Oct. 19, 1965 A. G. OWEN 3,213,401

ELECTRICAL RESISTOR

Filed July 30, 1962

Fig. 1.

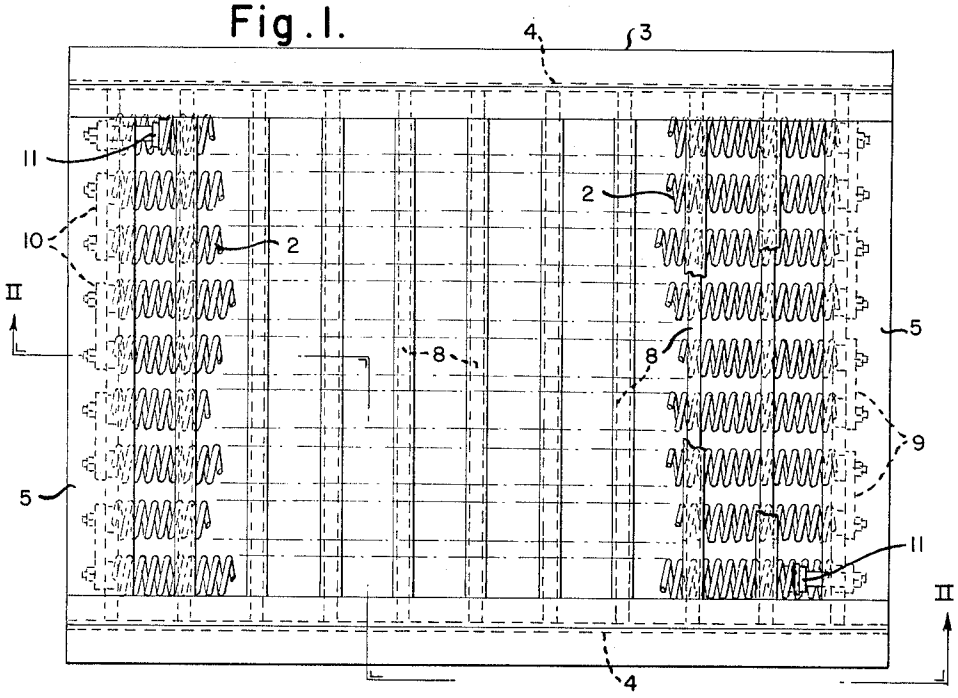


Fig. 2.

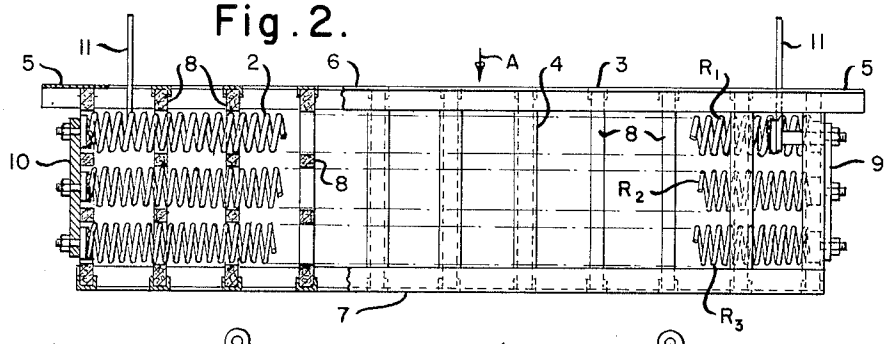
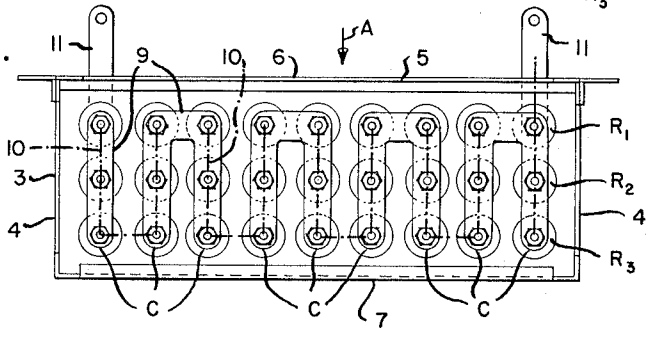


Fig. 3.



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ELECTRICAL RESISTOR

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This invention relates to an electrical resistor and has to do particularly with an electrical resistor having means for dissipating heat. The invention is concerned with a novel design and arrangement of resistor elements in relation to the direction of a cooling draft which is imposed on the resistor elements tending to equalize the operating temperature of the resistor elements and hence greatly increase the efficiency of the electrical resistor.

Electrical resistors provided with means for dissipating heat, i.e., means for cooling the resistor elements, have a wide variety of uses. One prominent use of such electrical resistors is in railroad locomotives employing dynamic braking systems. Dynamic braking systems are used on downgrade runs to relieve the loading and resultant wear and tear on the air operated shoe-type brakes. The electrical energy generated by the dynamic braking system causes heating of the resistor elements which are subjected to a cooling draft which is generally induced by the movement of the train but may be otherwise created.

An electrical resistor of the type referred to comprises a plurality of resistor elements arranged in spaced apart relationship in a two-dimensional field, the resistor elements being electrically connected to one another and to a source of current which may be the generator of the dynamic braking system, and the cooling draft is directed through the two-dimensional field of resistor elements. Normally the resistor elements are elongated and arranged in generally parallel relationship like the trees in a forest and the cooling draft moves through the resistor elements generally at right angles thereto as a wind moves through the trees of a forest. The cooling draft is initially relatively cool but its temperature is increased as it passes through the field of resistor elements since heat in the resistor elements is abstracted by the cooling draft and carried away. Hence the cooling draft becomes progressively hotter as it passes through the field of resistor elements.

The resistor elements may be in the form of resistor coils. The coils as mounted in the electrical resistor are coreless and normally their successive convolutions are spaced apart. Heretofore it has been the practice to utilize identical coils throughout the electrical resistor. The cooling draft directed through the coils has cooled the coils first engaged by the draft to a temperature lower than the temperature to which the coils later engaged by the draft have been cooled, first, because of the progressively increasing temperature of the coling draft as it passes through the field of coils, and, second, because the coils through which the cooling draft first passes have a shielding effect with respect to the coils through which the cooling draft later passes, decreasing the effectiveness of the cooling draft on the latter mentioned coils. The result has been that in operation the coils more remote from the source of the cooling draft have operated at a temperature substantially higher than the coils nearer the source of the cooling draft. A given coil can withstand only a certain temperature, after which it melts. The capacity of the electrical resistors heretofore employed has been limited by the maximum permissive temperature of the coils most remote from the source of the cooling draft. Since uniform coils have heretofore been used throughout the electrical resistor this has resulted in the coils nearer the source of the cooling draft, which are relatively cool, operating at materially less than theoretical potential with an overall sacrifice of efficiency in the electrical resistor.

I have devised an electrical resistor which cures the defect of prior electrical resistors as above explained. My electrical resistor is designed so that all of the resistor elements or coils of the electrical resistor operate at approximately the same temperature which enables maximum or optimum efficiency to be derived from each resistor element or coil with an unprecedented increase in the overall efficiency of the electrical resistor. I design the respective resistor elements or coils of different characteristics so that the electrical resistance of the resistor elements nearer the source of the cooling draft is less than that of those more remote from the source of the cooling draft, which results in a tendency (apart from the cooling draft) of the resistor elements closer to the source of the cooling draft to operate at a higher temperature than resistor elements more remote from the source of the cooling draft. I take into consideration the fact that the temperature of the cooling draft progressively increases as it passes through the field of resistor elements or coils. I further take into consideration the shielding effect of the coils nearer the source of the cooling draft upon the coils more remote from the source of the cooling draft and design the coils to obviate to a considerable extent the shielding tendency. As a result my electrical resistor operates at a relatively uniform temperature throughout, enabling for the first time realizing of optimum efficiency.

I provide an electrical resistor comprising a plurality of resistor elements arranged in spaced apart relationship in a two-dimensional field, means electrically connecting the resistor elements to one another and to a source of current so that the resistor elements are heated upon the passage of current therethrough and means directing a cooling draft against the resistor elements, the electrical resistance of resistor elements subjected to the cooling draft when such draft is relatively cool being less than the electrical resistance of resistor elements subjected to the cooling draft when such draft is relatively hot so as to tend to equalize the operating temperature of the resistor elements. It is generally preferable to arrange the resistor elements in rows and to direct the cooling draft generally transversely of the rows of resistor elements, the electrical resistor being designed so that the electrical resistance of resistor elements of a row relatively near the source of the cooling draft is less than the electrical resistance of resistor elements of a row relatively remote from the source of such draft.

As above indicated the resistor elements may be and in most instances preferably are in the form of coils. The cooling draft is directed through the coils and I preferably provide the effective length and hence the electrical resistance of coils subjected to the cooling draft when such draft is relatively cool to be less than the effective length and hence the electrical resistance of coils subjected to the cooling draft when such draft is relatively hot so as to tend to equalize the operating temperature of the coils.

I find it desirable to make the axial dimension of the coils substantially uniform and to make the pitch of coils subjected to the cooling draft when such draft is relatively cool greater than the pitch of coils subjected to the cooling draft when such draft is relatively hot. I may provide coils of substantially uniform effective length with the transverse cross-sectional area of the coiled element forming coils subjected to the cooling draft when such draft is relatively cool greater than the transverse cross-sectional area of the coiled element forming coils subjected to the cooling draft when such draft is relatively hot.

In my electrical resistor the pitch of the respective coils and the transverse cross-sectional area of the coiled ele-

ments forming the respective coils are preferably selected so that the electrical resistance of coils subjected to the cooling draft when such draft is relatively cool is less than the electrical resistance of coils subjected to the cooling draft when such draft is relatively hot; also preferably so that coils subjected to the cooling draft when such draft is relatively cool have relatively wide openings between their convolutions in contrast to coils subjected to the cooling draft when such draft is relatively hot to reduce obstruction to the cooling draft in its passage to coils subjected to the cooling draft when such draft is relatively hot.

The pitch of coils in a row relatively near the source of the cooling draft may be greater than the pitch of coils in a row relatively remote from the source of such draft so that the electrical resistance of the coils of the first mentioned row is less than the electrical resistance of the coils of the second mentioned row, and also the coils of the first mentioned row may have relatively wide openings between their convolutions to reduce obstruction to the cooling draft in its passage to the coils of the second mentioned row.

Preferably the resistor elements are arranged in rows and columns, the rows extending transversely of the direction of the cooling draft and the columns extending generally in the direction of the cooling draft, the elements of the respective rows in each column being electrically connected together in parallel or multiple ("parallel" and "multiple" are synonymous in the context of electric circuitry; "multiple" is used in the claims to avoid confusion with "parallel" used in defining the spatial relationship of the colums), the columns being electrically connected together in series.

Other details, objects and advantages of the invention will become apparent as the following description of a present preferred embodiment thereof proceeds.

In the accompanying drawings I have shown a present preferred embodiment of the invention in which:

FIGURE 1 is a face view, with portions cut away, of an electrical resistor embodying my invention;

FIGURE 2 is a cross-sectional view taken on the line II—II of FIGURE 1; and

FIGURE 3 is an end view of the electrical resistor shown in FIGURES 1 and 2 as viewed from the right in those figures.

The electrical resistor comprises twenty-seven coreless resistor coils **2** arranged as shown in the drawings in three rows R_1, R_2 and R_3 and nine columns C. The coils are mounted in a casing designated generally by reference numeral **3** having side members **4** connected together by end members **5** and the front **6** and the back **7** of the casing **3** being open to allow a cooling draft to be directed against and through the coils. The cooling draft is directed substantially in the direction of the arrow A in FIGURES 2 and 3 generally at right angles to the rows R_1, R_2 and R_3 of coils and in the direction of or along the columns C thereof. The cooling draft may be created by induction or by a blower blowing the cooling air into the field of resistor coils at **6** and out at **7**. In any event the cooling draft passes through the field of coils in the direction indicated and abstracts heat from the coils. The coils are mounted in the casing **3** by transite spacers **8** with holes cut therein for the coils to pass through. The coils are electrically connected together as shown in the drawings. The electrical connections at one end of the casing are designated **9** and the electrical connections at the other end of the casing are designated **10**. In FIGURE 3 the electrical connections **9** are at the end of the casing nearer the eye and the electrical connections **10** at the opposite end of the casing are indicated by chain lines. Thus it is seen that the coils of the respective rows R_1, R_2 and R_3 in each column C are electrically connected together in parallel and the columns C are electrically connected together in series. The electrical resistor is connected with the generator through terminals **11**.

The cooling draft engages first the coils of the row R_1, thereafter the coils of the row R_2 and finally the coils of the row R_3. If all of the coils were uniform in accordance with prior practice the coils of the row R_1 would operate at relatively low temperature the coils of the row R_2 would operate at intermediate temperature and the coils of the row R_3 would operate at relatively high temperature for the reasons above explained. To relatively equalize the temperature of operation of all of the coils I design the coils of the row R_1 to have minimum electrical resistance, those of the row R_2 to have intermediate electrical resistance and those of the row R_3 to have maximum electrical resistance. At the same time I prefer to reduce the shielding effect of the coils of the row R_1 by designing those coils with maximum pitch, i.e., with maximum spacing between their convolutions, the coils of row R_2 with intermediate pitch and the coils of row R_3 with minimum pitch. I find it desirable to use heavier wire for forming coils relatively near the source of the cooling draft and lighter wire for forming coils relatively remote from the source of the cooling draft. In an electrical resistor of the type shown in the drawings I desirably form the coils of row R_1 of No. 1 wire and the coils of rows R_2 and R_3 of No. 2 wire.

Since the voltage is constant the amperage per coil in the coils of row R_1 will be greater than the amperage per coil in the coils of row R_2 and the amperage per coil in the coils of row R_2 will be greater than the amperage per coil in the coils of row R_3 in order that the resistance per coil in the coils of row R_1 may be minimum that in the coils in the row R_2 may be intermediate and that the coils in the row R_3 may be maximum, resulting in operation of the electrical resistor at substantially uniform operating temperature throughout whereby maximum electrical efficiency is attained.

The following table lists the characteristics of a typical electrical resistor designed in accordance with my invention:

	Row R_1	Row R_2	Row R_3
Amperes per coil	250	180	170
Volts per coil	44	44	44
Turns per coil	59	63	69
Wire size per coil	#1	#2	#2
Resistance per coil, Ohms	.1761	.2444	.260
Watts per coil	11,000	7,920	7,480
Area surface per coil, Sq. In.	230.4	224	237
Watts per Sq. In.	47.6	35.4	31.5

In the exemplary electrical resistor the length of the coils is 29 inches, all coils of the three rows being of the same length. The turns per inch of the coils of row R_1 equals 2.035. The diameter of the wire of the coils of the row R_1 is .2893 inch so that the maximum possible number of turns would be 29/.2893 or approximately 100 turns (with no space between turns). 100/59 equals a space factor of 1.7, the space between coil convolutions being about 70% of the diameter of the wire. The maximum possible number of turns of the coils of rows R_2 and R_3 is 29 divided by .2576 (the wire diameter) or 112.5. 112.5/63 equals 1.79, the space factor in row R_2. The space factor in row R_3 is 112.5/69 or 1.63. Thus in all three rows a good space factor is maintained providing for free passage of air through the coils and about the respective convolutions of each coil. In the particular electrical resistor selected as an example the space factor in row R_2 is slightly greater than that in row R_1 but it is to be borne in mind that the wire in row R_2 is smaller than that in row R_1 and hence more easily cooled. The space factor in row R_3 is less since the coils of row R_3 do not shield any other coils and hence shielding effect is not a factor in the design of the coils of row R_3.

The most important consideration is the designing of the resistor elements or coils for minimum electrical resistance in row R_1, intermediate electrical resistance in row R_2 and maximum electrical resistance in row R_3. Electri-

cal resistance is a function of the diameter of the wire used for forming the coils and the effective length of such wire in the coil. Increase in wire diameter decreases electrical resistance while increase in the effective length of the wire increases electrical resistance so an optimum electrical resistance can be arrived at by proper relative selection of wire diameter and effective wire length in the coil. Also the pitch of the coil affects not only shielding effect but also cooling rate, a coil of greater pitch cooling more quickly than a similar coil of lesser pitch.

Another factor which enters the picture is turbulence but that factor is not capable of exact determination and has to be dealt with experimentally. Also there may be a tendency in certain installations for the cooling draft to channel toward one side of the electrical resistor. In such cases the resistor elements at the respective sides of the electrical resistor may differ somewhat in wire size and pitch to the end that the operating temperature throughout the electrical resistor is substantially the same which produces maximum electrical efficiency.

While I have shown and described a present preferred embodiment of the invention it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied within the scope of the following claims.

I claim:

1. An electrical resistor comprising a plurality of resistor coils arranged generally in rows and columns, the axial dimension of the coils being substantially uniform, means electrically connecting the coils to one another in multiple and means directing a cooling draft through the coils, the pitch of coils in a row relatively near the source of the cooling draft being greater than the pitch of coils in a row relatively remote from the source of such draft so that the electrical resistance of the coils of the first mentioned row is less than the electrical resistance of the coils of the second mentioned row and also the coils of the first mentioned row have relatively wide openings between their convolutions to reduce obstruction to the cooling draft in its passage to the coils of the second mentioned row, so as to tend to equalize the operating temperature of the coils when a current of electricity is passed therethrough.

2. An electrical resistor comprising a plurality of resistor elements arranged generally in rows and columns, the elements of the respective rows in each column being electrically connected together in multiple, the columns being electrically connected together in series, and means directing a cooling draft against the resistor elements generally transversely of the rows of resistor elements, the electrical resistance of resistor elements of a row relatively near the source of the cooling draft being less than the electrical resistance of resistor elements of a row relatively remote from the source of such draft so as to tend to equalize the operating temperature of the resistor elements when a current of electricity is passed therethrough.

3. An electrical resistor comprising a plurality of resistor coils arranged generally in rows and columns, the coils of each column being electrically connected together in multiple, the columns being electrically connected together in series, and means directing a cooling draft through the coils generally transversely of the rows of coils, the electrical resistance of coils of a row relatively near the source of the cooling draft being less than the electrical resistance of coils of a row relatively remote from the source of such draft so as to tend to equalize the operating temperature of the coils when a current of electricity is passed therethrough.

4. An electrical resistor comprising a plurality of resistor coils arranged generally in rows and columns, the axial dimension of the coils being substantially uniform, the coils of the respective rows in each column being electrically connected together in multiple, the columns being electrically connected together in series, and means directing a cooling draft through the coils generally transversely of the rows of coils, the pitch of the respective coils and the transverse cross-sectional area of the coiled elements forming the respective coils being selected so that the electrical resistance of coils of a row relatively near the source of the cooling draft is less than the electrical resistance of coils of a row relatively remote from the source of such draft so as to tend to equalize the operating temperature of the coils when a current of electricity is passed therethrough.

5. An electrical resistor comprising a plurality of resistor coils arranged in spaced apart relationship in a two-dimensional field, the axial dimension of the coils being substantially uniform, means electrically connecting the coils to one another in multiple and means directing a cooling draft through the coils, the pitch of the respective coils and the transverse cross-sectional area of the coiled elements forming the respective coils being selected so that the electrical resistance of coils subjected to the cooling draft when such draft is relatively cool is less than the electrical resistance of coils subjected to the cooling draft when such draft is relatively hot and coils subjected to the cooling draft when such draft is relatively cool have relatively wide openings between their convolutions in contrast to coils subjected to the cooling draft when such draft is relatively hot to reduce obstruction to the cooling draft in its passage to coils subjected to the cooling draft when such draft is relatively hot, so as to tend to equalize the operating temperature of the coils when a current of electriciy is passed therethrough.

6. An electrical resistor comprising a plurality of resistor elements arranged in generally parallel columns, the elements of each column being electrically connected together in multiple, the columns being electrically connected together in series, and means directing a cooling draft through the elements generally parallel to the columns, the electrical resistance of elements relatively near the source of the cooling draft being less than the electrical resistance of elements relatively remote from the source of such draft so as to tend to equalize the operating temperature of the elements when a current of electricity is passed therethrough.

References Cited by the Examiner

UNITED STATES PATENTS

561,294	6/96	Thomas	338—299
1,138,659	5/15	Huenerfauth	338—299 X
1,491,194	4/24	Burger	338—218 X
1,563,363	12/25	Hibbard	338—58
1,957,227	5/34	Reimers et al.	338—299 X
2,234,289	3/41	Tenney	338—51
2,596,327	5/52	Cox et al.	219—381
2,858,402	10/58	Griffes et al.	219—539 X
2,904,764	9/59	Minter	338—218 X
3,102,970	9/63	Haskell et al.	323—123

FOREIGN PATENTS

633,284	12/49	Great Britain.

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