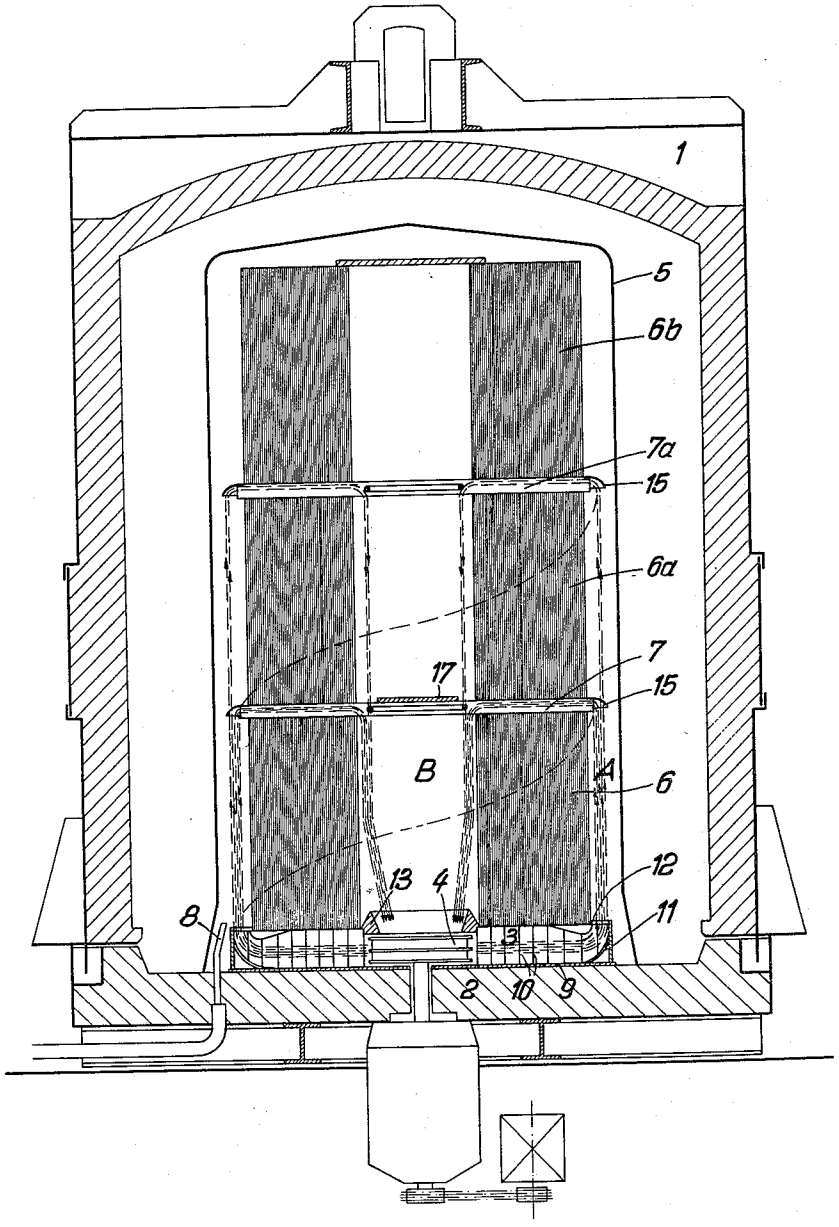
Aug. 29, 1961 H. CRAMER ET AL 2,998,236

METHOD OF ANNEALING IN BELL FURNACES

Filed July 10, 1957 8 Sheets-Sheet 1

Fig. 1



METHOD OF ANNEALING IN BELL FURNACES

Filed July 10, 1957 8 Sheets-Sheet 2

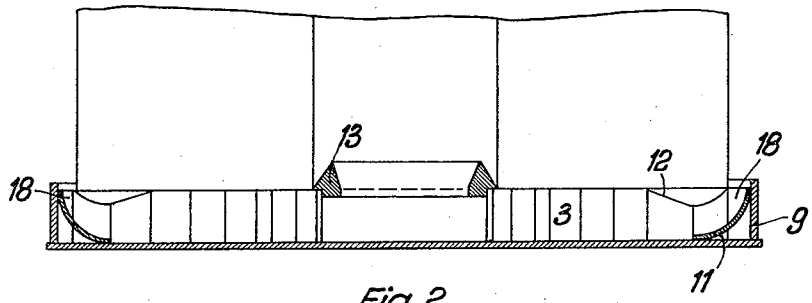


Fig. 2

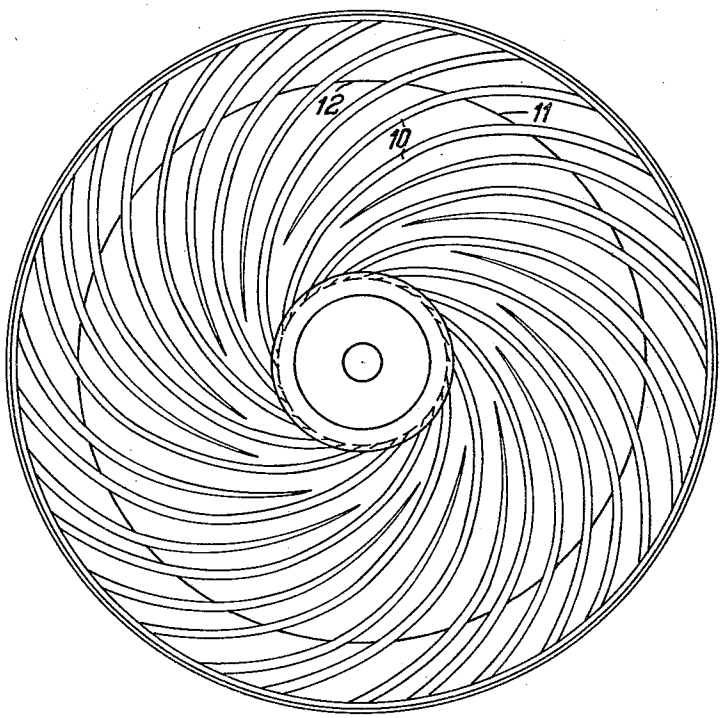


Fig. 3

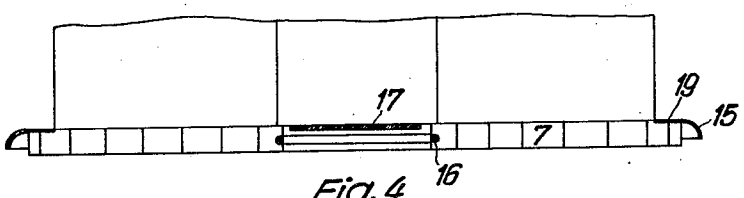


Fig. 4

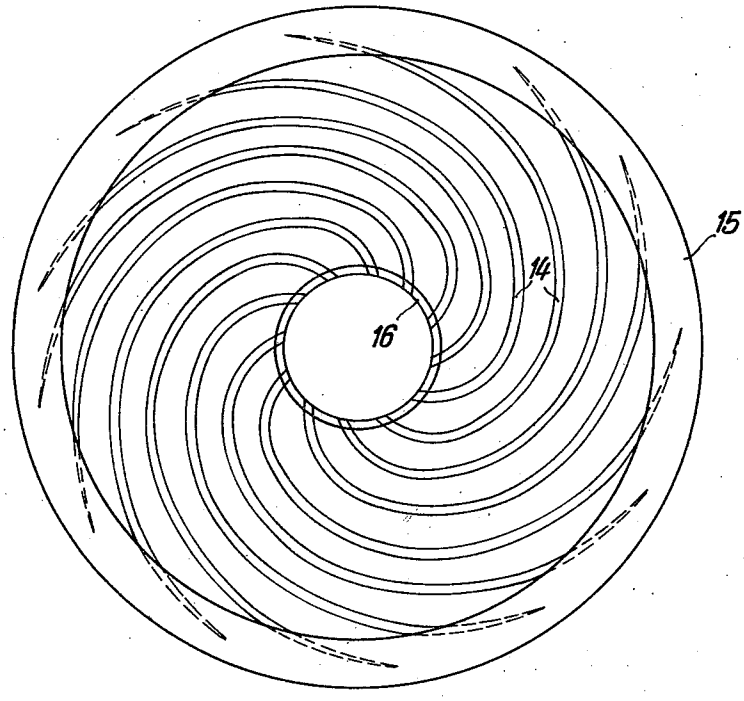


Fig. 5

METHOD OF ANNEALING IN BELL FURNACES

Filed July 10, 1957 8 Sheets-Sheet 4

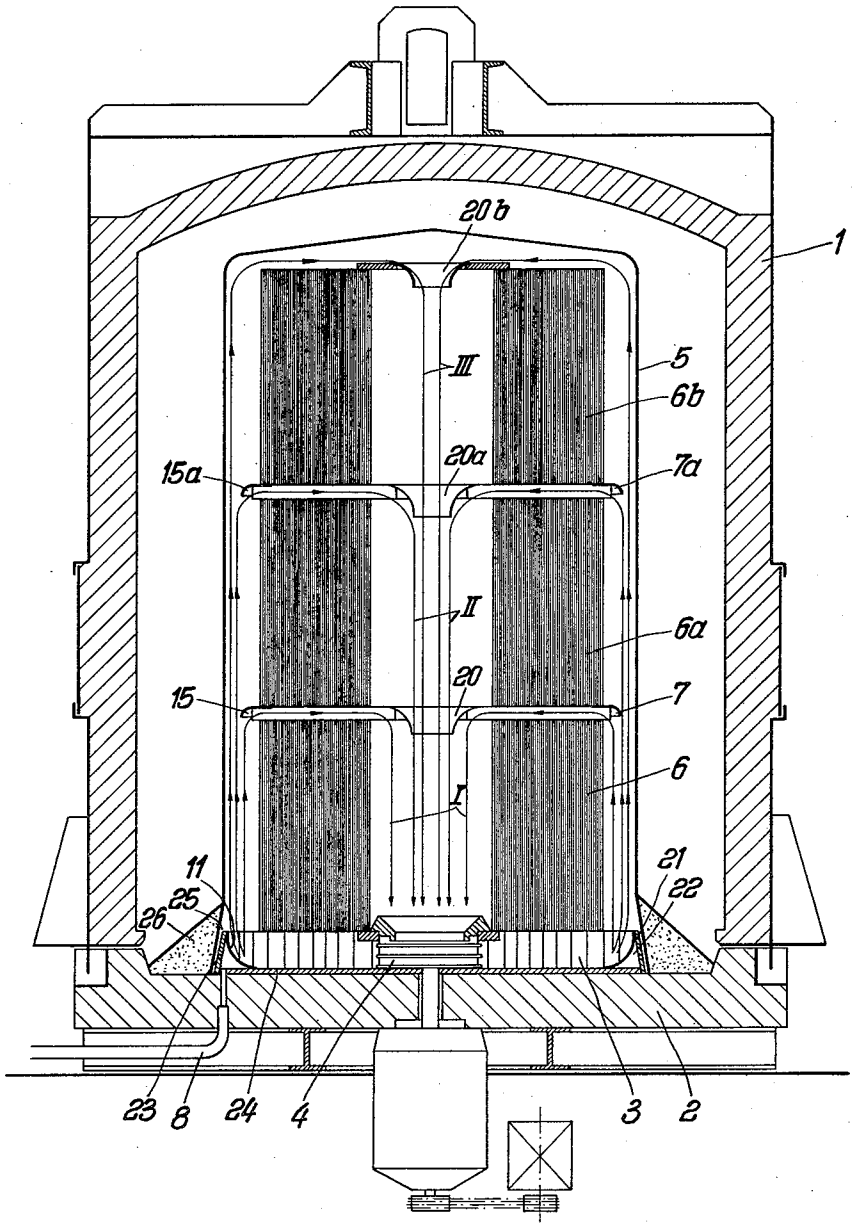


Fig. 6

Aug. 29, 1961 H. CRAMER ET AL 2,998,236

METHOD OF ANNEALING IN BELL FURNACES

Filed July 10, 1957 8 Sheets-Sheet 5

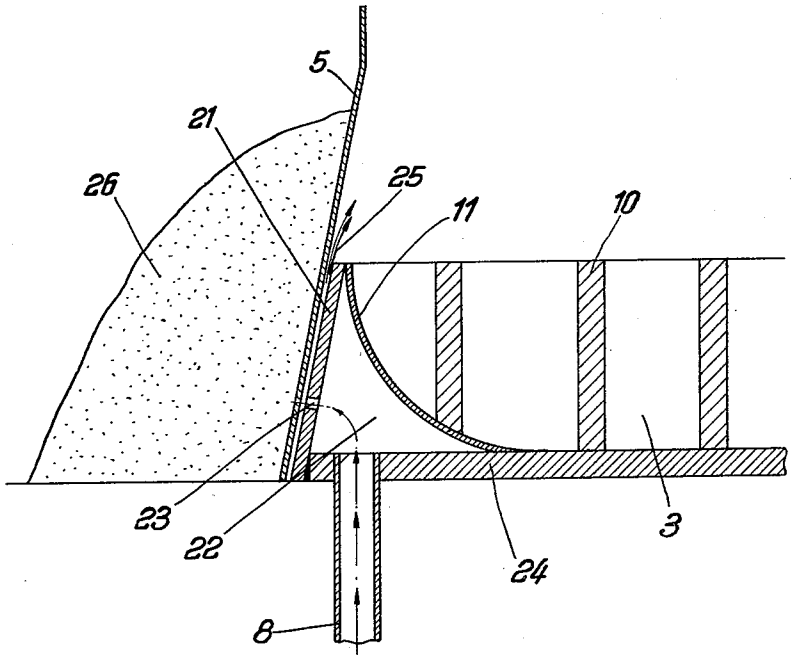


Fig. 7

METHOD OF ANNEALING IN BELL FURNACES

Filed July 10, 1957 8 Sheets-Sheet 6

Fig. 8

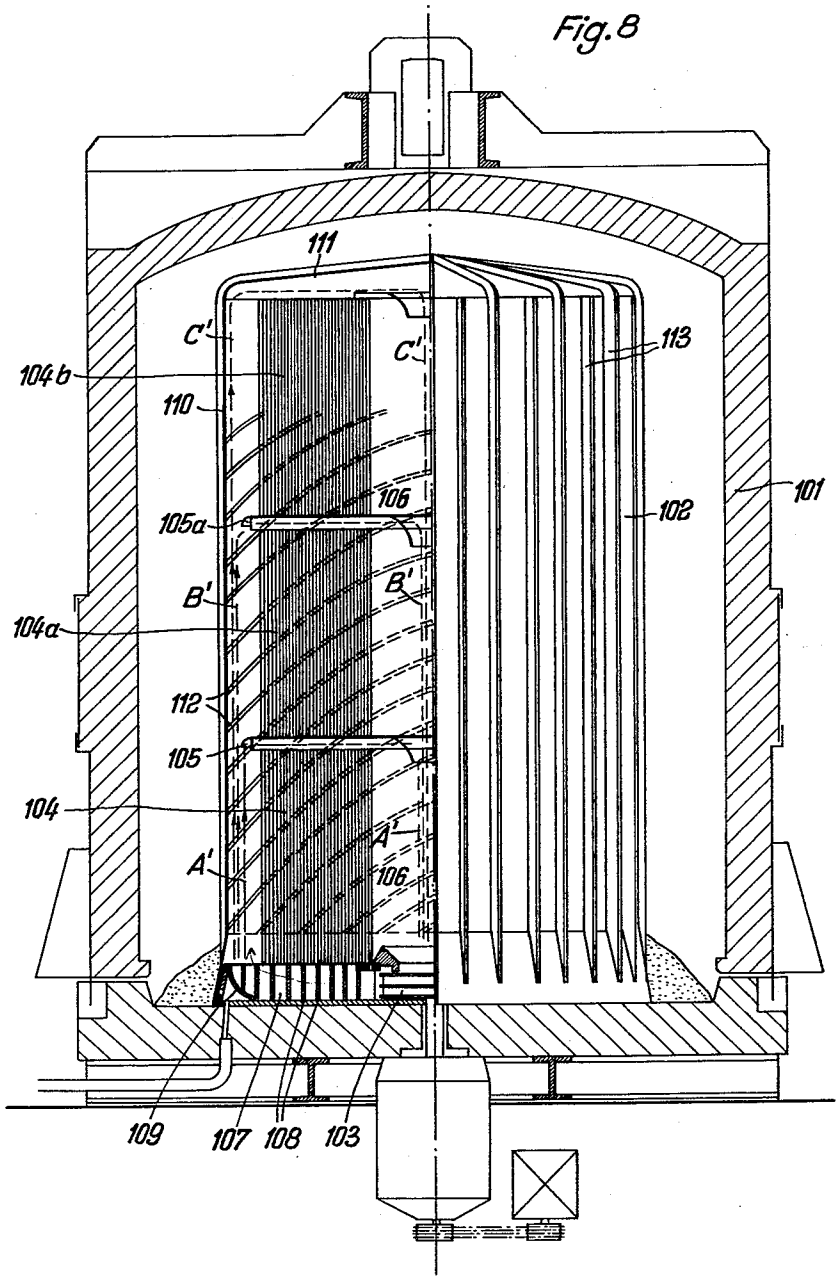


Fig. 9

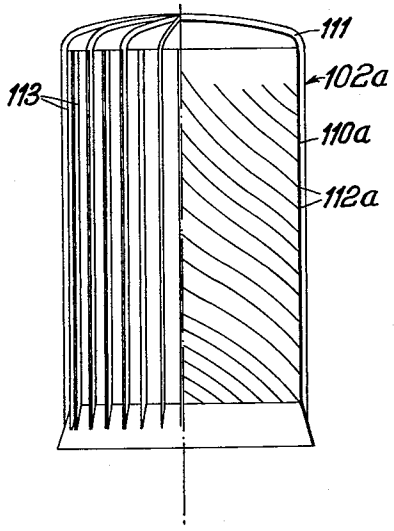


Fig. 10

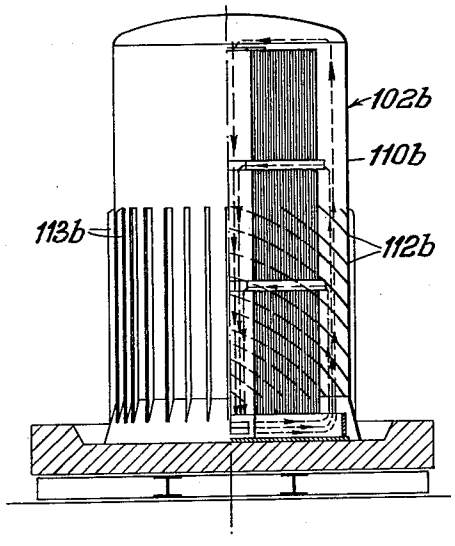


Fig. 11

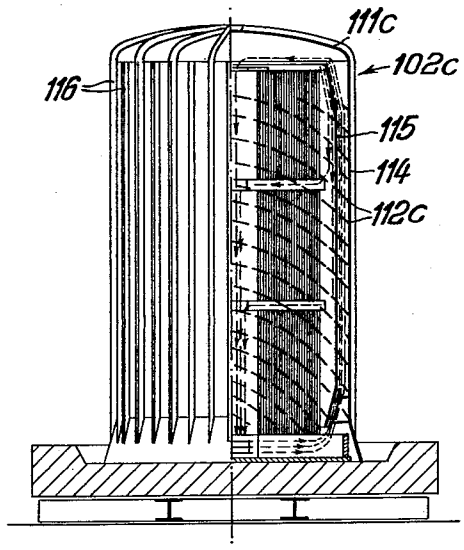
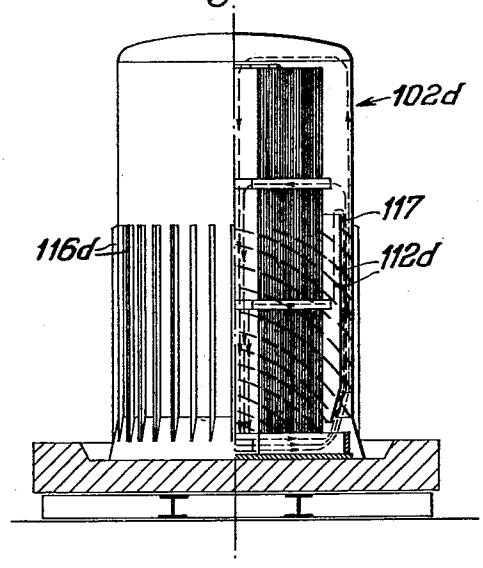


Fig. 12



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2,998,236

METHOD OF ANNEALING IN BELL FURNACES

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Filed July 10, 1957, Ser. No. 670,943
Claims priority, application Germany July 16, 1956
4 Claims. (Cl. 263—40)

This invention relates to bell furnaces for annealing, wherein the material to be annealed, for example, steel, copper or brass strip or wire, in coils or on spools, or miscellaneous parts loaded in baskets, are arranged in a vertical stack supported on a load platform within a retort carried by a fixed base which also supports a removable, bell-shaped furnace wall structure having heating units therein, and wherein a protective gas is circulated at high velocity, for example, by a fan or blower, within the retort and serves to transfer heat from the retort to the stacked material, during the annealing or heating up process, and to absorb heat from the stacked material for transfer to the retort, during the cooling of the material.

In the existing bell furnaces for annealing, the conditions of flow of the protective gas circulated within the retort have not been considered critical, and such flow conditions have not been controlled. By reason of the uncontrolled flow conditions of the protective gas, the upper portions of the stack of material being annealed are heated up more rapidly than the lower portions of the stack. However, since all portions of the stack of material must be heated up to a predetermined temperature and then maintained at such temperature for a predetermined time, the time required for the annealing process is controlled by the conditions in the least heated portion of the stack of material to be annealed, so that, in the existing furnaces of the described character, the non-uniform heating of the stack of material unnecessarily prolongs the time required for annealing and the efficiency of the furnace is therefore relatively low.

It is an object of the present invention to devise a process of effecting good heat transfer between an elongated furnace, such as a bell furnace, and material adapted for annealing therein.

It is a further object of the present invention to devise a process of annealing a stack of material in an elongate furnace wherein heating up of the lower portions of the stack is accelerated, thereby to produce more uniform heating of all portions of the stack and to shorten the time required for heating up of the entire stack.

Another object is to provide an annealing process of the described character wherein, by reason of the more uniform heating up of the stack of material in the furnace, the time during which the several portions of the stack of material are maintained or held at the annealing temperature is more uniform, thereby to decrease the total time required for annealing, while the quality of the annealed material is improved and made more uniform.

Still another object is to provide furnaces of the described character capable of more efficient utilization of the power required for operating the same.

A further object of the invention is to provide an annealing process wherein the temperatures of the circulated protective gas are kept as uniform as possible in all parts of the circulating system, thereby to promote the uniform and rapid heating up of all portions of the stack of material to be annealed.

In accordance with an aspect of this invention, bell furnaces for annealing have a diffuser arranged at the bottom of the stack of material to be annealed and receiving the protective gas discharged by the circulating

pump or blower, while the portions of the stack of material are separated by convectors which control the conditions of flow of the protective gas during the annealing and cooling stages, the diffuser and convectors or guide members being preferably constructed to produce turbulence-free flow of the protective gas, as well as to improve the heat transfer between the circulated protective gas and the retort and between the gas and the material to be annealed.

Preferably, the diffuser is formed of elements which, at their upper edge surfaces, support the stack of material to be annealed, and thereby form a load platform for the latter, and which also impart a tangential or swirling movement to the protective gas discharged from the pump or blower, so that such discharged gas is made to spiral upwardly between the retort and the stack of material to be annealed, thereby to increase the flow path of the protective gas for correspondingly improving the heat transfer by convection.

Further, it is a feature of furnaces embodying the present invention to provide the convectors interposed between successive portions of the stack of material with annular guide rings which project outwardly beyond the stack in order to promote the flow of at least a portion of the upwardly spiraling protective gas into the related convector which, preferably, also has spirally arranged vanes for improving the heat transfer during flow through each convector.

In accordance with still another aspect of this invention, at least one removable or variable guide member is disposed within a central passageway extending through the stack of material to be annealed and communicating with the inlet of the circulating fan or blower, thereby to further control the flow conditions of the circulated protective gas.

In accordance with still another aspect of this invention, the surface area of the retort available for heat exchange purposes is substantially increased by providing ribs either on the exterior or interior surfaces of the retort or on both of such surfaces, and such ribs are disposed to guide the flow of the protective gas within the retort as well as the flow of cooling air through the space between the retort and the bell-shaped outer furnace wall. Thus, the inner ribs of the retort are preferably inclined with respect to the vertical axis of the latter in order to promote the spiral movement of the protective gas, while the outer ribs of the retort may extend vertically, that is, parallel to the axis of the retort, in the general direction of the stream of cooling air. Further, in the case of multi-walled retorts, at least one of the walls of the retorts is preferably constructed with ribs as described above. It is also intended that, where the inner and outer surfaces of the retort are provided with ribs, the heat exchanging characteristics of such inner and outer surfaces will be adapted for maximum efficiency by suitably selecting the number, location and sizes of the ribs.

The above, and other objects, features and advantages of the invention, will be apparent in the following detailed description of illustrative embodiments thereof which is to be read in connection with the accompanying drawings forming a part hereof, and wherein:

FIG. 1 is a vertical sectional view of a bell furnace for annealing constructed in accordance with an embodiment of the present invention;

FIG. 2 is a vertical sectional view of a diffuser included in the furnace of FIG. 1;

FIG. 3 is a top plan view of the diffuser of FIG. 2;

FIG. 4 is a vertical sectional view of a convector included in the furnace of FIG. 1, and having a guide member inserted therein;

FIG. 5 is a top plan view of the convector of FIG. 4;

FIG. 6 is a view similar to that of FIG. 1, but showing a bell furnace for annealing constructed in accordance with another embodiment of the invention;

FIG. 7 is an enlarged detail view of a portion of the structure illustrated in FIG. 6;

FIG. 8 is a view similar to that of FIG. 1, but showing a bell furnace for annealing constructed in accordance with still another embodiment of the invention, and with the retort thereof being shown partly in section and partly in side elevation;

FIG. 9 is a side elevational view, partly broken away and in section, of a form of retort embodying the present invention and adapted for use in the furnaces of FIGS. 1, 6 and 8; and

FIGS. 10, 11 and 12 are views similar to that of FIG. 9, but showing still other forms of retorts adapted for use in furnaces embodying the present invention.

Referring to the drawings in detail, and initially to FIG. 1 thereof, it will be seen that a bell furnace for annealing constructed in accordance with the present invention includes the usual bell-shaped, removable outer furnace wall **1** which may be heated directly, for example, by heating units supported inside the wall, or indirectly, for example, by products of combustion circulated within the bell-shaped furnace wall, and which is supported on a base **2**, with a suitable seal, for example, a liquid seal, being provided between the bottom edge of the wall **1** and the periphery of the base **2**. A diffuser **3**, hereinafter described in detail, rests upon the base **2**, and a circulating device **4**, for example, a centrifugal blower, is disposed centrally within the diffuser **3** and is suitably driven, for example, by an electric motor or the like supported below the base **2**. A downwardly opening retort or muffle **5** rests, at its lower edge, upon the base **2**, and the material to be annealed, for example, coils or spools of steel, copper or brass strip or wire, or baskets containing miscellaneous parts, is arranged in a vertical stack or pile disposed within the retort **5** and consisting of superposed portions **6**, **6***a* and **6***b*. Convectors **7** and **7***a*, hereinafter described in detail, are interposed between the portions **6** and **6***a* and the portions **6***a* and **6***b*, respectively, of the stack of material to be annealed.

A protective gas for preventing oxidation, corrosion or other deterioration of the material being annealed is introduced into the space enclosed by the retort **5** through a pipe **8** which projects upwardly through the base **2** into an annular space between the periphery of the diffuser **3** and the surrounding wall of the retort.

It will be seen that the superposed portions **6**, **6***a* and **6***b* of the stack of material to be annealed have their peripheries spaced radially inward from the side wall of the retort **5** to define a pressure space A therebetween, while the superposed coils, spools or baskets forming the several portions of the stack have central vertical openings aligned with each other to define a suction space B so that the blower **4**, having its inlet communicating with the suction space B, provide a circulating flow of the protective gas introduced through the pipe **8**, which flow moves upwardly in the pressure space A and then downwardly in the suction space B.

In the existing bell furnaces the circulating flow of the protective gas within the retort or muffle was such that the upper portions of the material to be annealed received much more heat than the lower portions thereof. This resulted in a substantial delay in the heating up of the lower portions of the material to the predetermined annealing temperature, so that the annealing time for the entire charge was considerably prolonged. In order to ensure that the bottom portion **6** of the stack of material to be annealed will be heated up to the predetermined annealing temperature at substantially the same time as the upper portions **6***a* and **6***b*, the bell furnace embodying the present invention includes structural members for controlling the direction and quantity of the flow of protective gas so that uniform heating of the entire stack or pile is achieved.

As seen in FIGS. 2 and 3, the diffuser **3** of a furnace embodying this invention includes an upwardly opening, shallow receptacle **9** having spiral vanes **10** therein which are arranged so that the protective gas discharged by the blower **4** into the spaces between the successive vanes **10** will be made to flow tangentially at the outer periphery of the diffuser. The vanes **10** are of sufficient number and strength to permit their upper edges to directly carry the stack of material to be treated, so that the diffuser **3** serves as a convector for promoting heat transfer between the lowermost portion **6** of the stack and the protective gas, thereby saving energy as well as eliminating the additional structure that would be represented by the usual load platform carrying the stack.

In order to direct the flow of protective gas upwardly into the pressure space A upon discharge from the diffuser **3**, the latter includes at least a bottom, annular guide plate **11** which curves upwardly and imparts a vertical component to the flow of protective gas, so that the tangential movement of the latter, at the outer periphery of the diffuser, is converted into a helical or upwardly spiralling movement through the pressure space A. In addition to the bottom guide plate **11**, the diffuser **3** preferably also includes an annular, top guide plate **12** of arcuate cross-section which cooperates with the bottom guide plate **11** to form an annular discharge nozzle **18** (FIG. 2) opening upwardly into the pressure space A. By reason of the helical or upwardly spiralling movement of the flow of protective gas through the pressure space A, the time of contact between the protective gas and the retort for the purpose of heat transfer therebetween is substantially increased over the condition in existing furnaces, wherein the protective gas flows substantially vertically upward within the retort.

In order to separate the pressure chamber A from the suction chamber B at the bottom thereof, the diffuser **3** embodying the present invention is provided with a guide ring **13** on the top thereof which has upwardly converging inner and outer surfaces and abuts the inner periphery of the lowermost coil. In separating the pressure space A from the suction space B, the guide ring **13** ensures that the flow in both spaces will be free of turbulence by preventing a secondary stream flowing past the inner periphery of diffuser **3**, and the guide ring **13** further functions to center the stack of material to be annealed with respect to the diffuser **3** and the retort **5** and to prevent interference of the material in the lowermost postion **6** of the stack with the inlet of the blower **4**.

As seen in FIGS. 4 and 5, each of the convectors **7** and **7***a* includes an annular, downwardly curved rim **15**, an inner ring **16**, and spirally arranged blades or vanes **14** which taper towards sharp outer ends. The outer end portions of the blades or vanes **14** are secured, at their top edges, to the underside of a horizontal inner portion of the outer rim **15**, while the inner ends of the vanes are obtusely connected with the ring **16**. As seen in FIG. 1, the outer guide rim **15** projects radially beyond the adjacent portions of the stack of material to be annealed and into the pressure space A so that the rim **15** of each of the convectors **7** and **7***a* deflects a quantity of the protective gas flowing helically upward through the space A, and the deflected quantity of protective gas is directed into the related convector for heating the bottom portion of the material thereabove, while the remainder of the protective gas continues to flow upwardly through the space A. An annular cover plate **19** is employed in conjunction with rim **15** and the outside diameter of plate **19** corresponds with the inner diameter of the rim, whereas the inner diameter of plate **19** corresponds with the outer diameter of the coils.

A guide member **17**, which is in the form of a baffle plate in the illustrated embodiment of the invention, is supported within the suction space B at the level of the

convector 7 (FIG. 1). This guide member may be in the form of a baffle ring (whereby the central portion of plate 17 is removed), nozzle or the like rather than the baffle plate, as illustrated. The guide member 17 serves to restrict the open cross-sectional area within the space B at the level thereof and serves to promote the circulation of the stream of protective gas in the lower portion of the retort 5.

The number of convectors provided in the furnace will depend upon the number of superposed portions in the stack of material to be treated, and a convector is provided between each two adjacent, superposed portions.

By reason of the control exercised over the flow of the circulated protective gas by the rim portions 15 of the convectors 7 and 7*a* and by the guide member 17, the lower portions in the stack of material to be annealed are heated as quickly as the upper portions in such stack so that uniform temperatures are obtained throughout the stack during the entire annealing process, that is, during the steps of heating, soaking and cooling. Such uniform temperature throughout the stack results in better annealing and, hence, in an improved quaility of the resulting material. Further, by dividing the entire quantity of heat in accordance with the requirements of the individual portions of the stack of material, the entire stack is not only heated more uniformly but also more quickly, whereby the hourly output is improved.

In the bell furnace for annealing, as illustrated in FIG. 6, wherein the parts corresponding to those described with reference to FIG. 1 are identified by the same reference numerals, the pipe 8, through which the protective gas is introduced, opens into an annular chamber 22 which is defined by the bottom guide plate 11 of the diffuser 3, the peripheral portion of the bottom plate 24 and the annular side wall 23 which conforms generally to the shape of the lower edge portion of the retort 5 and has a series of radial openings 23 therein. The annular wall 21 is spaced radially inward from the corresponding edge portion of the retort 5 by a relatively small distance to provide an annular gap 25 therebetween. Thus, as distinguished from the arrangement in the furnace of FIG. 1, wherein the pipe 8 opens directly into the pressure space A within the retort 5 so that the discharge of protective gas from the pipe 8 may result in uneven pressure and flow conditions within the retort, the arrangement described above with reference to FIG. 6, ensures the uniform distribution of the added protective gas around the entire perimeter of the diffuser. Protective gas is added, for discharge uniformly around the gap 25 during the annealing or heating and cooling phases of the process in order to make up for losses thereof.

Further, it has been found that the power for requiring circulation of the protective gas, that is, for driving the blower 4, is better utilized when the flow of gas is practically free from turbulence. In this connection, it has been found that baffle plates or rings disposed within the suction space B, for example, a baffle plate 17, as shown in FIG. 1, may produce turbulence which impede the smooth flow of the circulated protective gas. To avoid this possibility, in the furnace illustrated in FIG. 6, such baffle plates or rings are replaced by convergent nozzles 20, 20*a* and 20*b* arranged at appropriate locations within the suction space to advantageously guide the circulation of the protective gas and to avoid the introduction of turbulance in such circulation.

Since the output of an annealing furnace of the described character depends, not only on the freedom from turbulence in the flow of circulated protective gas, but also on the rate of convective heat transfer and on the rate and velocity of flow of the circulated gas, which, in turn, depend on the undisturbed flow of the protective gas through the diffuser 3 and the convectors 7 and 7*a*, it has been found desirable to form the blades or vanes of the diffuser and convectors as logarithmic spirals.

Although the nozzles 20, 20*a* and 20*b* have been illustrated as downwardly convergent annular nozzle rings located at levels corresponding to the top of each of the superposed portions of the stack of material to be annealed, it is apparent that such nozzles may be constructed in any other suitable manner and may be of a number different from the number of portions in the stack and disposed at locations different from those illustrated in FIG. 6. Further, the annular gap 25 through which additional protective gas is uniformly distributed serves to provide a pressure chamber within the gap 25 which effectively prevents the infiltration of sand from the packing 26 around the lower edge portion of retort 5 and which serves to burn any atmospheric oxygen entering through the sand packing, thereby to render harmless such oxygen. Although a particular construction has been illustrated for defining the chamber 22, it is apparent that other suitable structures may be realized.

Referring now to FIG. 8 of the drawings, it will be seen that the bell furnace for annealing there illustrated, as before, includes a bell-shaped outer wall structure 101 into which heat is introduced for transfer to a retort 102 either directly by convection, or indirectly by radiation. The material to be annealed is arranged in a vertical stack within the retort 102 and is made up of the portions or units 104, 104*a* and 104*b* having convectors 105 and 105*a* interposed therebetween and formed in the manner previously described herein. The protective gas is circulated within the retort 102 by a blower 103 which is centrally located within the diffuser 107 supporting the stack of material to be annealed. The circulation of protective gas induced by the blower 103 includes an upward flow path through the annular space between the stack and the side wall of the retort 102 and a downward flow path through the central suction space 106 extending vertically through the center of the stack. The protective gas absorbs heat from the wall of the retort 102 and yields such heat to the superposed portions 104, 104*a* and 104*b* of the stack during its flow through the successive zones A', B' and C' and while flowing inward through the convectors 105 and 105*a* and over the top of the uppermost portion 104*b* prior to return through the suction space 106 for recirculation by the blower 103. Preferably, as previously described, the blades 108 of the diffuser 107 are in the form of logarithmic spirals, while the diffuser further includes an upwardly curved annular outer wall 109, so that the circulated protective gas has a helical movement imparted thereto upon discharge from the diffuser 107.

In the embodiment of FIG. 8, the retort 102 includes a generally cylindrical side wall 110 and a top wall or cover 111 both formed of sheet iron. Ribs or corrugations 112 are welded or otherwise suitably formed on the inner surface of the side wall 110 in order to substantially increase the effective surface area of the retort available for heat transfer between the latter and the protective gas. Preferably, the ribs or corrugations 112 are given spiral configurations having pitch angles which depend upon the pitch of the helical flow of the protective gas discharged from the diffuser 107. This increase in the effective area of the inner surface of the retort 102 for promoting the transfer of heat from the latter to the circulated protective gas requires a corresponding increase in the ability of the retort 102 to absorb heat from within the bell-shaped furnace wall structure 101. Thus, the outer surface of the retort 102 is preferably also provided with ribs or corrugations 113 which alternately extend vertically along the side wall 110 and along the side wall and onto the top wall 111 of the retort. The increase in the effective area of the outer surface of the retort provided by the ribs or corrugations 113 not only improves the ability of the retort 102 to absorb heat from within the furnace wall structure 101, but also advantageously increases the rate at which heat can be removed from the retort 102 during the cooling process and further structurally strengthen the relatively thin walled retort.

The increases in the effective areas of the inner and outer surfaces of the retort **102** and the directional control of the circulation of the protective gas provided by the corrugations **112** and **113** result in a particularly rapid and uniform heating of all of the material within the vertical stack.

Since there is a tendency for the material in the upper portion of the vertical stack to be heated more rapidly than the portions at the bottom of the stack, the pitch of the sloping or spiral ribs or corrugations **112***a* (FIG. 9) provided on the inner surface of the side wall **110***a* of the retort **102***a* may be varied throughout the vertical height of the latter so that a larger effective area, or greater increase in effective area, is provided at the bottom portion of the retort than at the upper portion of the retort thereby to promote or increase the heating of the portions of the stack at the bottom of the latter. The same purpose can be achieved, as shown in FIG. 10, by providing he inner and outer surfaces of the side wall **110***b* of the retort **102***b* with ribs or corrugations **112***b* and **113***b*, respectively only in the lower portion of the side wall. Similarly, the heat transfer to and from the lower portion of the stack can be increased in the lower portion thereof relative to the upper portion, by providing the lower portion of the side wall of the retort with a greater number of ribs or corrugations than in the upper portion of such side wall.

Heretofore, it has been known to provide double-walled retorts for use in bell furnaces for annealing, for example, as shown in FIG. 11, wherein the circulated protective gas is heated while flowing upwardly between the outer side wall **114** and the inner side wall **115** which terminates near to the top wall **11***c*. In order to increase the effective area available for heat transfer during the flow of the protective gas between the walls **114** and **115**, spiral ribs **112***c* are provided on one of the confronting surfaces of the walls **114** and **115**, for example, on the inner surface of the outer wall **114**, as shown in FIG. 11, while vertical ribs or corrugations **116** are provided on the outer surface of outer wall **114**. Thus, the retort **102***c* of FIG. 11 may be used in place of the retort **102** in FIG. 8 in order to attain the advantages of the double-walled construction as well as the advantages resulting from the ribs or corrugations provided in accordance with the present invention.

In order to overcome the tendency of the lower portions of the stack of material to be heated more slowly than the upper portions of the stack, a double-walled retort **102***d* (FIG. 12) may be formed with an inner wall **117** which terminates substantially below the upper edge of the outer wall, while the inner and outer ribs or corrugations **112***d* and **116***d*, respectively, are provided only on the lower portion of the outer wall, so that a major portion of the stream of protective gas is reversed downwardly after flowing between the inner and outer walls, while only a relatively small proportion of the circulated protective gas flows over the upper portions of the stack, whereby a more uniform heating of the entire stack is obtained.

Although all of the embodiments of the invention described above with reference to the accompanying drawings have had only a single stack of material to be annealed disposed within the retort under the bell-shaped furnace wall structure, it is to be understood that the invention can be equally applied to furnaces wherein a plurality of stacks of material to be annealed, each enclosed within a protective retort, are all disposed within

a single furnace wall structure to which heat is supplied. Further, it will be understood that the invention is not limited to the precise embodiments described and illustrated herein, and that various changes and modifications may be effected in such embodiments without departing from the scope or spirit of the invention, except as defined in the accompanying claims.

What is claimed is:

1. A process of effecting heat transfer between an elongated furnace having a longitudinal wall and end walls and material adapted for annealing therein comprising forming spaced annular sections of the material into a stack extending coaxially in the furnace and spaced from the longitudinal and end walls thereof, introducing a heat transfer fluid at one end of the stack to the peripheral space separating the stack from the longitudinal wall of the furnace, circulating the fluid about the stack by directing the fluid through a flow path extending spirally fully around the outer periphery of and longitudinally toward the other end of the stack, withdrawing successive portions of the fluid moving through the peripheral space and directing each portion through one of the transverse spaces separating adjacent sections of the material in a flow path extending inward from the outer periphery of the stack while the remainder of the fluid in the peripheral space continues in its flow path toward said other end of the stack, directing the portion emanating from each transverse space through the center space of the stack in a flow path extending within and longitudinally toward the first named end of the stack, and directing the fluid emanating from the center space through the end space separating the first named end of the stack from the adjacent end wall of the furnace in a flow path extending outward from the inner periphery of the stack, whence the fluid is recirculated about the stack.

2. A process according to claim 1 wherein successive portions of the fluid moving through the peripheral space are withdrawn and each portion directed through one of the transverse spaces separating adjacent sections of the material in a flow path extending spirally inward from the outer periphery of the stack while the remainder of the fluid in the peripheral space continues in its flow path toward said other end of the stack.

3. A process according to claim 1 wherein the portion emanating from each transverse space is directed through the center space of the stack in a flow path extending spirally within and longitudinally toward the first named end of the stack.

4. A process according to claim 1 wherein the fluid emanating from the center space is directed through the end space separating the first named end of the stack from the adjacent end wall of the furnace in a flow path extending spirally outward from the inner periphery of the stack.

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