July 19, 1960 J. S. BALLANTINE 2,945,756

ELECTRIC ARC RESISTANCE FURNACE, AND METHOD OF MELTING REFRACTORY MATERIALS

Filed April 20, 1959 4 Sheets-Sheet 1

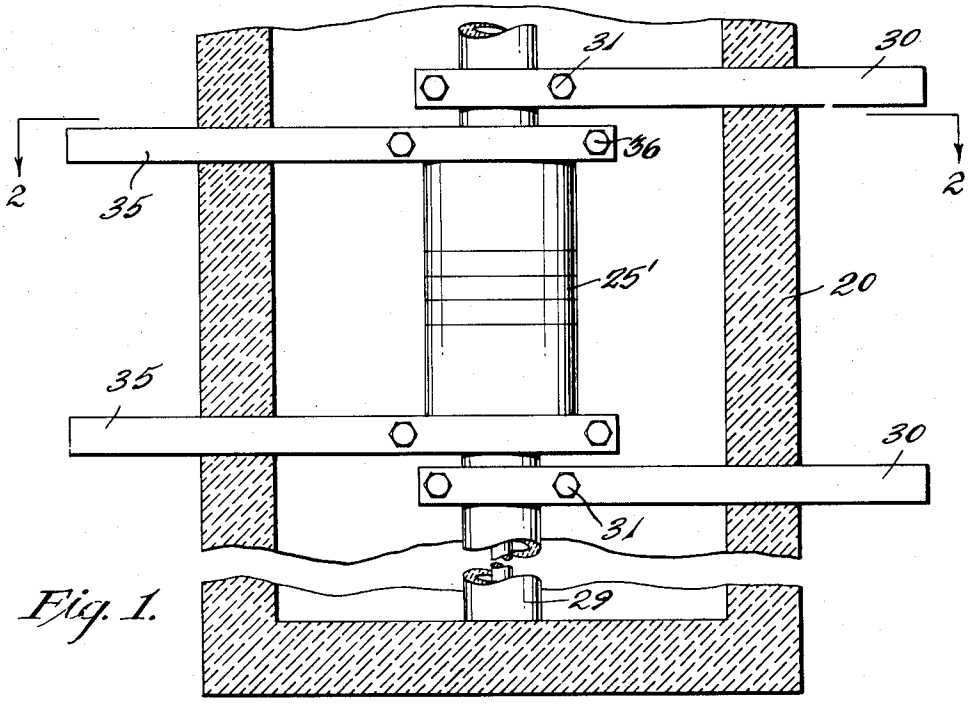


Fig. 1.

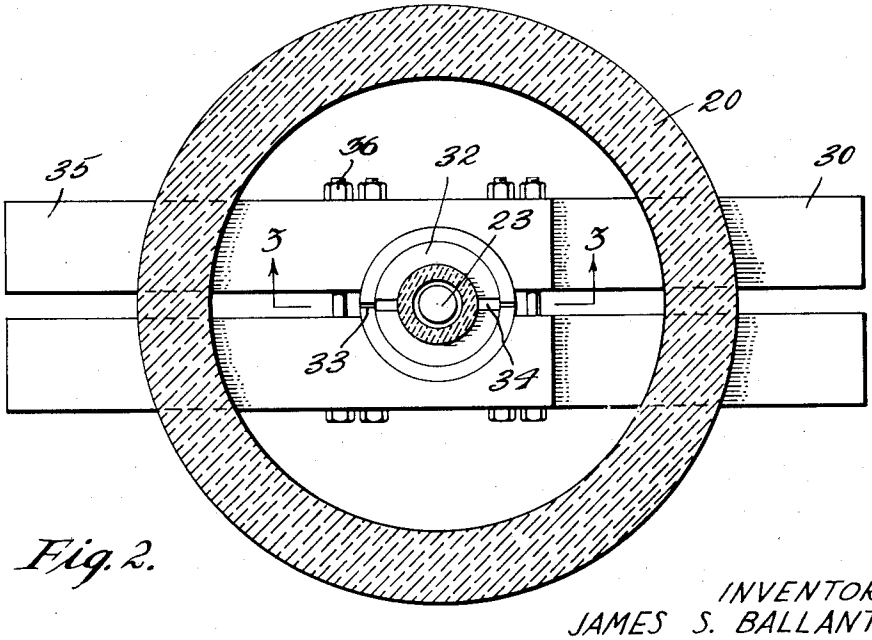


Fig. 2.

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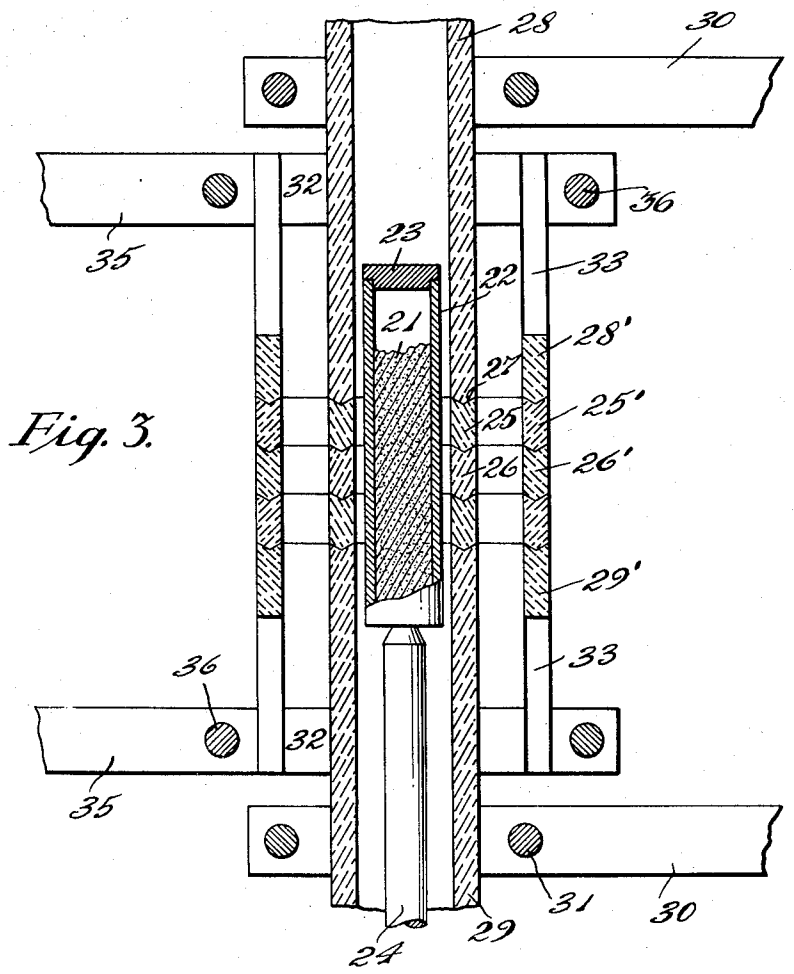


Fig. 3.

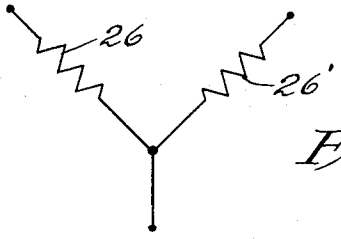


Fig. 4.

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ELECTRIC ARC RESISTANCE FURNACE, AND METHOD OF MELTING REFRACTORY MATERIALS

Filed April 20, 1959 4 Sheets-Sheet 3

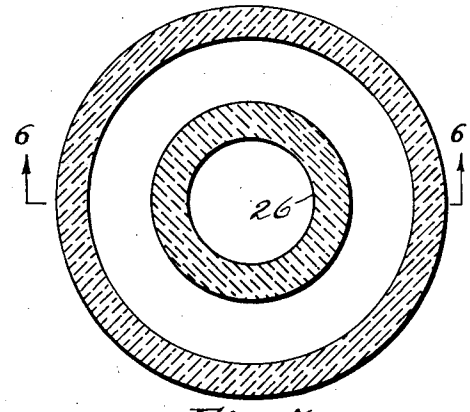


Fig. 5.

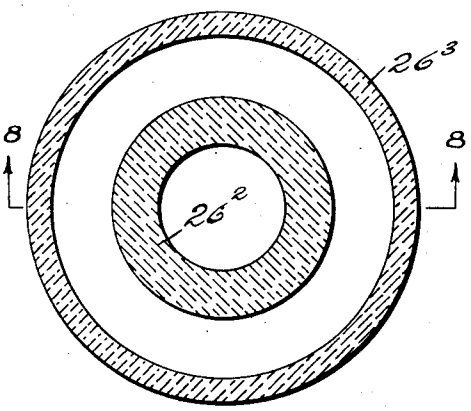


Fig. 7.

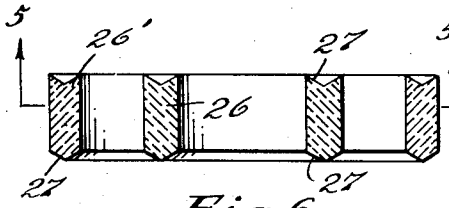


Fig. 6.

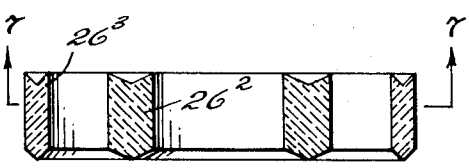


Fig. 8.

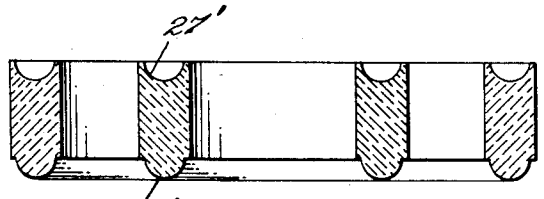


Fig. 9.

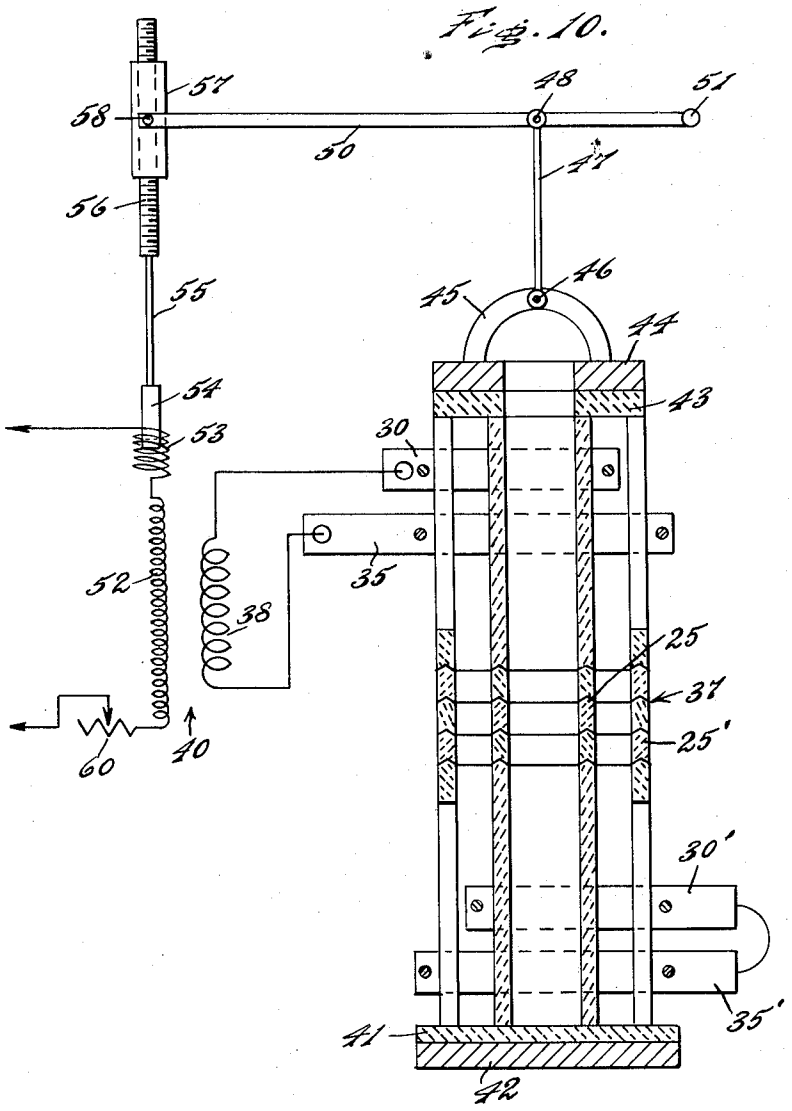
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ELECTRIC ARC RESISTANCE FURNACE, AND METHOD OF MELTING REFRACTORY MATERIALS

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Fig. 10.



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United States Patent Office 2,945,756 Patented July 19, 1960

2,945,756

ELECTRIC ARC RESISTANCE FURNACE AND METHOD OF MELTING REFRACTORY MATERIALS

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Filed Apr. 20, 1959, Ser. No. 807,673

7 Claims. (Cl. 75—10)

The present invention relates to electric arc resistor furnaces of the type which are particularly useful for melting highly refractory metals and similar materials.

A purpose of the invention is to regulate the pressure on a stack of arc-resistor rings to assure most effective arcing, maintaining an axial pressure in the range of between 10 and 150 p.s.i. and preferably in the range between 50 and 125 p.s.i. and most desirably between 75 and 100 p.s.i.

A further purpose is to apply a high pressure on the stack initially so as to maintain resistance heating conditions for preheat and elimination of gases, desirably using initial pressure in excess of 200 p.s.i. and suitably in the range between 200 and 400 p.s.i., and then to adjust the pressure into the arcing pressure range, and permissibly increase the voltage to promote arcing.

A further purpose is to concentrate the heat of an electric arc-resistor furnace more effectively in the charge and obtain a higher temperature.

A further purpose is to divide the load of an electric resistor furnace more evenly between different parts of an electric circuit, especially different phases.

A further purpose is to employ tubular refractory terminals for the stacks and desirably clamp the terminals by terminal clamps.

A further purpose is to make the tubular refractory terminals resilient by slitting them near the ends remote from the stack.

A further purpose is to transmit clamping pressure from the terminals of the outer stack to the terminals of the inner stack for the purpose of supporting the outer stack.

Further purposes appear in the specification and in the claims.

In the drawings I have chosen to illustrate a few only of the numerous embodiments in which my invention may appear, selecting the forms shown from the standpoints of convenience in illustration, satisfactory operation and clear demonstration of the principles involved.

Figure 1 is a diagrammatic fragmentary central vertical section of the furnace of the invention.

Figure 2 is a section of Figure 1 on the line 2—2 thereof.

Figure 3 is an enlarged fragmentary section of Figure 2 on the line 3—3.

Figure 4 is a circuit diagram showing one circuit arrangement which may be used.

Figure 5 is an enlarged plan section through concentric rings of an inner and outer stack, the section being taken on the line 5—5 of Figure 6.

Figure 6 is a section on the line 6—6 of Figure 5.

Figures 7 and 8 are views corresponding to Figures 5 and 6 respectively but illustrating a variation in which the cross sections of the resistor rings transverse to the axis in both stacks are the same.

Figure 7 is a plan section on the line 7—7 of Figure 8 and Figure 8 is a section on the line 8—8 of Figure 7.

Figure 9 is an axial section similar to Figure 6 showing a variation in which the interlocks are of U-shape rather than V-shaped.

Figure 10 is a circuit diagram showing the adjustment of the pressure in accordance with the invention.

Describing in illustration but not in limitation and referring to the drawings:

In the prior art there has been great difficulty in melting and superheating highly refractory materials and especially metals, and accomplishing alloying and purifying of melts of such material. The present invention makes possible the melting, superheating, alloying and refining of highly refractory materials such as elemental zirconium, tungsten, hafnium, titanium, boron, molybdenum, cobalt, and mixtures of the same in any proportions, and radioactive isotopes of the same. The invention may also be applied to metals of the platinum group, including platinum, palladium and iridium alone or in mixtures. The invention may also be applied to the melting of any of the above elements in combination with other metals, such as copper, iron, nickel, zinc, vanadium, manganese and the like. The invention is also applicable to the melting of refractory compounds of the elements, especially those mentioned above, and particularly carbides.

In accordance with the invention, melting is accomplished by an arc-resistor furnace in which the arcing distance is small and is the distance of contact between successive arc-resistor rings in stacks which suitably surround the charge. In accordance with the invention preferably two or more concentric resistor stacks surround the charge, so that heat losses of the inner stack are prevented or compensated for by heat developed in the outer stack.

In the preferred embodiment of the invention, arcing is assured by controlling the pressure on the stack so that the stack will be maintained under a pressure within favorable arcing limits.

In the preferred embodiment of the invention a stack of interlocked resistor rings is arranged endwise to form each resistor path, the interlocks being preferably of V or U formation in axial section at the ends.

The arc electrodes are simple to replace and repair as they can readily be assembled and disassembled. Each different phase desirably has substantially the same resistance, and this can be adjusted by providing the same cross section in inner and outer resistor rings, for example where there is the same number of rings in the stacks.

Tubular refractory terminals endwise of the stacks transmit current to the resistor rings, and in at least some cases the clamping pressure of the outer terminals is transmitted from an outer stack to an inner stack through spacer segments.

For high temperature work the arcing electrode rings and terminals consist of carbon. In making them up it is desirable to include a small percentage, preferably not more than about 2 percent, of silicon as a binder. In operation, the silicon distills off leaving substantially only carbon as the resistor. The carbon used will preferably be of the character employed for electric arc furnace electrodes. For low temperature work the rings and the terminals may be of silicon carbide.

The refractory to contain the charge will in many cases be carbon in the form of a crucible or in the form of loose granules. In other cases the oxide or other refractory compound of the material being melted will form the refractory lining. It has been found to be desirable to employ an inert gas around and in the furnace during operation. The preferred inert gas is helium, although another inert gas such as argon, neon, xenon or

krypton may be used. Nitrogen is generally not recommended because of the danger of forming cyanogen.

Alternating current is preferred, preferably of commercial frequency as it causes a stirring effect which is desirable to eliminate gas from the charge. Direct current, however, can be used. If the melt is allowed to solidify while alternating current is still passing through the resistor (the current being cut down to allow solidification) it has been found that large crystals are obtained with better crystal orientation. It will be understood, however, that the invention is useful even though this feature is not employed.

It will be understood that the currents employed in accordance with the invention will be relatively large, preferably of the order of several thousand amperes at relatively low voltages, suitably in the range of from 10 to 60 volts on the secondary.

It has been found experimentally that the stack of electrode rings actually develops a high temperature in the charge with a lower current consumption when arcing than a corresponding continuous refractory resistor, the reason evidently being that heat is more effectively concentrated in the charge and less heat is dissipated in the case of arcing rings than with a continuous resistor. The localized arcing from ring to ring greatly increases the temperature in the rings and heats the charge up more quickly since the point of arcing becomes incandescent almost immediately. It has also been found that much more accurate regulation of heating can be obtained using the electrode rings of the invention.

In the forms shown in the drawings the furnace of the invention comprises an over-all furnace casing **20** of suitable refractory which forms an envelope and supports the internal structure. In the interior of the furnace a charge **21** to be melted, suitably one of the elements mentioned above or a mixture, is contained in any suitable container, here a carbon crucible **22** covered by a relatively loose fitting cover **23** which permits the escape of contained gas. The crucible rests on a vertical support **24** extending to the bottom of the furnace casing and suitably consisting of carbon. Surrounding the crucible, desirably in slightly spaced relation, is a stack **25** of inner refractory resistor rings **26**, which have at the top and bottom interlocks **27**, suitably consisting of cooperating male and female V-shaped grooves and ridges. If desired, however, the interlocks may be of U cross section as shown at **27'** in Figure 9.

The number of refractory rings in the stack will vary although in many cases three rings are suitable for small furnaces, and four to five arcing rings are believed to be adequate for most installations.

The refractory rings **26** of the stack are connected at the top and bottom to tubular refractory terminals **28** and **29** which suitably have ends cooperating with the interlocks of the rings. The refractory rings and the terminals are suitably of carbon.

The refractory terminals **28** and **29** are suitably clamped at a position remote from the resistor rings by contact clamping terminals **30** secured together by bolts **31** and extending through the furnace wall as shown in Figures 1 and 2. The refractory terminal **29** desirably rests at its bottom on the bottom of the furnace casing. The terminals **30** are air-cooled through passages not shown.

Surrounding stack **25**, and in spaced relation from it, is a second stack **25'** of refractory resistor rings **26'**. These have similar interlocks **27** or **27'** at the two ends and form a continuous end-to-end engaging stack. The outer stack **25'** connects at its upper end with an annular refractory terminal **28'** of the same diameter as the stack **25'** and likewise at the bottom connects to an annular refractory terminal **29'** surrounding the refractory terminal **29**.

Inside the terminals **28'** and **29'** at the respective upper and lower ends are placed refractory spacer segments **32** (Figure 2) which occupy most of the space between the terminals **28'** and **28** and **29'** and **29**. Each of the outer terminals **28'** or **29'** at its outer end is longitudinally slit at **33** suitably at diametrally opposite positions, and the slit **33** is desirably lined up with the space **34** between the respective spacer segments **32**. Conductive clamping terminals **34** surround the remote ends of the tubular refractory terminals **28'** and **29'** and are clamped together by bolts **36**.

The terminals **35** extend out through the casing in the furnace as shown in Figure 1 and are water-cooled by means not shown.

The refractory resistor rings **26'** are desirably of carbon like the rings **26** and the terminals **28'** and **29'** are likewise desirably of carbon while the clamps **30** and **35** are desirably of a metal such as copper.

In the forms shown in the drawings, there are only two concentric stacks of refractory electrode rings but it will be understood that additional stacks can be placed around the outer stack **25'**, each stack being of successively larger diameter and spaced from the stack inside and the stack outside.

The respective stacks are desirably connected in different phases of the electric circuit as shown in Figure 4 which provides an open delta circuit with the stack **26** in one phase, the stack **26'** in another phase and the third phase containing no resistor. However, as later explained, single phase operation is also quite practical.

It is desirable to balance the electrode stacks of the different phases as there is danger that if this is not done the arcing surfaces will later change due to a tendency to equalize the arcing resistance of the different stacks. Any suitable arrangement in which the different stacks have the same arcing resistance is suitable. Figure 7 shows a construction having inner electrode rings 26^2 which are of small diameter but respectively thicker cross section and outer electrode rings 26^3 which are of large diameter and relatively less thickness, the overall cross sections transverse to the axis of the rings 26^2 and 26^3 being substantially the same, and in this case the number of rings in each stack being the same.

In order to obtain effective operation of the arcing electrodes, it is quite important to control the pressure on the stack. I illustrate in Figure 10 a furnace **37** having an inner stack of arcing rings **25** as previously described and having an outer set of arcing rings **25'**, with suitable electrical terminals **30** and **30'** for the inner stack and **35** and **35'** for the outer stack.

In this case a single phase is used placing the stacks electrically in series with secondary **38** of power transformer **40**.

The stacks suitably rest upon an insulating support **41** and a base **42**. At the top an insulating ring **43** applies pressure to both of the stacks from a pressure ring **44** which is provided with a bridge **45** pivotally connecting at **46** to a link **47** which pivotally connects at **48** to a lever **50** which is on fixed pivot **51**. The primary **52** of transformer **40** is in series with solenoid **53** whose core or armature **54** is connected to pull rod **55** which is adjustably threaded at **56** into a nut **57** which is pivoted at **58** to the end of the lever **50** remote from the lever fixed pivot. Also in series with the solenoid **53** is a variable resistor **60**, the solenoid, the primary and the resistor being across the power lines.

In operation of the device of Figure 10, a suitable weight is initially applied to the end of the lever adjoining the nut **57**, so as to place the arcing rings of the stack under a pressure in excess of 200 p.s.i. and preferably between 200 and 400 p.s.i., a preferred pressure being of the order of 250 p.s.i. The variable resistor **60** is then adjusted to provide a voltage across the secondary of the transformer of approximately 10 volts. The stacks heat up and in the course of about one hour's preheating achieve a temperature of 2000° F. After

uniform preheating has been achieved the weight is removed from the end of the lever **50**, and the resistor **60** is readjusted to apply a secondary voltage which is suitably in the range of 40 to 60 volts. The pressure then applied by the solenoid **53** to the stack is in the range of 10 to 150 p.s.i. and suitably about 75 p.s.i. Under these conditions of relatively low pressure, arcing occurs and a temperature is built up in excess of 5000° F., and in some cases as high as 10,000° F. under a current of 1500 to 2500 amperes. In the particular installation being described, a cross section of each of the rings was of the order of 1.25 square inches, and the interior diameter of the smaller ring was of the order of 1.8 inches.

It will be evident that it is important that there be some pressure maintained, as otherwise the mechanical force would be sufficient to separate the arcs, and also as the carbon becomes consumed the arc spacing increases and the device would cease to operate.

It will be understood that the pressure regulation can be accomplished by other means than that shown.

The present application is a continuation-in-part of my application Serial No. 389,373, filed Oct. 30, 1953, for Electric Arc Resistance Furnace, now abandoned.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention, without copying the process and apparatus shown, and I, therefore, claim all such insofar as they fall within the reasonable spirit and scope of my claims.

Having thus described my invention what I claim as new and desire to secure by Letters Patent is:

1. An electric arc resistance furnace, comprising a plurality of refractory combined arcing and resistor rings arranged in contact end to end in a stack, terminals connected at each end to the stack of rings, a source of electric current connected to the terminals across through the stack, and means for maintaining pressure on the stack in the range between 10 and 150 p.s.i.

2. A furnace of claim 1, in combination with automatic means responsive to the input current to maintain a predetermined pressure level on the rings.

3. The method of developing high temperature, using a stack of arc-resistor rings, which comprises passing an electric current through the stack of arc-resistor rings, and maintaining a pressure axially of the stack which is in the range between 10 and 150 p.s.i. to promote arcing.

4. The method of maintaining a high temperature, using a stack of arc-resistor rings, which comprises compressing the stack axially under a pressure exceeding 150 p.s.i., passing an electric current through the stack to preheat the stack, the rings acting as resistors, then reducing the pressure axially of the stack to a pressure between 10 and 150 p.s.i. and increasing the voltage to promote the arcing.

5. In an electric arc resistance furnace, an inner stack of concentric refractory resistor rings engaging one another end to end and constructed and arranged to surround the charge, an outer stack of refractory resistor rings engaging one another end to end, surrounding the inner stack in spaced relation and concentric therewith, tubular refractory terminals engaging the ends of the inner stack and extending in prolongation thereof, tubular refractory terminals engaging the ends of the outer stack in prolongation thereof, terminal clamps engaging the outsides of the terminals for the outer stack and pressure spacers interposed between the terminal of the outer stack at each end and transmitting pressure from the terminal clamps of the outer stack to the terminals of the inner stack.

6. In an electric arc resistance furnace, an inner stack of concentric refractory resistor rings engaging one another end to end and constructed and arranged to surround the charge, an outer stack of refractory resistor rings engaging one another end to end, surrounding the inner stack in spaced relation and concentric therewith, tubular refractory terminals engaging the ends of the inner stack and extending in prolongation thereof, tubular refractory terminals engaging the ends of the outer stack in prolongation thereof, the terminals of the outer stack being slit longitudinally at the ends remote from the stack, refractory pressure segments interposed between the slit portions of the terminals for the outer stack and the terminals for the inner stack, and terminal clamps surrounding the slit portions of the terminals for the outer stack and engaging the same.

7. The method of obtaining a preferred crystal orientation in refractory materials using a stack of refractory arc-resistor rings which comprises melting a charge comprising a refractory material by passing alternating current of the order of several thousand amperes through a stack of refractory arc-resistor rings surrounding the charge while maintaining electric arcs from ring to ring, thus rendering the refractory material highly fluid, stirring the fluid refractory material vigorously by induction from the arcing current, and then reducing the alternating current and allowing the charge to solidify, while passing through the rings alternating current insufficient to hold the charge molten.

References Cited in the file of this patent

UNITED STATES PATENTS

984,119	Wood	Feb. 14, 1911
1,023,309	Helberger	Apr. 16, 1912
1,177,680	Brown	Apr. 4, 1916
1,663,810	Morse	Mar. 27, 1928
2,402,582	Scaff	June 25, 1946
2,657,247	Bretschneider	Oct. 27, 1953

FOREIGN PATENTS

169,756	Great Britain	Oct. 3, 1921
915,619	France	Nov. 13, 1946