Aug. 7, 1945. D. R. CROSBY 2,381,724

RESISTOR

Filed Oct. 13, 1943

Fig. 1.

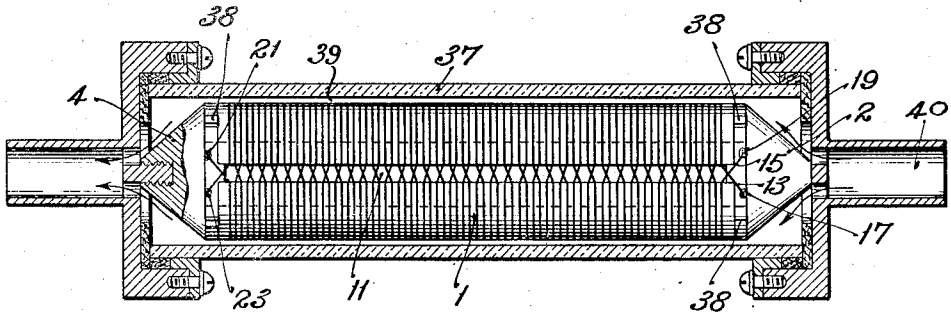



Fig. 2.

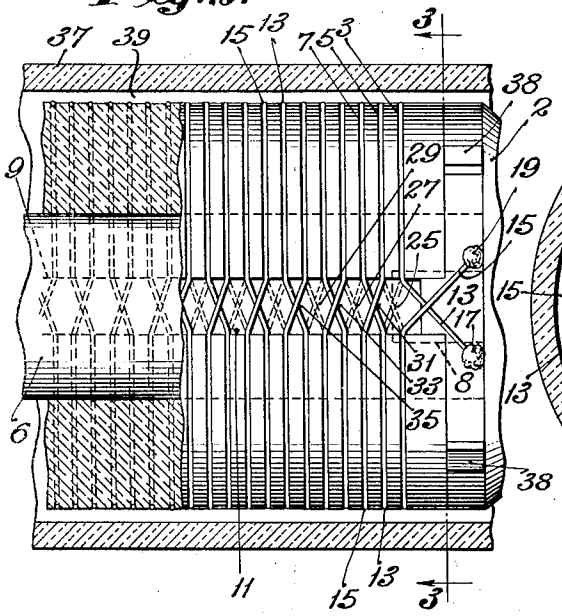



Fig. 3.

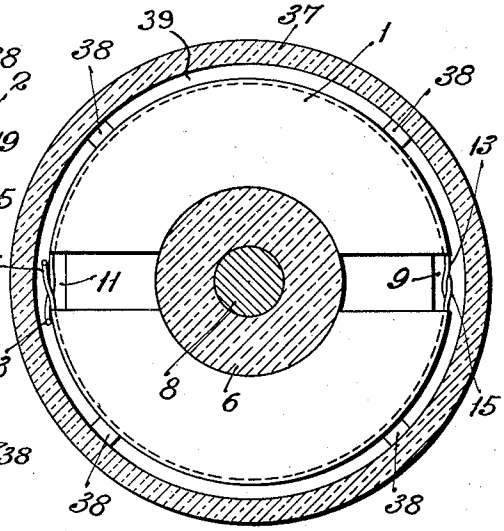
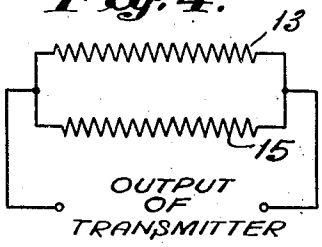



Fig. 4.




Inventor

David R. Crosby

By C. A. Snow & Co.

Attorney

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# UNITED STATES PATENT OFFICE

2,381,724

## RESISTOR

David R. Crosby, Haddonfield, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application October 13, 1943, Serial No. 506,038

14 Claims. (Cl. 201—67)

This invention relates to resistors and more particularly to 'fluid cooled" load resistors used in testing high power radio frequency transmitters and oscillators.

In testing apparatus of the general character described, it is frequently necessary to dissipate radio frequency power of the order of 50 to 100 kilowatts and upward; it is also often desired to measure the input and output temperatures of the cooling fluid and its rate of flow, whereby radio frequency power may be calculated from the formula:

$$P=K\times(\text{G.P.M.})\times(\Delta^\circ\text{C.})$$

where

P=the radio frequency power output in kilowatts,

K is a constant for any given cooling fluid; where water is used K=.264,

G. P. M.=the rate of flow in gallons per minute of the water or other cooling fluid caused to flow over the resistor through which such power is being dissipated, and

Δ° C.=the difference in the input and output temperatures of the cooling fluid in degrees centigrade.

Wire wound resistors used for these purposes hitherto have had poor impedance versus frequency characteristics, have been difficult to construct, and have been extremely cumbersome in themselves, and particularly when regard is had to the impedance matching network which necessarily accompanied them. Nor could they be used at substantially different frequencies without lengthy and complicated adjustment.

Since such resistors must be substantially non-inductive various forms of opposed winding have been used, the characteristic feature of all of which is that the inductance of one turn cancels that of its counterpart. By way of example, a resistor of this type is described on pages ii and vii in the supplement at the end of the December, 1939, issue of the Proceedings of the Institute of Radio Engineers under the heading "Commercial engineering developments." However, because all of these windings are helical, the space where the wires cross occupies an appreciable part of a turn, and they therefore tend to slide around, causing arcs.

Among the objects of the invention is the provision of an improved resistor with substantially negligible reactance for the dissipation and measurement of radio frequency power; one which has a good impedance versus frequency characteristic; which is compact in construction and use; and needs no impedance matching network for its operation.

Further objects of the invention are to provide a resistor of the character described whose resistance does not deteriorate with time, which needs no substantial adjustment over a wide range of frequencies, and where the windings remain taut, and the tendency to arc between turns is eliminated.

An additional object of this invention is to provide an improved method of winding wire resistors.

These and other objects are accomplished in a preferred embodiment of the invention by carrying the two windings in peripheral grooves formed on the outer surface of an insulating member, which has also two diametrically opposed longitudinal slots formed on that surface. Each of the windings is held tautly in alternate halves of the grooves in opposed relation, and the advance from one turn to the next takes place only in the longitudinal slots. The windings therefore form a series of parallel circles spaced longitudinally along the insulating member and broken only at the slots. The defects of a helical winding are avoided in this way.

The invention will best be understood from the following description of a specific embodiment thereof when read in conjunction with the accompanying drawing, in which

Figure 1 is a front view in elevation (partly in section) of one embodiment of the invention, showing the resistor assembly adapted to be cooled by water,

Figure 2 is an enlarged elevational view (partly in section) of the end of the resistor shown at the right of Figure 1,

Figure 3 is a sectional view taken along the line 3—3 in Figure 2, and

Figure 4 is a schematic diagram of the resistor showing its relation to the electrical circuit of which it is to form part.

In the preferred embodiment, the insulating member 1 is of hollow cylindrical construction. It is made preferably of a machineable ceramic material. As will appear later in this description, water is caused to flow through and around this member, and the heat, generated by the radio frequency power flowing through the resistor, raises the temperature of the water. A typical increase is from an ambient temperature of 18° C. to approximately 38° C. Ceramic material has been found in practice to withstand the effects of immersion in water at these temperatures

much better than Bakelite or other materials formerly used. Previously, malformation of the member 1 resulting from such immersion caused loosening of the winding of the resistor.

Circumferential parallel grooves, 3, 5, 7, etc., are formed on the outer surface of the member. These grooves form complete circles on the surface of the member, and permit an essentially different winding from grooves cut in helical form. The grooves lie in planes normal to the longitudinal axis of the member, and are closely spaced from each other in a direction longitudinally thereof, in order to achieve maximum mutual inductance between the turns of the windings carried in the groove. By way of example, there may be 50 grooves per inch. Two longitudinal diametrically opposed slots, 9, 11 are also formed on the outer surface of the member 1, as shown in the drawing. Running through member 1, and supporting it, is an insulating core 6, to which the conical end pieces 2, 4 of conducting material, preferably brass, are rigidly connected in any practical manner, for example, as by the stud 8.

The member 1 carries two windings 13, 15. They are, for example, of wire having a diameter of .008 inch, and are composed of an alloy containing 80 percent of nickel, and 20 percent of chromium. This wire has a rated resistance of approximately 10 ohms per foot.

Winding 13 begins at, and is soldered to terminal 17 rigidly connected to end piece 2. This winding is carried tightly in groove 3 across the upper half of member 1 to slot 9, at which point it has formed approximately a semi-circle; it then crosses diagonally downward in slot 9 to groove 5, in which it forms another approximate semi-circle on the lower half of the periphery of member 1 back to slot 11, which it now crosses diagonally upwards to groove 7. Winding 13 continues to form alternate semi-circles and ends at terminal 21, rigidly connected to conical end piece 4 at the other end of member 1.

Winding 15, wound in the opposite direction from winding 13, begins at terminal 19 and ends at terminal 23, rigidly connected to conical end pieces 2 and 4 respectively, like terminals 17 and 21. It occupies the portions of grooves 3, 5, 7, etc., not occupied by winding 13, thereby forming semi-circles in opposed relation to those made by winding 13. The two windings cross each other only in slots 9 and 11. The crossing points in slot 9 are numbered 25, 27, 29, etc., and in slot 11, 31, 33, 35, etc. The distance from terminal 17 along winding 13 to crossing point 25 is equal to the distance from terminal 19 along winding 15 to the same crossing point. There is therefore no potential difference at that point between either winding. By similar reasoning, it will be found that there is no potential difference between the windings at any other crossing point, and the tendency to arc is therefore entirely eliminated. It is immaterial whether the wires touch or not, Since each turn is held tightly in a groove there is no sliding around at the point where the wires cross each other as there is with a helical winding.

The inductance of each half-circle of winding is cancelled by the inductance of the opposing half-circle and the mutual inductance of the adjacent turns. The two windings are connected in parallel as shown in Fig. 5.

It is not essential that there should be only two slots 9, 11; there may be any number of pairs of diametrically opposed slots. The windings will then form quadrants or other sections of the periphery of member 1.

A resistor wound in the manner described may be cooled by air blast or by any suitable fluid such as water. In the latter event, the resistor should be surrounded by an envelope 37, preferably of glass or other transparent material, held in radially spaced relation with the resistor, as by the protuberances 38, and separated from the resistor by a substantially annular air space 39, having a width, in the preferred embodiment, of .035 inch. Cooling fluid from the pipe 40 is caused to flow through this air space in the direction shown by arrows in Fig. 1. This fluid takes up the heat created in the resistor by the applied radio frequency power. Ordinary tap water at the regulation pressure of approximately 50 pounds per square inch, may be used; the only precaution which need be taken is to insert a filter in the path of the water before it comes in contact with the resistor, so as to prevent any coarse particles held in the water from blocking the annular air space, wholly or even in part. In this connection, it should be observed that both the member 1 and the envelope 37 should be made to fine tolerances, since even partial obstruction of the flow of water in the air space 39 may cause overheating of the resistor at the point of obstruction.

A resistor of the type described in this specification was wound on a tube of ceramic material eight inches long and two inches in diameter. With a water flow of nine gallons per minute, the resistor easily dissipated 120 kilowatts of radio frequency power, which corresponds to 2300 watts per square inch of coil surface. This resistor had only one-tenth the weight and volume of its conventional predecessor.

Resistors of the character herein described need not be limited in use to the dissipation and measurement of radio frequency power. They will find ready use in any application where their distinctive qualities of (*i*) compactness, (*ii*) negligible reactance, (*iii*) stable resistance in handling large amounts of radio frequency power and (*iv*) good frequency versus impedance characteristic, are necessary or desirable features.

I claim as my invention:

1. An insulating member and a resistor, consisting of two conductive elements carried on the outer surface of said member in parallel planes substantially normal to the longitudinal axis of said member, said elements occupying alternate sections of the periphery of said member in said planes in opposed relation, and crossing each other at points on said surface, said points forming at least one pair of diametrically opposed straight lines on said surface parallel with said axis.

2. The invention set forth in claim 1 characterized in that said planes are closely spaced from each other in a direction longitudinally of said member.

3. The invention set forth in claim 1 characterized in that said elements are connected in parallel in any electrical circuit of which they form part.

4. The invention set forth in claim 1 characterized in that said elements are so disposed as to be at equal potential at said points in any electrical circuit of which they form part.

5. The invention set forth in claim 1 characterized in that said elements lie in a single layer on said surface.

6. The invention set forth in claim 1 charac-

terized in that said member is composed of material which is highly impervious to the effect of immersion in water at high temperatures.

7. The invention set forth in claim 1 characterized in that said elements are carried in peripheral grooves formed on the outer surface of said member.

8. The invention set forth in claim 1 characterized in that said elements are carried in peripheral grooves formed on the outer surface of said member, and characterized further in that said member has a pair of diametrically opposed longitudinal slots formed on said surface, said elements crossing each other in said slots only and being secured to terminals rigidly connected to each end of said member, whereby said elements are held tightly against said surface, and prevented from movement in any direction thereon.

9. A support for a wire-wound resistor comprising an integral insulating member having a plurality of grooves formed on its outer surface for holding the turns of the resistor, said grooves lying in parallel planes substantially normal to the longitudinal axis of said member and being closely spaced from each other in a direction longitudinally of said member, said member also having a pair of diametrically opposed longitudinal slots formed on its outer surface.

10. A single layer resistor, consisting of two conductive elements wound around a tubular insulating member, each of said elements forming a plurality of parallel semi-circles on the periphery of said member, said semi-circles lying in planes normal to the longitudinal axis of said member and being closely spaced from each other in a direction longitudinally of said member, said elements crossing each other at points forming two straight lines on said periphery parallel to said axis.

11. A single-layer, wire-wound resistance unit comprising in combination an insulating member having a plurality of peripheral grooves formed on the outer surface thereof, said grooves lying in parallel planes normal to the longitudinal axis of said member and being closely spaced from each other in a direction longitudinally of said member, said member also having two diametrically opposed longitudinal slots formed on its outer surface, said slots intersecting said peripheral grooves at diametrically opposite points, and two conductive elements wound tightly around said member, said elements occupying alternate halves of said grooves in opposed relation and crossing each other only in said slots at points intermediate said first named points.

12. Two conductive elements carried tautly on and around the outer surface of an insulating member, said elements occupying alternate halves of the periphery of said member in opposed relation in planes normal to the longitudinal axis of said member, said planes being closely spaced from each other in a direction longitudinally of said member, each of said elements advancing from one plane to the next in two diametrically opposed channels on said surface only, said channels being parallel with said axis.

13. The combination of an insulating member having a plurality of peripheral grooves formed on the outer surface thereof, said grooves lying in parallel planes normal to the longitudinal axis of said member and being closely spaced from each other in a direction longitudinally of said member, said member also having two diametrically opposed longitudinal slots formed on said outer surface, said slots intersecting said grooves at diametrically opposite points, two conductive elements wound tightly around said member, said elements occupying alternate halves of said grooves in opposed relation and crossing each other only in said slots at points intermediate said first-named points, an envelope surrounding said elements, said envelope having the same cross-sectional configuration as said member, means for holding said envelope in radially spaced relation with said elements, leaving an air space substantially annular in cross-sectional configuration and concentric with said member between said elements and said envelope, and means connected to said envelope whereby a fluid may be caused to flow through said air space.

14. The combination of a resistor, consisting of two conductive elements carried on the outer surface of an insulating member in parallel planes substantially normal to the longitudinal axis of said member, said elements occupying alternate halves of the periphery of said member in said planes in opposed relation, and crossing each other at points on said surface, said points forming two diametrically opposed straight lines on said surface parallel with said axis, an envelope surrounding said elements, said envelope having the same cross-sectional configuration as said member, means for holding said envelope in radially spaced relation with said elements leaving an air space substantially annular in cross-sectional configuration and concentric with said member between said element and said envelope, and means connected to said envelope whereby a fluid may be caused to flow through said air space.

DAVID R. CROSBY.