June 30, 1970 R. W. OHNSORG ET AL 3,518,351

HEATING ELEMENT

Filed Dec. 16, 1968

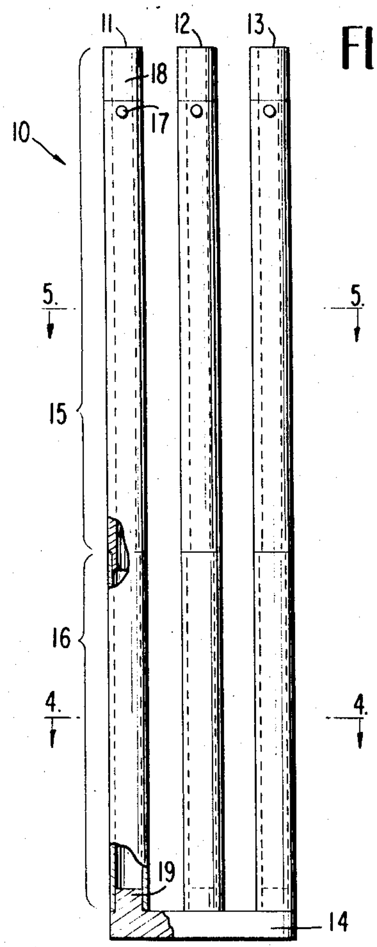


FIG. 1

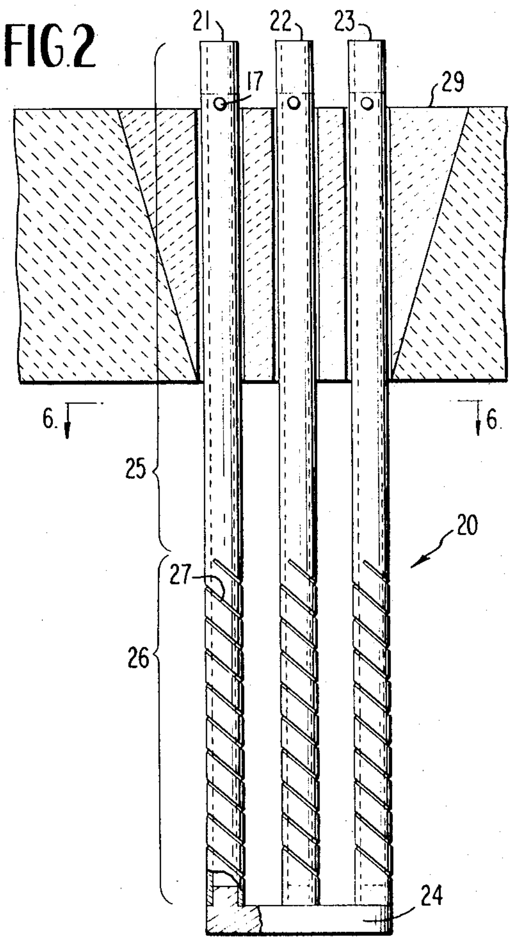


FIG. 2

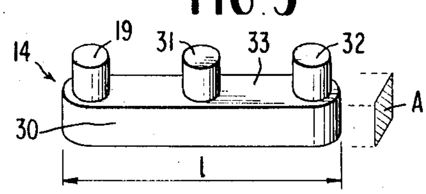


FIG. 3

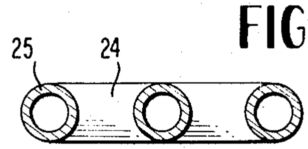
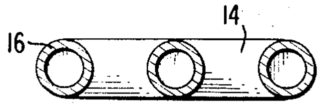


FIG. 6

FIG. 4



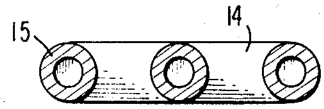


FIG. 5

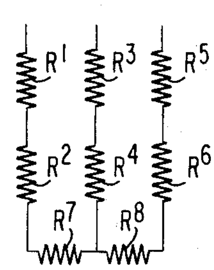


FIG. 8

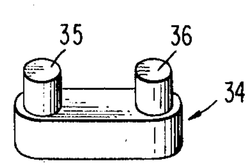


FIG. 7

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3,518,351

Patented June 30, 1970

3,518,351
HEATING ELEMENT

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Filed Dec. 16, 1968, Ser. No. 783,851
Int. Cl. H05b *3/40, 3/60*
U.S. Cl. 13—25 14 Claims

ABSTRACT OF THE DISCLOSURE

A heating element especially useful for connection to a source of three phase electric power. The element comprises three parallel hollow conductors mutually connected at one end by a connecting member having a resistance less than that of any one conductor. The connecting member is preferably of a material of low resistivity and preferably comprises a base portion having cylindrical projections that are individually received in the respective conductors to form a rigid, electrically conductive junction. Such heating elements are especially useful in the production of float glass wherein they are maintained at temperatures between 1000 and 1500° C. for long periods of time.

BACKGROUND OF THE INVENTION

Electrical heating elements such as those of silicon carbide which are capable of producing and withstanding temperatures in the range of 1000 to 1500° C. are well-known in the art as described, for example, in Swiss Pat. 310,066 (1955), British Pat. 845,496 (1960) and British Pat. 1,049,082 (1966). These heating elements are used in a variety of applications but are especially useful in the production of float glass wherein they are inserted into a furnace through a hole in the furnace wall. These prior heating elements generally comprise three elongated conductors each having a low resistance segment and a high resistance segment wherein the high resistance segments are connected to one another by a connecting member in a Y. The connecting member is generally of a material having the same resistivity as the high resistance segments of the elongated conductors. The elongated conductors are generally in the form of hollow tubes in order to provide a high surface area for heat radiation while providing a relatively small cross section of material transverse to current flow to provide for electrical resistance heating. These elongated conductors are generally inserted in holes in the connecting member. When the elongated conductors are in the form of tubes, plugs are inserted in the ends of the conductors in order to eliminate oxidation of the tubes caused by hot gases passing therethrough, i.e. the so-called "chimney effect" which occurs when the tubes are in a vertical position.

Although such heating elements have found wide acceptance they suffer from a number of disadvantages. First the plugs are prone to fall out damaging the glass underneath and permitting the above-described undesirable chimney effect to oxidize and degrade the heating element. Differences in resistance between the legs of the Y also frequently cause undesirably uneven heating. Since the elongated conductors are inserted in the connecting member the transverse dimension of the connecting member must be greater than that of the elongated conductors requiring a larger hole in the furnace wall.

SUMMARY OF THE INVENTION

Accordingly it is an object of the present invention to provide novel heating elements substantially free of one or more of the disadvantages of prior elements.

Another object is to provide novel heating elements which do not require the use of plugs in order to eliminate the chimney effect.

A further object is to provide novel heating elements having substantially equal resistances in each leg of the Y, giving even heating, and therefore being resistant to localized overheating.

A still further object is to provide novel heating elements having a transverse dimension no greater than the distance between extreme elongated conductors.

Yet another object is to provide novel heating elements of a compact structure which can be inserted into a furnace through a small opening in the furnace wall.

Still another object is to provide a novel connecting member useful in single and three phase heating elements such as those of silicon carbide.

The above and other objects are accomplished according to the present invention by providing a heating element having a plurality of conductors connected to a common connecting member of a material of lower resistivity than that of the conductor. According to another aspect of the present invention a connecting member is provided which has a number of projections designed to fit inside each conductor to fixedly attach the conductor to the connecting member.

DESCRIPTION OF THE DRAWINGS

Several preferred embodiments of the invention are illustrated in the accompanying drawings wherein:

FIG. 1 is a side elevational view partially in cross section of a heating element according to this invention;

FIG. 2 is a side elevational view, partially in cross section of a modified form of the heating element according to this invention;

FIG. 3 is a perspective view of the connecting member of FIG. 1;

FIG. 4 is a cross-sectional view of the heating element along line **4**—**4** of FIG. 1;

FIG. 5 is a cross-sectional view along the line **5**—**5** of FIG. 1;

FIG. 6 is a cross-sectional view along the line **6**—**6** of FIG. 2;

FIG. 7 is a perspective view of a connector of the present invention designed to be used with a single phase heating element; and

FIG. 8 is a schematic diagram of the resistances of the various portions of the heating elements of FIGS. 1 and 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and in particular to FIGS. 1, 4 and 5 there is shown a heating element **10** of the present invention including three elongated tubular parallel conductors **11**, **12** and **13** joined together at one end by a connecting member **14**.

The conductor **11** has a low resistance segment **15** and a high resistance segment **16**. In the end of the low resistance segment **15** is a transverse hole which receives a pin **17** which is employed in a known manner to keep the heating element **10** from slipping into the furnace. The end of the conductor **11** is provided with an aluminum coating **18** which constitutes means for attaching this end to a source of power not shown. The low resistance segment **15** is attached to the high resistance segment **16** by any convenient means such as welding or by use of the cementitious composition described in U.S. Pat. 2,907,-972 and especially Example 2 thereof. The low resistance segment **15** can be of any suitable material which will withstand the temperatures to which the heating element is raised but is preferably a carbonaceous material which has been impregnated with silicon metal in order to reduce its total overall resistance and is preferably constructed of a material having a resistivity of 0.0005 to 0.010 and preferably 0.002 to 0.003 ohm-centimeters at room temperature. One such material found suitable for the purpose is that made according to U.S. Pat. No. 2,431,326. The tubular low resistance segment **15** and the tubular high resistance segment **16** generally have equal outer diameters but the inside diameter of the low resistance segment is preferably less than that of the high resistance segment. The high resistance segment **16** can be any suitable material which will withstand the temperatures to which it is raised but is generally large grain silicon carbide having a resistivity of 0.001 to 10.0 and preferably 0.09 to 1.10 ohm-centimeters measured at the operating temperature and is preferably a silicon carbide body produced as described in U.S. Pat. No. 2,941,962. The conductors **12** and **13** are identical to conductor **11**. The connecting member **14** fabricated in one piece is provided with a cylindrical projection **19** having an outside diameter substantially equal to the inside diameter of the high resistance segment **16** of the conductor **11**. The cylindrical projection **19** is received in the conductor **11** to form a rigid, electrically conductive junction.

Referring now to FIG. 2 there is shown another embodiment of the present invention in the form of a heating element **20** comprising three conductors **21**, **22** and **23** connected on one end to connecting member **24** which is identical to connecting member **14**. The conductor **21** comprises a low resistance segment **25** and a high resistance segment **26** formed by cutting one parallel spiral slit **27** through the wall of the segment **26**. The conductors **22** and **23** are identical to the conductor **21** and are connected to the connecting member **24** in the same manner as in the heating element **10**. FIG. 2 illustrates the manner in which the heating elements **10** and **20** are inserted through a hole in the wall of the furnace. The conductors **21**, **22** and **23** fit through holes in a frustoconical plug **29** which is seated in a correspondingly shaped hole in the upper wall of the furnace. When inserted in the hole the plug **29** occupies the illustrated position under its own weight and that of the heating element **20**. The pin **17** which may be a refractory metal or ceramic material keeps the element **20** from slipping into the furnace.

As shown in FIG. 3 the connecting member **14** comprises a base portion **30** having attached to the upper surface thereof three cylindrical projections **19**, **31** and **32** the axes of each of which are perpendicular to the upper surface **33** of the base member **30** and are parallel to one another. As is apparent the projections **19**, **31** and **32** serve to close the ends of the conductors **11**, **12** and **13** and therefore eliminate the chimney effect. Furthermore should one of the projections come loose the connecting member **14** will still be fixedly held by the other two projections and cannot fall into the furnace as can the plugs used in prior elements. The connecting member **14** is made of material of high density and low resistivity and preferably one having a density of 3.00 to 3.10 grams per cubic centimeter and a resistivity of 0.001 to 1.0, and preferably 0.01 to 0.10 ohm-centimeter at room temperature. The connecting member **14** is most preferably silicon carbide produced as described in U.S. Pats. Nos. 2,907,972 and 2,938,807. The area, A, measured transverse to the direction of flow of current in the base portion **30** is greater and preferably at least three times greater than the area measured transverse to current flow of the segments **16** or **26**. The length, *l*, of the connecting member **14** is preferably no greater than the maximum distance between extreme portions of the conductors **11** and **13**. By means of this construction the heating elements **10** or **20** can be inserted through a hole in the furnace wall which is no bigger than the maximum distance between extreme portions of the conductors **11** and **13**. Furthermore, in existing furnaces designed to accommodate heating elements employing the larger prior connecting members, heating elements of the present invention can be employed which have conductors of larger diameters and therefore larger heat radiating surfaces.

FIG. 7 shows a connecting member **34** similar in all respects to the connecting member **14** except having only two projections **35** and **36** making it suitable for use in a single phase system.

The particular advantages of the materials and structures of the heating elements of the present invention are illustrated schematically in FIG. 8 wherein R^1 represents the resistance in ohms of the low resistance segment **15** of the conductor **11**; R^2 represents the resistance in ohms of the high resistance segment **16** of the conductor **11**; R^3 and R^4 represent corresponding segments of the conductor **12**; and R^5 and R^6 represent corresponding segments of the conductor **13**; R^7 represents the resistance in ohms of that portion of the connecting member **14** lying between the conductors **11** and **12**; and R^8 represents the resistance in ohms of that portion of the connecting member **14** lying between the conductors **12** and **13**. In general R^1 is smaller than R^2 in order to confine the heat producing portion of the conductor **11** to that portion furthest from the furnace wall. Since the conductors **11**, **12** and **13** are manufactured by mass production techniques the resistances R^1, R^3 and R^5 are substantially equal to one another as are the resistances R^2, R^4 and R^6. In prior heating elements the connecting member was typically made of the same material as the conductors, the resistance of the first leg being equal to the sum of the resistances R^1, R^2 and R^7, that of the second leg being equal to R^3 plus R^4 and that of the third leg being equal to the sum of R^5, R^6 and R^8. However in the present invention because of the large area A and the use of silicon carbide of low resistivity, R^7 and R^8 are substantially equal to zero resulting in an element having substantially equal resistances in all legs of the Y.

Although the invention has been described in considerable detail with reference to certain preferred embodiments thereof, it will be understood that variations and modifications can be effected within the spirit and scope of the invention as described above and as defined in the appended claims.

We claim:

1. A three phase Y heating element for an electric furnace having three conductors at least a portion of each of which is silicon carbide, one end of each conductor being connected to a common connecting member of silicon carbide of lower resistivity than that of the conductors.

2. A three phase Y heating element of claim **1** having three conductors at least a portion of each of which is silicon carbide, each conductor having a low resistance segment and a high resistance segment connected to a common connecting member of silicon carbide material of lower resistivity than the material of the conductor and wherein the total resistance in ohms of that portion of the connecting member in series circuit with adjacent conductors is less than the resistance in ohms of the high resistance segment of each conductor.

3. A three phase heating element of claim **1** comprising:

(a) three heating conductors each conductor comprising:
  (1) a low resistance segment, and
  (2) a high resistance segment;

(b) a common connecting member having three projections adapted to fit inside each of the conductors to fixedly attach the conductors to the connecting member.

4. The heating element of claim **3** wherein the low resistance segment is constructed of a carbonaceous material impregnated with silicon.

5. The heating element of claim **3** wherein the high resistance segment is constructed of silicon carbide.

6. The heating element of claim **5** wherein the silicon carbide has a resistivity of 0.001 to 10.0 ohm-centimeters.

7. The heating element of claim 3 wherein the high resistance segment comprises a spiral portion.

8. The heating element of claim 4 wherein the connecting member is constructed of a material having a resistivity of 0.001 to 1.0 ohm-centimeter at room temperature.

9. The heating element of claim 4 wherein the connecting member is constructed of silicon carbide having a resistivity of 0.001 to 1.0 ohm-centimeter at room temperature.

10. A three phase heating element of claim 1 comprising:

(a) three elongated cylindrical conductors each conductor comprising:

(1) a first tube having means at one end to connect it to a source of power and connected at the other end to:

(2) a second tube whose outside diameter is substantially equal to the outside diameter of the first tube and whose inside diameter is substantially greater than the inside diameter of the first tube;

(b) a connecting member having:

(1) a base member whose area transverse to flow of current is greater than the area transverse to flow of current in the second tube,

(2) three cylindrical projections the outside diameter of each being substantially equal to the inside diameter of the second tube;

the axes of the cylindrical projections being substantially parallel to one another and substantially perpendicular to the upper surface of the base member; the length of the base member being no greater than the outside extreme distance between the first and third conductors, wherein the three cylindrical projections of the connecting member fixedly hold the conductors substantially parallel to one another.

11. A three phase heating element of claim 1 comprising:

(a) three elongated cylindrical conductors each conductor comprising:

(1) a first segment having means at one end to connect it to a source of power and

(2) a second segment having spiral slits defining spiral portions of the tube,

(b) a connecting member having:

(1) a base member whose area transverse to flow of current is greater than the area transverse to flow of current in the conductors,

(2) three cylindrical projections the outside diameter of each being substantially equal to the inside diameter of the conductors,

the axes of the cylindrical projections being substantially parallel to one another and substantially perpendicular to the upper surface of the base member; the length of the base member being no greater than the outside extreme distance between the first and third conductors, wherein the three cylindrical projections of the connecting member fixedly hold the conductors substantially parallel to one another.

12. A connecting member which can be used in combination with three conductors to form a three phase heating element, said connecting member comprising a base member and three projections fixedly attached to the base member, the projections being adapted to fit inside each of the conductors to fixedly attach the conductors to the connecting member.

13. A connecting member which can be used in combination with three conductors to form a three phase heating element, the connecting member comprising a base member and three projections fixedly attached to the base member, the axes of the cylindrical projections being substantially parallel to one another.

14. A connecting member of claim 12 which can be used in combination with three conductors to form a three phase heating element, said connecting member comprising a base member and three cylindrical projections fixedly attached to the base member, the axes of the cylindrical projections being substantially parallel to one another and being substantially perpendicular to the upper surface of the base member.

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H. B. GILSON, Primary Examiner

U.S. Cl. X.R.

13—20