July 5, 1966 S. F. VOGEL 3,259,784

NON-INDUCTIVE WIRE CONFIGURATIONS

Filed Dec 23, 1963 3 Sheets-Sheet 1

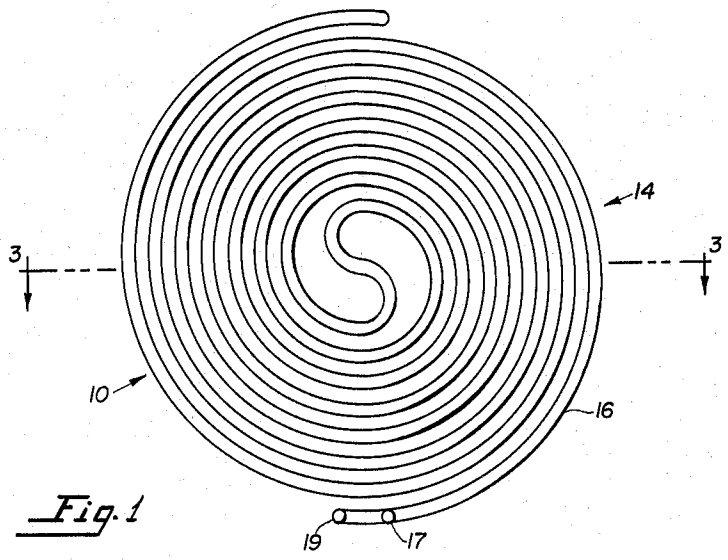

Fig. 1

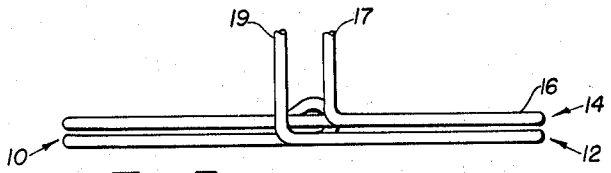

Fig. 2

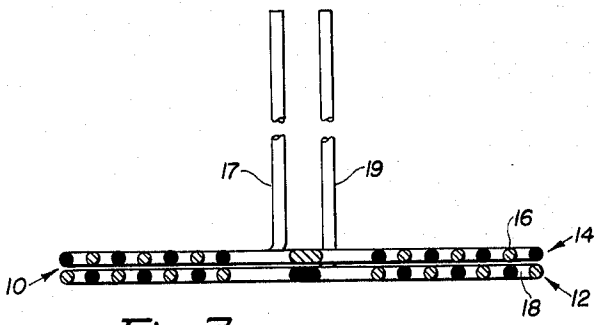

Fig. 3

INVENTOR.
SIEGFRIED F. VOGEL

BY Harry M Weiss
Robert W. Dilts

ATTORNEYS

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NON-INDUCTIVE WIRE CONFIGURATIONS

Filed Dec. 23, 1963 3 Sheets-Sheet 2

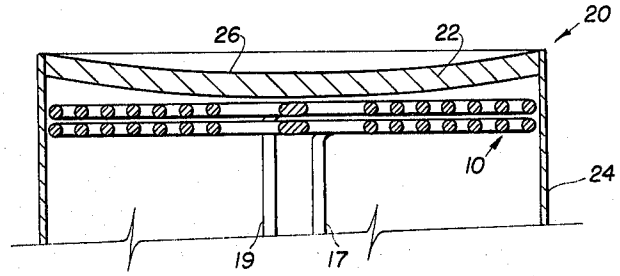

Fig. 4

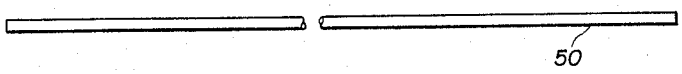

Fig. 5a

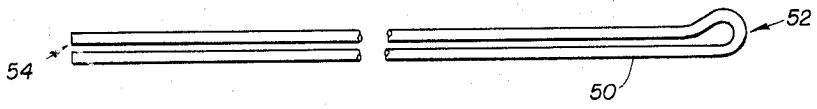

Fig. 5b

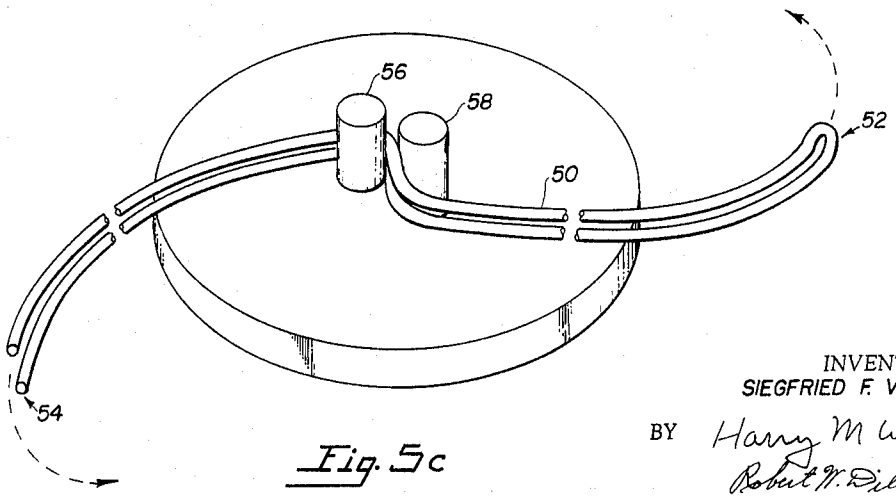

Fig. 5c

INVENTOR.
SIEGFRIED F. VOGEL

BY Harry M Weiss
Robert W. Dilts

ATTORNEYS

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NON-INDUCTIVE WIRE CONFIGURATIONS

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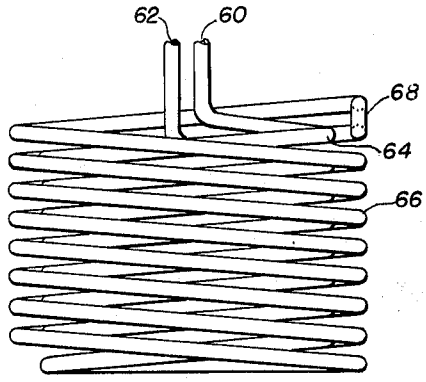

Fig. 6

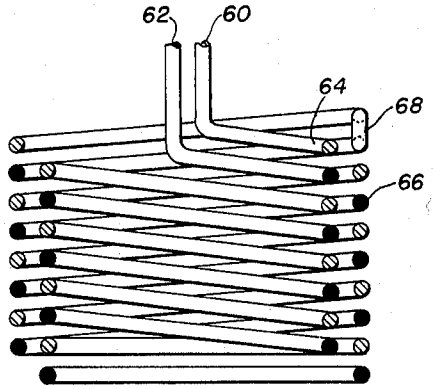

Fig. 7

INVENTOR.
SIEGFRIED F. VOGEL

BY Harry M Weiss
Robert W. Diltz
ATTORNEYS

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3,259,784

NON-INDUCTIVE WIRE CONFIGURATIONS

Siegfried F. Vogel, Belmont, Calif., assignor, by mesne assignments, to Varian Associates, a corporation of California

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13 Claims. (Cl. 313—342)

This invention relates generally to non-inductive wire configurations and more specifically to non-inductive heaters for use in heating electron emitting cathodes.

Conventional non-inductive wire configurations, formed as either a circuit element, such as a resistor, or as a heater for a cathode of an electron tube, are used to minimize magnetic fields which are always created when current is passed through a wire. Each segment of wire sets up its own magnetic field when current is applied thereto and the magnetic field set up by a number of segments of wire are reduced in a conventional non-inductive wire configuration by having oppositely directed magnetic fields set up in the adjacent segments of wire which tend to cancel out the magnetic field of each wire segment.

Nevertheless, standard or conventional non-inductive wire configurations, which usually had a double spiral single layer arrangement, still exhibited a magnetic field totaling about one gauss.

In certain circuit and in certain cathode heater applications, a magnetic field as low as one gauss provided by conventional non-inductive wire configurations cannot be tolerated because of its effects on circuit elements or electrons emitted from the cathode.

In electron tubes having cathodes heated by standard non-inductive wire heaters, a magnetic field as low as one gauss causes emitted electrons to be deflected because of the magnetic field lines. The electron current is modulated at the same frequency as the frequency of the current applied to the heater and hence, the resultant radio frequency output is similarly modulated. In addition, interference or grid interception effects in power grid tubes due to electron modulation by the magnetic field of the heater result in lowering tube efficiency.

Klystrons, as well as other electron beam type tubes, depend a great deal upon well defined electron beams. Conseqeuntly, irregularities in an electron beam caused by the effects of the magnetic fields of a heater wire located adjacent the cathode reduces the energy exchange efficiency and hinders beam transmission through the tube.

Scalloping of the electron beam and changes in the velocity of portions of the electron beam are other effects created by the presence of a small magnetic field in the vicinity of the cathode.

One solution to this problem is to position the cathode heater at a distance from the cathode so that the magnetic field would not extend into the electron emitting portion of the cathode. This solution reduces the effectiveness of the heater and hence, reduces the efficiency of the tube.

Accordingly, it is an object of this invention to provide an improved non-inductive wire configuration.

It is a further object of this invention to provide an improved non-inductive heater for use in an electron tube.

It is a still further object of this invention to provide a non-inductive circuit element.

It is another object of this invention to provide a non-inductive resistor.

It is a further object of this invention to provide an improved cathode-heater package.

It is another object of this invention to provide a method for forming the improved non-inductive wire configuration of this invention.

Briefly described, this invention relates to a non-inductive wire configuration having a plural layer wire arrangement. Each layer of wire contains a plurality of wire sections. Each wire section in each layer of wire has a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire. Furthermore, each wire section in each layer of wire has a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire.

The nature of the invention will be more clearly understood from the following description given with reference to the accompanying drawing.

In the drawing:

FIGURE 1 is a plan view of one embodiment of the improved non-inductive wire configuration of this invention;

FIGURE 2 is a side view of the non-inductive wire configuration of FIGURE 1;

FIGURE 3 is a cross-sectional view of the non-inductive wire configuration of FIGURE 1;

FIGURE 4 is a cross-sectional view of a cathode-heater package incorporating the improved non-inductive heater of this invention;

FIGURES *5a*, *5b*, and *5c* are perspective views of the steps for making the improved non-inductive wire configuration of FIGURE 1;

FIGURE 6 is a side elevational view of another embodiment of this invention; and

FIGURE 7 is a partial sectional view of the embodiment of FIGURE 6.

Referring to FIGURES 1, 2 and 3, a two layer, double spiral, non-inductive wire configuration **10** is shown. The non-inductive wire configuration **10** has a first non-inductive wound wire layer **12** and a second non-inductive wound wire layer **14** located adjacent to the first non-inductive wound wire layer **12**. Wire layers **12** and **14** are, preferably, wound from a single continuous wire. The non-inductive wound wire layer **14** is a double spiral wound wire **16** having adjacent segments or sections of the wire **16** in opposite current carrying direction with respect to each other. Similarly, the non-inductive wound wire layer **12** is a double spiral wound wire **18** having adjacent segments or sections of the wire **18** in opposite current carrying direction with respect to each other.

Referring to FIGURE 3, the current carrying directions of adjacent sections of the wire **16** of the second non-inductive wound wire layer **14** and the current carrying directions of adjacent sections of the wire **18** of the first non-inductive wound wire layer **12** are shown. The blackened cross-sectional ends of alternate sections of the wire **16** and **18** indicate the current to be moving in one direction and the open cross-sectional ends of the adjacent sections in wire **16** and **18** indicate the current to be flowing in the opposite direction. This view clearly shows the non-inductive relationship between each of the adjacent sections of wire **16** and **18** and the non-inductive relationship between adjacent sections of wire in layers **12** and **14**. This arrangement provides a three dimensional non-inductive wire configuration. For maximum effectiveness, each of the sections of wire **16** in wire layer **14** is lined up directly behind the adjacent sections of wire **18** in the adjacent layer of wire **12**. A non-inductive wire configuration wound in accordance with the arrangement shown in FIGURES 1, 2 and 3 exhibited a magnetic field of less than 0.1 gauss during the application of a 60 cycle per second alternating current thereto.

Leads **17** and **19** are provided for wire layers **14** and **12**, respectively. If desired, leads **17** and **19** can be provided in the center of the non-inductive wire configuration **10** instead of on the outside as shown in FIGURES 1, 2 and 3.

Non-inductive wire configurations having even numbered non-inductive layers of wire greater than two can also be used in accordance with this invention.

Non-inductive wire configurations are shown in FIGURES 1, 2 and 3 and are useful as either a circuit element, such as a resistor, or as a heater for a cathode of an electron tube.

FIGURE 4 illustrates the use of the improved non-inductive wire configuration **10** as a heater wire made of a metal, such as tungsten, located in a cathode-heater package **20** for use in a beam type electron tube, such as a klyston. The cathode-heater package **20** comprises a concave cathode element **22** and a cylindrical metal support **24**, which is connected to the peripheral end surface of the concave cathode element **22**. The cathode element **22** is shown to be adjacent the non-inductive heater element **10** so as to permit the cathode element **22** to be radiantly heated. The non-inductive heater element **10** can be placed in contact with the cathode element **22** so as to also conductively heat the cathode **22**. When current is applied to the non-inductive heater element **10** through leads **17** and **19**, the cathode element **22** is heated and emits electrons from cathode surface **26** which contains electron emitting material. If desired, the non-inductive heater **10** can be formed in a curved configuration corresponding to the concave cathode **22** with each layer of wire lying on a curved surface parallel to the curved surface of the adjacent layer of wire. One example of a non-inductive heater **10** made in accordance with this invention used a 36 mil diameter wire.

In FIGURES *5a*, *5b*, and *5c*, the method of making the improved non-inductive wire configuration of FIGURES 1, 2 and 3 of this invention is shown. A long single wire **50** (FIGURE *5a*) is bent in half (FIGURE *5b*) providing a closed end portion **52** and an open end portion **54**. The bent wire is placed between two parallel extended elements **56** and **58** and the closed end portion **52** of the wire **50** is turned in a counterclockwise direction and the open end portion **54** of the wire **50** is turned in the same counterclockwise direction about elongated elements **58** and **56**, respectively. The direction that both the closed and open end portions of the wire **50** are turned is irrelevant and they both can be turned either clockwise or counterclockwise. The wire **50** is thus wound into the non-inductive wire configuration of FIGURES 1 through 4.

FIGURES 6 and 7 refer to another embodiment of this invention wherein a cylindrical non-inductive wire configuration is provided in accordance with this invention. Leads **60** and **62** for a first layer of wire **64** are shown in FIGURES 6 and 7 to be located on the inside of a second layer of wire **66**. Such an arrangement is not critical and the leads **60** and **62** can be part of an outside layer of wire which would then position loop **68** as part of the inside layer of wire.

FIGURE 7 illustrates in cross-section the direction of current flow of adjacent sections of wire in each of the wire layers **64** and **66**. The blackened cross-sectional ends of certain sections of wire in each of the wire layers **64** and **66** indicate current flow to be in one direction and the open cross-sectional ends of adjacent sections of wire in each of the wire layers **64** and **66** indicate current flow to be in the opposite direction. Hence, a three dimensional non-inductive wire cylindrical configuration is provided by the wire arrangement of FIGURES 6 and 7. The wire configuration of FIGURES 6 and 7 has application as a heater for a cylindrical cathode in an electron tube.

The cylindrical non-inductive wire configuration of FIGURES 6 and 7 is formed by helically winding about a first cylindrical element either the open or closed end portion of a wire which has been bent in half. After approximately half of the bent wire has been helically wound, then the remainder of the wire is helically wound in a reverse pitch about a second cylindrical element whose diameter is different than the diameter of the first cylindrical element. Accordingly, the first and second layers of wire are concentrically disposed with respect to each other.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. A non-inductive wire configuration adaptable for the passage of a current therethrough comprising a combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire.

2. A non-inductive wire configuration adaptable for the passage of a current therethrough comprising in combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire, each of said layers of wire of said plural layer wire arrangement having a spiral configuration.

3. A non-inductive wire configuration adaptable for the passage of a current therethrough comprising in combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire, each of said layers of wire of said plural layer wire arrangement having a spiral configuration, said plural layer wire arrangement consisting of a single continuous wire.

4. A non-inductive wire configuration adaptable for the passage of a current therethrough comprising in combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire, each of said layers of wire of said plural layer wire arrangement having a spiral configuration, said plural layer wire arrangement consisting of a single continuous wire, each of said wire sections in each layer of wire being lined up directly behind the adjacent wire section in said adjacent layer of wire.

5. A non-inductive wire configuration adaptable for the passage of a current therethrough comprising in combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of

wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire, each of said layers of wire of said plural layer wire arrangement having a spiral configuration, said plural layer wire arrangement consisting of a single continuous wire, each of said wire sections in each layer of wire being lined up directly behind the adjacent wire section in said adjacent layer of wire, each of said layers of wire of said plural layer wire arrangement lying in a plane parallel to the plane of the adjacent layer of wire.

6. A non-inductive wire configuration adaptable for the passage of a current therethrough comprising in combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire, each of said layers of wire of said plural layer wire arrangement having a spiral configuration, said plural layer wire arrangement consisting of a single continuous wire, each of said wire sections in each layer of wire being lined up directly behind the adjacent wire section in said adjacent layer of wire, said plural layer wire arrangement consisting of two layers of wire.

7. A non-inductive heater adaptable for the passage of a heater current therethrough comprising in combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path oposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire.

8. A non-inductive circuit element adaptable for the passage of a current therethrough comprising in combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire.

9. A non-inductive resistor adaptable for the passage of a current therethrough comprising in combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire.

10. A non-inductive wire configuration adaptable for the passage of a current therethrough comprising in combination, a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire, each of said layers of wire having a cylindrical configuration and being concentrically disposed with respect to the adjacent layer of wire.

11. A cathode-heater package comprising, in combination, a cathode having an electron emitting surface, a support for said cathode, and a non-inductive heater mounted adjacent said cathode, said non-inductive heater comprising a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire.

12. A cathode-heater package comprising, in combination, a cathode having an electron emitting surface, a support for said cathode, and a non-inductive heater mounted adjacent said cathode, said non-inductive heater comprising a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the direction of the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire, each of said layers of wire of said plural layer wire arrangement having a spiral configuration, said plural layer wire arrangement consisting of a single continuous wire, each of said wire sections in each layer of wire being lined up directly behind the adjacent wire section in each adjacent layer of wire, and each of said layers of wire of said plural layer wire arrangement lying in a plane parallel to the plane of the adjacent layer of wire.

13. A cathode-heater package comprising, in combination, a cathode having an electron emitting surface, a support for said cathode, and a non-inductive heater mounted adjacent said cathode, said non-inductive heater comprising a plural layer wire arrangement having a plurality of wire sections in each layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the current flow path in the adjacent wire section in the adjacent layer of wire, each one of said plurality of wire sections in each layer of wire having a current flow path opposite in direction to the directions of the current flow paths of the adjacent wire sections in the same layer of wire, each of said layers of wire of said plural layer wire arrangement having a spiral configuration, said plural layer wire arrangement consisting of a single continuous wire, each of said wire sections in each layer of wire being lined up directly behind the adjacent wire section in said adjacent layer of wire, each of said layers of wire of said plural layer wire arrangement lying on a curved surface parallel to the curved surface of the adjacent layer of wire.

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JOHN W. HUCKERT, *Primary Examiner.*

DAVID J. GALVIN, *Examiner.*

A. J. JAMES, *Assistant Examiner.*