construction comprising a plurality of the resistors of Fig. 1;

Fig. 5 is an enlarged perspective view of a portion of an alternate form of resistor construction;

Fig. 6 is a sectional view of the resistor of Fig. 5 along the line VI—VI;

Fig. 7 is a sectional view of the resistor element of Fig. 6 along the line VII—VII;

Fig. 8 is a side elevation view of a different embodiment of our invention; and

Fig. 9 is an end elevation view in part of the embodiment of Fig. 8.

Referring particularly to Figs. 1 and 2 of the drawings, the reference numeral **10** denotes generally a resistor comprising a frame **12** having a strip or ribbon resistance element **14** supported therein, so as to allow for expansion and contraction of the element without subjecting parts of the resistor to undue stress.

The frame **12** may preferably be fabricated from structural steel shapes, in any suitable manner, so as to provide a substantially rigid support for the resistance element **14**. As it is preferable to install neutral grounding resistors outdoors on account of their size, without any housing or other protection from the weather, the frame **12** may be heavily galvanized or otherwise weatherproofed, so as to prevent corrosion.

In order to provide a resistance element for grounding the neutral point of a system, having a high degree of resistance to corrosion, and a high degree of mechanical strength at relatively high temperatures, so as to resist deformation and prevent sagging of the element at the relatively high temperatures under which it may operate, we prefer to form the resistance element **14** from a strip of one of the nickel chromium alloy steels, commonly known as stainless steels. At temperatures ranging as high as 800° C. and 100° C., the short time tensile strength of stainless steel is of the order of 15,000 and 3,000 pounds per square inch, respectively, thus permitting the safe operation of the resistor at temperatures far above the safe operating temperature of cast iron grids, and materially reducing the mass of resistance element necessary to dissipate a surge of energy in limiting a fault disturbance in the system.

In our preferred form of construction, a flat strip of stainless steel may preferably be formed flatwise into a plurality of substantially parallel back and forth turns, having rounded U-shaped ends **16** therebetween, which is commonly referred to as a zigzag shape. If desired, the straight portions of the back and forth or zigzag turns may be stiffened, by providing them with one or more longitudinal indentations **18** through a suitable pressing operation, thus giving the resistance element a dished cross-section, as shown in Figs. 6 and 7, for the purpose of preventing undue vibration of the element and increasing its resistance to deformation. Insulating spacers **19**, which are clearly illustrated in Figs. 1 and 2, may be provided, comprising a plurality of spaced apart fingers **20** which may be disposed between the adjacent straight portions of the resistance element, near the central portion thereof, to further increase the rigidity thereof. Connection may be made to the resistance element **14** in any suitable manner, such as by connecting a bus bar **22** directly to the resistance element by suitable means, such as the bolts **23**, which may be reinforced by welding if desired.

Support members **28** may be provided for supporting the resistance element **14** in the frame **12** so as to provide for a yielding or lost-motion connection therebetween. In a preferred form, as is clearly shown in Fig. 3 of the drawings, the support member **28** may comprise a substantially flat strip of stainless steel, or other suitable material, having a reasonable degree of flexibility and of sufficient width to prevent undue side sway, one end of which is preferably bent flatwise at a slight angle to the main body, and subjected to a forming operation to provide upstanding edges **29** by which it may be connected to the resistance element **14** at the rounded U-shaped end portion **16**, being, for example, welded thereto. The other end of the support member **28** may be connected by any suitable means, such as the bolts **29**, to an insulator support **30** which comprises, for example, a substantially hollow body member of a refractory material, having a flanged base portion **32**. In this manner, we provide a flexible hinge or support for allowing expansion and contraction of the resistance element **14** without subjecting it to undue stress.

Bracket members **35** may be provided for securing the insulator supports to the frame **12**, comprising, for example, channel members having inturned longitudinal edges **36** and **37** which are disposed to form a longitudinal pocket in which the flanged base portions **32** of the insulator supports **30** may be positioned. By utilizing such a form of construction, the insulator supports **30** may be readily slid into position through the open end of the bracket members **35**. If desired, the edge portion **37** of the bracket member **35** may comprise a separate member removably secured to the base thereof, and upon removal thereof, any or all of the insulator supports **30** may be removed, and cleaning or repair-

ing thereof may be easily effected when desired. In order to provide further insulation between the resistance element 14 and the frame 12 of the resistor, the bracket members 35 may be positioned in the frame 12 by being mounted in any suitable manner on insulators 40, which are secured to the frame.

Referring particularly to Fig. 4, it may be seen that a compact and efficient resistor may be provided by combining a number of resistors, such as illustrated in Fig. 1, in stacked relation, utilizing either separate frame structures or a single frame having a plurality of pairs of support brackets 35 secured thereto in the manner hereinbefore disclosed in connection with Figs. 1 and 2. Suitable connection may be made between the different tiers of resistance elements 14 by the conductor 22, which may be easily connected to the resistance elements by any suitable means, such as the bolts 23, and welded, to provide an integral connection with no loose connections to corrode or become open.

Referring to Figs. 5, 6 and 7, which illustrate details of an alternate form of resistor construction, the reference number 45 designates a modified form of support member which is disposed to be secured to the rounded end portion 16 of the resistance element 14 for supporting the resistance element in the frame 12 and providing a yielding or lost-motion connection therebetween, so as to permit expansion and contraction of the element without subjecting it to undue stress.

The support member 45 may, as indicated particularly in Figs. 5 and 6 of the drawings, comprise a C-shaped body, preferably formed by bending a length of stainless steel strap flatwise, and providing a suitable wear bushing 47, located in the central portion of the body for reducing friction and eliminating localized wear. Parallel slots may be cut in the lip portions of the support member 45, and the centrally disposed tongue portion 48 defined thereby may be bent outwardly to occupy the position shown in dotted lines in Fig. 6. By then placing the lip portions of the support member 45 against the resistance element 14 and bending the tongue portions 48 inwardly about the resistance element, the support member 45 may be secured to the resistance element without impairing the current carrying capacity of the element, and without providing too ready a path for the flow of heat from the resistance element to the means of support, thus facilitating high temperature operation of the resistance element.

In order to yieldingly support the resistance element in the frame 12 and provide for relative motion therebetween, support insulators 49 may be provided, having an extending support pin 50 which is disposed to effect a sliding fit in the bushing 47 of the support member 45. In this manner, the resistance element 14 may be properly supported in the frame 12, and yet free to expand and contract without setting up undue stresses. If desired, suitable baffle members or cooling fins 52 may be provided in connection with the support pins 50, for additionally reducing the flow of heat between the resistance member and the insulators 49, and permitting the resistance element 14 to operate at a higher temperature, thus further reducing the required amount of mass of the element.

In Figs. 8 and 9 a different embodiment of our invention is illustrated wherein a flexible stainless steel resistance element 14 is disposed to be suspended in looped relation in a rigid frame structure 60, which may be of any suitable form, comprising, for example, structural steel members or pipe members.

In a preferred form of construction, horizontal side members 62 may be secured to the frame 60 and provided with suitable insulator members 64 secured thereto in any desirable manner, such as by means of the clamp type brackets 65 for positioning upper and lower support members 66 and 68. These support members may, for example, comprise suitable lengths of pipe having a plurality of oppositely disposed laterally extending fingers 69. Grooved insulating spools 72 of a refractory material may be positioned on the fingers 69 for supporting the resistance element 14. If desired, these spools may be secured to the fingers 69 so as to be rotatable thereon, for a reason which will be hereinafter explained in detail.

Suitable saddle members 74 and 76 may be provided for securing the upper and lower support members 66 and 68, respectively, to their respective insulator members 64. The support members may be provided with suitable means, such as the projecting pins 78 for engagement with openings in the top of the saddle members so as to prevent rotation of the support members therein. By making the throat portion of the lower saddle member 76 sufficiently deep, provision may be made for relative vertical movement of the support member 68 therein.

The resistance element 14 may then be suspended from the upper support member 66 by looping the element 14 alternately about successive spools 72 of the upper and lower support members to provide a plurality of zig-zag back and forth turns. By looping the element 14 about the insulator spools 72 of the upper and lower support members with the lower support member 68 in a raised position in the saddle member 76, a moderate loading may be placed upon the loops of the resistance element 14 because of the downward force exerted by the lower spacing member 68, so that the back and forth portions thereof may be maintained in tension, unaffected by expansion of the element when under load, or the subsequent contraction thereof when cooling after the load is removed. Since the spools 72 are rotatable upon the fingers 69, uneven expansion of the resistance element may be compensated for, as the element may move relative to the points of support. The turns of the resistance element may thus be maintained under a constant tension and the spacing between successive turns may be maintained without the necessity of intermediate spacers or support members.

It may be seen from the above detailed description, taken in connection with the accompanying drawings, that we have by our invention provided an improved construction for resistors whereby a non-corrosive continuous strip resistance element may be supported in a rigid frame in such a manner as to allow for expansion and contraction of the element without impairing the current carrying capacity thereof. With the resistance element secured to the support members in the manner hereinbefore disclosed, the transfer of heat from the element to the supporting insulators is reduced to a minimum, so that the element may safely operate at relatively high temperatures. By utilizing commercial stainless steel, which may be easily secured in any desirable length, thickness and

width, a resistance element may be provided which has a high cooling factor, a high degree of resistance to corrosion, and is highly resistant to deformation, even at relatively high temperatures. Accordingly, we are able to provide a neutral grounding resistor of rugged construction, having a non-corrosive high strength resistance element wherein the number of joints is held to a minimum, which will not fail when subjected to a heavy surge of current, and which may comprise a reduced mass because of the permissible higher operating temperatures, thus insuring the reliability of the resistor in service, and a low cost of maintenance.

While our invention has been found of particular value in connection with applications of neutral grounding resistors, where sudden and excessive surges of fault current must be carried, it is to be understood that the invention is not intended to be limited to such applications, and may be readily and advantageously used wherever an economical, reliable resistor is desired.

Since certain changes may be made in the above construction, and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings, shall be considered as illustrative, and not in a limiting sense.

We claim as our invention:

1. A resistor comprising, a frame structure, a resistor element formed of a relatively wide strip of flexible material bent flatwise to provide a plurality of substantially horizontal back and forth turns on edge and having a width sufficient to prevent undue sagging of the center portions of the turns when supported only at the ends, a plurality of insulating members supported by the frame structure in spaced relation with the said ends of the back and forth turns, and connecting means interposed between the insulating members and the ends of the back and forth turns for supporting said resistor element from said insulating members, said connecting means comprising relatively wide vertically rigid metal support members rigidly secured to said ends of the back and forth turns and having a limited area of contact therewith to reduce the heat flow to the insulating members, and means connecting the support members to the insulating members to provide a substantially rigid vertical support for supporting the ends of the said turns in spaced relation to the insulating members, said connecting means functioning to provide a support yieldable horizontally in the longitudinal direction of the back and forth turns to permit longitudinal expansion and contraction of the back and forth turns and support the back and forth turns rigidly in the vertical direction.

2. A neutral grounding resistor comprising, a frame, insulating support members removably supported thereby, a continuous strip resistance element comprising a plurality of substantially horizontal back and forth turns on edge, means comprising metallic support members having the ends rigidly secured to the resistance element adjacent the opposite edges thereof at the ends of the said turns and having openings intermediate the ends, and support means projecting from the insulating support members positioned in said openings for connecting the resistance element to the insulating support members and rigidly supporting the resistance element vertically in the frame in spaced relation to the insulating support members without appreciably stressing the turns longitudinally to allow longitudinal movement of the ends of the turns of the element relative to the frame.

3. A resistor comprising, a frame, a horizontally disposed resistance element having a plurality of back and forth turns of stainless steel ribbon on edge with a width sufficient to render the turns self-supporting when supported at the end thereof, a plurality of oppositely disposed insulator supports removably secured to the frame, and means comprising a plurality of flexible hanger members for resiliently supporting the resistance element at the said ends from the insulator supports without appreciably stressing the turns longitudinally for movement in a horizontal direction only to provide for expansion and contraction of the resistance element.

4. A resistor comprising, a frame, insulating means disposed to be removably secured to the frame, a plurality of substantially horizontal back and forth turns of flexible resistance ribbon formed from a non-corrosive nickel chromium alloy steel having a high temperature of deformation, and resilient support means comprising a plurality of hangers dependent from the insulating means disposed to support the resistance ribbon in yielding relation with the insulating means without appreciably stressing the resistance ribbon longitudinally.

5. A resistor comprising, a frame, a plurality of insulating members supported by the frame, a resistance element comprising a plurality of substantially horizontal back and forth turns formed from a continuous strip of resistance material, and a plurality of substantially flat hanger members dependent from the insulating members connected to the resistance element at fixed points so as to permit movement of said points only in the longitudinal direction of expansion and contraction of the spaced turns of the resistance element.

6. A resistor comprising, a frame, a continuous ribbon resistance element comprising a plurality of substantially horizontal back and forth turns, a plurality of insulating members supported by the frame having metallic pins projecting substantially horizontally therefrom, and means comprising substantially C-shaped support members rigidly connected to the resistance element at the ends of the back and forth turns having openings, for receiving the metallic pins, said pins and support members functioning to slidably support the resistance element on the pins in spaced relation to the insulating members.

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