GRAPHITE CLOTH HEATING ELEMENT CLAMPED ON BUS BARS

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FIG. 1

FIG. 2

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ABSTRACT OF THE DISCLOSURE

A heating element in which a flexible graphite cloth resistance element extends between a pair of spaced cylindrical bus bars. Resilient clips secure the cloth resistance element to the bus bars. The bus bars are connected by suitable conductors to an electric power supply.

This invention relates to a heating element, and more particularly to a flexible heating element for use at high temperatures in vacuum or inert atmosphere resistance furnaces.

A flexible sheet of conductive graphite cloth or tape is a desirable heating element for use in a high temperature vacuum resistance furnace. Graphite cloth or tape has good flexibility and has convenient resistance values for use as a resistance heating element. Although graphite cloth cannot be conveniently employed as a resistance heating element in an oxidizing environment due to reaction with oxygen, graphite cloth is a very good heating element in a high vacuum, of for example, less than one torr, or in an inert atmosphere where it is capable of extended operation at temperatures of the order of 2500° C. without significant deterioration or evaporation losses. The only other materials which may be used as resistance heating elements at these high temperatures are the refractory metals such as tungsten, tantalum, and molybdenum. Refractory metals, however, are expensive, and difficult to fabricate, and are therefore less desirable than graphite cloth for use in vacuum or inert atmosphere resistance furnaces.

Although graphite cloth has significant advantages as a heating element for a high temperature vacuum furnace, some difficulties have heretofore been encountered in attaching the graphite cloth to rigid bus bars in order to establish good electrical contact between the graphite cloth and the bus bars. Known techniques for securing the edges of the cloth to the bus bars include bolted clamps with asbestos pressure pads, metalizing the edges of the cloth, clamping the edge of the cloth between two rigid members, and utilizing multiple folds in the cloth to provide increased strength and to achieve uniform contact pressures. These means of connecting graphite cloth to the bus bars frequently exhibit relaxation at high temperatures, causing the cloth to sag, and the high mechanical pressures may crush, fray or tear the cloth. Furthermore, installation of a heating element using these known types of connections often is difficult in that the connections are hard to make in order that the cloth or tape has uniform tension across its width and does not sag or bow. Such connections are also often unwieldy to adjust and hard to remove, making replacement of the heating element difficult or impossible.

It is a principal object of the present invention to provide an improved flexible heating element for high temperature vacuum resistance furnaces.

Another object of the invention is to provide a flexible graphite cloth heating element having improved electrical contact between the graphite cloth and the bus bars.

A further object of the invention is to provide a flexible graphite cloth heating element wherein the tension of the graphite cloth is easily adjusted and replacement of the graphite cloth is readily accomplished.

Other objects of the invention and the various features thereof will become apparent from the following description taken in connection with the accompanying drawing wherein:

FIGURE 1 is a plan view of a heating element constructed in accordance with the invention; and

FIGURE 2 is a sectional view taken along the line 2--2 of FIGURE 1.

Very generally, and having reference to FIGURE 1 of the drawing, the heating element of the present invention comprises a pair of spaced bus bars 11, 13, a flexible graphite cloth resistance element 15 extending between the bus bars 11, 13 and resilient spring clips 17 for securing the graphite cloth 15 to the bus bars 11, 13. The bus bars 11, 13 are connected by suitable conductors 19, 21 to a power supply 23.

It has been discovered that heating elements constructed in accordance with the present invention are convenient and economical for use at high temperatures in vacuum or inert atmosphere furnaces. The heating elements are constructed from relatively inexpensive materials, have a relatively long life, and are particularly easy to install since there are no bolts, pressure pads, or other devices required to secure the graphite cloth to the bus bars. The spring clips may be easily snapped around the bus bars to secure the graphite cloth to the bus bar, and the tension in the graphite cloth may be easily adjusted after a period of operation to remove sags or folds in the graphite cloth resistance element without having to remove the spring clips from the bus bars. Furthermore, the spring clips utilized to secure the graphite cloth to the bus bars provide uniform compression of the graphite cloth against the bus bars over a relatively large surface area of the graphite cloth thereby eliminating the tendency of the graphite cloth to tear or rip at the points where high mechanical compression is applied, as was previously encountered when bolted clamps were utilized. The spring clips also allow for quick and easy replacement of the graphite cloth resistance element by removing the clips whereupon the graphite cloth resistance element may be removed. This is a desirable feature where the interior of the vacuum furnace is confined and it is difficult to work within the interior of the furnace.

Referring now to the drawing in detail, a preferred embodiment of the invention is illustrated in FIGURES 1 and 2. Although the following detailed description is with reference to this preferred form of the heating element, it is to be understood that the teaching of the invention can be applied to devices other than the precise configuration shown in the drawing.

The heating element includes a pair of spaced conductive bus bars 11 and 13 which are preferably parallel to one another. In a preferred form of the invention the conductors are cylindrical, as further discussed henceforth. The bus bars 11 and 13 are connected by suitable conductors 19 and 21 to a suitable power supply 23 of either the alternating current or direct current type in order to establish a potential between the bus bars 11 and 13 and a current flow therebetween through the graphite cloth resistance element 15. As shown in FIGURE 2, it is contemplated that the bus bars 11 and 13 may be annular in cross sectional shape defining passages 25 and 27 respectively in order that a fluid coolant may be passed through the passages 25 and 27 from a source not shown, to cool the bus bars 11 and 13.

The flexible graphite cloth 15 extends between the bus bars 11 and 13 and is maintained in electrical contact therewith as described hereinbefore, in order that a current will flow through the graphite cloth upon energization of the power supply 23. The graphite cloth has an electrical
resistance which, when current is passed through the cloth, produces heat which is radiated by the cloth. This heat is used in the furnace for heating a desired material disposed around the furnace. The graphite cloth may be in the form of a relatively large sheet, as shown in FIGURE 1, or may be in the form of narrow tapes, depending on the particular use desired of the heating element.

Various types of graphite cloth are commercially available which may be utilized as the resistance element in the heating element of the present invention. An example of a suitable graphite cloth is that sold by National Carbon Company, grade WCB.

It is desirable, for effective operation, that the graphite cloth 15 be connected to the conductors 11 and 13 such that it is capable of conducting high currents and is not subject to mechanical damage. It is also desirable that the cloth not sag or bow and that the tension of the cloth be adjustable and that the cloth be readily replaceable. Herefore, known techniques for making high current connections to graphite cloth and tape have proved unsatisfactory under many circumstances. This has been particularly true where the graphite cloth, as illustrated in FIGURE 1, has significant width. Problems of effecting proper connection along the full width of the cloth have not been satisfactorily solved with previous techniques.

In accordance with the present invention, and as illustrated in FIGURE 2, the edge portions 29 and 31 of the graphite cloth 15 are wrapped about a portion of the circumference of the bus bars 11 and 13, and are preferably disposed about one-half or more of the circumference of the bus bars. The edge portions 29 and 31 of the graphite cloth 15 which are wrapped around the respective bus bars 11 and 13 contact the surface of the bus bars along the full width of the graphite cloth.

In order to secure the edge portions 29 and 31 of the graphite cloth 15 against the bus bars 11 and 13 to afford a secure electrical and mechanical connection, one or more spring clips 17 are provided.

As can be seen in FIGURE 2, the spring clips 17 are formed having a cross-sectional shape that is substantially identical to the cross-sectional shape of the bus bars 11 and 13. In an unstressed condition at least one dimension of the spring clips 17 is less than the corresponding cross-sectional dimension of the bus bars 11 and 13 so that when the spring clips 17 are placed around the bus bars 11 and 13 with the graphite cloth 15 between the clips and the bus bar, the resilient characteristics of the spring clips 17 will cause the graphite cloth 15 to frictionally engage the circumference of the bus bars 11 and 13 over the length of the spring clips 17.

In the preferred embodiment of the invention illustrated in FIGURE 2 the bus bars 11 and 13 are cylindrical in cross section, and the spring clips 17 have an arcuate shape and are formed so that the spring clips 17 will extend around at least about one-half of the circumference of the bus bars 11 and 13. The spring clips preferably are formed having outturned flanges 33 and 35 rounded contact surfaces 37 and 39 for engaging the graphite cloth thereby reducing the possibility of tearing or ripping the graphite cloth. As shown in FIGURE 1, when the graphite cloth 15 is in the form of a sheet of substantial width, it is desirable to utilize a plurality of tubular spring clips 17 to connect the graphite cloth 15 to each of the bus bars 11 and 13.

The spring clips 17 are formed from a refractory material selected from those refractory materials which retain a sufficient amount of their resiliency at the operating temperature contemplated for use of the heating element to retain the graphite cloth resistance element 15 in frictional contact with the bus bars 11 and 13. Suitable materials which may be utilized to form the spring clips 17, include stainless steel, molybdenum, tungsten, tantalum, and niobium, and alloys of these and similar metals. The refractory material may have a thickness of the order of 5 to 10 one-thousandths of an inch or any other suitable thickness.

It is also contemplated to utilize bus bars and spring clips having different cross-sectional shapes than the cylindrical shape illustrated. However, the cylindrical shape is generally preferred in that it has been found that this shape provides the most uniform contact between the graphite cloth 15 and the bus bars 11 and 13, and also provides for the easiest adjustment of the tension of the graphite cloth.

The spring clips 17 fit closely over the bus bars 11 and 13 and press a substantial area of the edge portions 29 and 31 of the graphite cloth 15 against the circumference of the bus bars 11 and 13. The number of clips used depends upon their length and the width of the cloth 15. The frictional force exerted between the edge portions 29 and 31 of the graphite cloth 15 and the bus bars 11 and 13 maintains the graphite cloth 15 at a predetermed tautness and the tautness in the cloth may be adjusted by rotating the clips about the bus bar. The required tautness at installation is easily obtained by pulling the graphite cloth to the necessary tension and slipping on the spring clips. The clips may be turned on the conductors if adjustment is needed. Saging and bowing does not occur because the uniform holding force distribution, along the width of the cloth and the length of the bus bars 11 and 13, effects an even tautness throughout the full area of the cloth 15. The cloth is therefore not subjected to high localized stresses such as stretch or warp.
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formed from a refractory material which retains substantial resiliency at the operating temperature of said heating element.

2. A heating element in accordance with claim 1 wherein said bus bars and clips are cylindrical and wherein said edge portions of said graphite cloth and said clips extend around at least about one-half of the circumference of said bus bars.

3. A heating device in accordance with claim 2 wherein said spring clips are provided with out-turned flanges adjacent their edges.

4. A heating element in accordance with claim 1 wherein said clips are comprised of stainless steel, molybdenum, tungsten, tantalum, niobium or alloys thereof.

5. A heating element in accordance with claim 1 wherein each of said bus bars is hollow for conducting coolant.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

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It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 3, between lines 57 and 58, insert -- adjacent the edges thereof. The flanges 33 and 35 form --.

Signed and sealed this 10th day of February 1970.

(SEAL)

Attest:

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Commissioner of Patents