

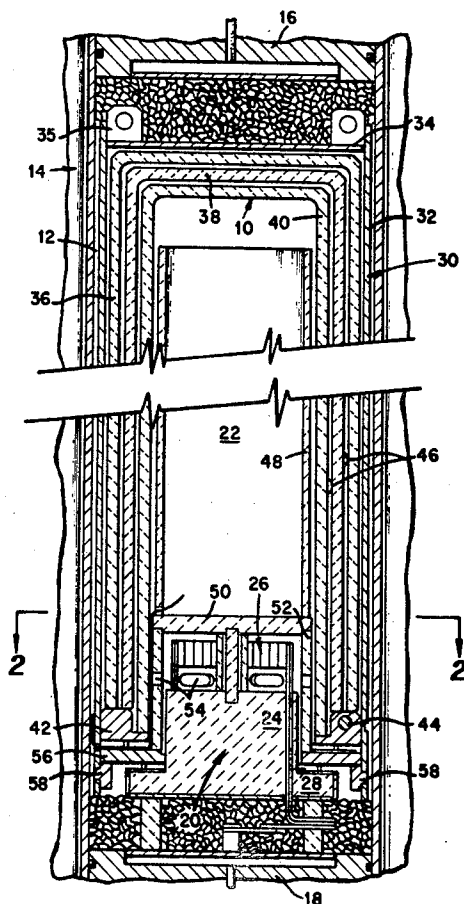
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 [73] Assignee **The United States of America as represented**
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[56] **References Cited**
UNITED STATES PATENTS
 3,419,935 1/1969 Pfeiler et al..... 18/5
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[54] **HOT-ISOSTATIC-PRESSING APPARATUS**
 8 Claims, 4 Drawing Figs.

[52] U.S. Cl..... 18/5,
 18/hi pressure dig, 18/47, 75/226
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 B22f 3/14
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ABSTRACT: An improved bell assembly is provided for use in a hot-isostatic-pressing apparatus wherein a gas provides the material pressing and heating medium. The thermal insulating and sealing properties of the bell assembly substantially enhance the efficiency of the natural-convection, closed-loop gas heating system by significantly decreasing heat losses and gas escape.



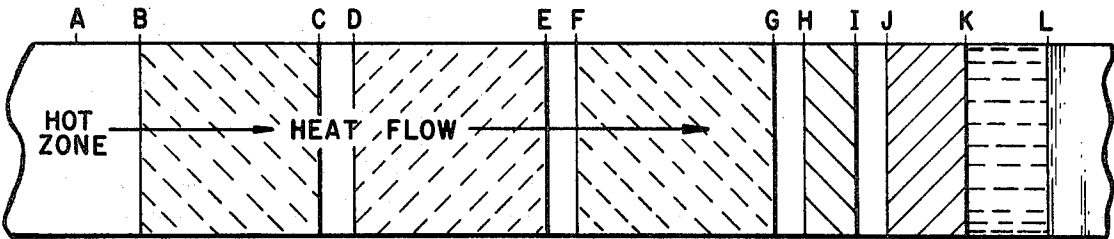


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REGION	MATERIAL	TEMPERATURE (°C)
A — B	ARGON	1704
B — C	1 3/8" ALUMINA	1533
C — D	1/4" ARGON	1158
D — E	1 1/2" ALUMINA	954
E — F	1/4" ARGON	604
F — G	1 1/2" ALUMINA	451
G — H	1/4" ARGON	252
H — I	3/8" TYPE 304L SS.	127
I — J	1/4" ARGON	117
J — K	5/8" ALUMINUM	11
K — L	WATER	9

Fig. 4

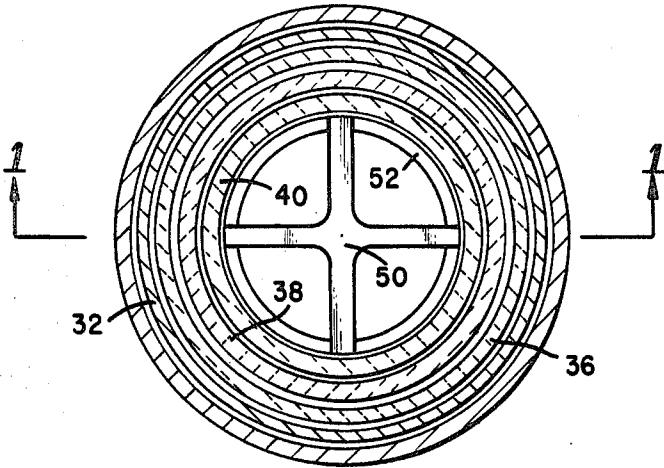


Fig. 2

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HOT-ISOSTATIC-PRESSING APPARATUS

The present invention relates generally to an apparatus for hot-isostatically pressing materials, and more particularly to an improved bell assembly for use in the aforementioned apparatus whereby the thermal insulating and fluid sealing properties of the bell assembly provide a significant increase in the efficiency of the apparatus especially at temperatures in the range of about 1000—3000°C. This invention was made in the course of, or under, a contract with the U.S. Atomic Energy Commission.

The bell assembly of the present invention is particularly suited for employment in the gas autoclave set forth in assignee's U.S. Pat. No. 3,419,935 which was issued Jan. 7, 1969, and entitled "Hot-Isostatic-Pressing Apparatus." Briefly, this patented apparatus comprises a gas autoclave wherein products exhibiting uniform densification are prepared in a hot-isostatic-pressing furnace by employing a gas as the heat and stress transmitting medium. Uniform temperature distribution throughout an enclosed thermal-pressure or work zone is achieved by employing a natural thermal convection heating system operating in a closed loop. An inert gas is heated by a gas heating mechanism disposed in the lower section of the working zone of a pressure vessel and is caused to flow upwardly under the influence of natural convection forces through an annular channel defined by a workpiece and its containment structure and a tubulation disposed thereabout. As this gas rises, the heat contained therein is transferred to the workpiece primarily by convection. After the gas reaches the top or uppermost portion of the closed upper end of the working zone, it is caused to flow outwardly and downwardly through a further annular channel defined by the tubulation and the inner wall portions of a bell assembly disposed in the pressure vessel and encircling the tubulation. This downward flow of gas is due to the cooling effect the bell wall portions have upon the gas within this further or outermost channel. In other words, as the gas enters this further channel, the bell wall portions function as a heat sink to draw heat from the gas and thereby increase the density of the gas for causing it to flow in a downwardly oriented direction. These wall portions may be further cooled by heat exchange means, e.g., a water jacket, disposed in close proximity to the outermost surface or wall portions of the bell for enhancing the flow of gas through the channel formed by the wall portions and the tubulation. The downflowing cooler gases return to the gas heating mechanism, are heated, and thereafter recycled. Thus there is provided an arrangement wherein the gases are continually recycled to establish an internal, relatively turbulence-free, natural-convection, closed-loop gas heating system for uniformly heating the entire workpiece.

While it was known that the aforementioned apparatus had the capability of operating in a temperature range varying from about ambient to about 2,000° C., it was discovered that at temperatures greater than about 1,000° C. there was an excessive loss of hot gases at the bottom of the furnace bell assembly as well as a considerable heat loss through the walls of the bell assembly. In a gas autoclave having a working zone 60 inches long by 20 inches in diameter there is a steady-state heat loss of about 65 kw. when operating the autoclave at a temperature of 1,000° C. and a pressure of 15,000 p.s.i.. This heat loss increases significantly when higher temperatures are employed and may cause permanent vessel damage when the heat input exceeds the heat dissipating ability of a pressure vessel by conduction and natural convection. Consequently, suitable precautions must be taken to assure that the temperature of the vessel walls is sufficiently low to prevent damage by thermal overstress and vessel creep during a hot-pressing operation. Of course, the possible problems due to overstress and creep may be minimized by reducing the operating pressure in the vessel as the vessel temperature increases or by limiting the operating temperatures of the vessel, but such a reduction in the vessel pressure and the use of relatively low operating temperatures somewhat compromise the usefulness of the gas autoclave and are not desirable solutions for the aforementioned problem.

In the above-referred-to gas autoclave, the lowermost surface or edge of the bell assembly formed a seal with the hearth carrying the heating mechanisms to contain the hot gases within the autoclave working zone defined by the bell assembly and the hearth. It was found that excessive quantities of the hot gases escape at this sealing point when employing operating temperatures greater than about 1000° C. due to distortion of the bell assembly because of a large temperature differential between the inside walls of the bell assembly and the relatively cooler outside walls of the latter that are disposed in close proximity to the pressure vessel walls. In other words, the inner and outer walls of the bell assembly undergo a thermal expansion due to a temperature gradient through the thickness of the bell assembly, thus causing the bottom of the bell to undergo distortion or buckling and thereby inhibiting the bottom of the bell assembly from effecting an adequate seal with the hearth.

Accordingly, it is the principal object of the present invention to provide an improved bell assembly for use in the aforementioned gas autoclave whereby operating temperatures up to about 3,000° C. may be employed without suffering excessive heat transfer through the bell assembly and hot gas loss through a sealing arrangement of the bell assembly with the hearth. The bell assembly of the present invention is provided by a plurality of nested, concentrically disposed, cuplike liners housed in a casing or shell. The nested liners are separated from one another and the shell to provide a space therebetween fillable with gas to enhance the thermal insulating properties. The lower end of the bell assembly is provided with a "knife-edge" sealing arrangement which comprises an annular vertically extending flange affixed to the bottom of the bell assembly and an annulus of resilient insulation disposed upon the furnace hearth whereby the flange projects into the insulation and effects therewith a gas seal which assures that only a minimal or negligible amount of hot gases escapes from the working zone during operations at any temperature in the above range.

Other and further objects of the invention will be obvious upon an understanding of the illustrative embodiment about to be described, or will be indicated in the appended claims, and various advantages not referred to herein will occur to one skilled in the art upon employment of the invention in practice.

A preferred embodiment of the invention has been chosen for the purpose of illustration and description. The preferred embodiment illustrated is not intended to be exhaustive or to limit the invention to the precise form disclosed. It is chosen and described in order to best explain the principles of the invention and their application in practical use to thereby enable others skilled in the art to best utilize the invention in various embodiments and modifications as are best adapted to the particular use contemplated.

In the accompanying drawings:

FIG. 1 is a somewhat schematic sectional view of a preferred form of the improved bell assembly as employed in a hot-isostatic-pressing apparatus essentially as described in the aforementioned patent;

FIG. 2 is a sectional plan view taken along line 2-2 of FIG. 1 and illustrating the spatial relationship of the various liners of the bell assembly;

FIG. 3 is a fragmentary sectional view of FIG. 1 illustrating in greater detail the knife-edge seal structure employed at the bottom of the bell assembly; and

FIG. 4 is a schematic illustration of the bell assembly cross section and the thermal insulating characteristics obtained by the structural arrangement of the bell assembly.

With reference to FIGS. 1-3 of the accompanying drawings, the bell assembly 10 of the present invention is shown disposed within the cavity 12 of pressure vessel 14 with opposite ends of the cavity being closed by water-cooled closures or seal assemblies 16 and 18. The lower end of the bell assembly 10 rests upon a hearth 20 which, together with the inner walls of the bell assembly, forms a working chamber or

zone 22 within which a material or workpiece (not shown) is pressed. The hearth 20 has a centrally oriented boss 24 which projects into the bell assembly 10 and supports the heating element 26. This boss 24 preferably extends into the bell assembly 10 a distance somewhat greater than that provided by the hearth in the aforementioned patented apparatus so as to increase the spacing between the heating element 26 and the lower edge of the bell assembly and thereby substantially reduce the temperatures of the hot gases in the area adjacent the lower end of the bell assembly, as will be discussed in greater detail below. The hearth 20 also includes a peripherally extended shoulder or skirt 28 at the lower end thereof for supporting or carrying the bell assembly.

The bell assembly 10 comprises a casing or shell 30 formed of a tubulation 32 closed at one end (the upper end as shown) by an end cap 34 which may be provided with suitable lifting tabs such as shown at 35 for facilitating the moving of the bell assembly into and out of the pressure vessel. The shell is preferably fabricated from a suitable structural metal such as stainless steel or the like. Within the shell 30 there is housed in a nesting relationship a plurality of inverted, cuplike members or liners 36, 38, 40 with a closed end of each liner being disposed in the shell 30 adjacent to the end cap 34. These liners are supported within the shell 30 by a ring support 42 secured to the casing 30 adjacent the lower end thereof and projecting laterally inwardly into the shell a distance sufficient to underlie the lower end of the innermost liner 40. The ring 42 may be releasably secured to the shell in any suitable manner, such as, for example, by a plurality of pins, one of which is shown at 44, that project through apertures in the shell 30 and the ring 42. The liners are disposed within the shell 30 in such a manner as to be separated or spaced from one another to provide cavities between the adjacently disposed liners and between the outermost liner 36 and the shell 30. These cavities are filled with the gas or gases, e.g., argon, employed in the pressing operation to enhance the thermal insulating properties of the bell assembly. The gas enters the cavities between the liners during pressurization of the working chamber 22 by passing beneath the lower ends of the liners resting on the ring 42 and by passing directly through the liners, with the quantity of gas leaking through the liners being dependent upon the porosity of the particular liner material being employed. The liners may be retained in their spatial nesting relationship by an suitable spacing means such as protuberance disposed on the surfaces of the liners, as generally indicated at 46.

The bell assembly 10 further acts as a support for the tubulation 48 employed in the working zone as the channel-providing structure for effecting the gas recycling as described above, as well as a support for the work-supporting grate 50 and a perforated sleeve 52 disposed between the grate 50 and the skirt 28 and in general alignment with the tubulation 48. The perforations 54 in the sleeve allow the cooler gas returning from the top of the working zone to be recycled through the heating element 26 as previously described. A ring 56 projects laterally inwardly from the shell, overlaps the skirt 28 on the hearth, and terminates at a location in a close spatial relationship with the outer surfaces of the boss with the innermost end of the ring 56 underlying and supporting the sleeve 52, the grate 50, and the tubulation 48 in a stacked relation. The ring 56 is in turn retained in the shell 30 by suitable readily removable means such as the easily-knocked-out pins shown at 58.

With the bell assembly assembled as above described, disassembly may be readily accomplished by removing the ring retaining pins 58 from the shell and lifting the shell and the attached liners from the ring 56 and the autoclave components supported thereby to provide easy ingress into and egress from the working zone 22. The liners 36, 38, and 40 may also be readily separated from the shell by removing the retaining pins 44.

At the lower surface of the rings 42 and 56, as shown, there are disposed the knife-edge seals of the present invention. As

best illustrated in FIG. 3, the seal construction associated with the ring 42 comprises an annular downwardly projecting flange 62 fixedly secured to the lowermost surface of the ring 42 intermediate the inner and outer peripheral surfaces by welding or the like to assure an airtight connection therewith. This flange 62 projects laterally or vertically, as shown, from the surface of the ring 42 as sufficient distance, e.g., about one inch, so as to bear against the uppermost surface of the ring 56 while maintaining the rings 42 and 56 in spaced-apart locations. The seal is effected by placing an annular sheet of resilient insulation 64, such as asbestos or the like, on the upper surface of the ring 56 and under the flange 62 whereby the latter rests on the insulation 64 with the weight of the liners and shell causing the flange 62 to bear into and deform the insulation for establishing the seal. As shown in FIG. 3, this also provides a convenient arrangement for introducing leads 66 for thermocouples and other condition-sensing devices (not shown) into the working zone 22 from a location external of the bell assembly. The lower ring 56 is also provided with an underlying annular flange 68 which, like the aforementioned flange 62, is secured to the ring and projects downwardly into an annulus of insulation 70 which, in this case, is disposed on the upper surface of the hearth flange 28. This lower seal is the seal primarily responsible for preventing the escape of hot gases from the working zone. The sealing characteristics of the knife-edge seal are enhanced by the fact that the ring 56 is disposed at a considerable distance from the heating element as provided by the boss 24 so that the temperature of the gas reaching the seal is somewhat below that of the gas in the working zones so as to further reduce the possibility of encountering the aforementioned temperature gradients which previously contributed significantly to the leaking of the working gas. For example, with a boss 24 of about 7 inches in length the temperature of the gas adjacent the lower seal is about 200° C. when the temperature in the working zone is about 1,700° C. While each of the sealing means is shown employing a single flange, additional flanges may be utilized if desired.

In order to prevent the possibility of leakage of hot gas through the bell liners, the bell liners 36, 38, and 40 are preferably of one-piece construction with no seams, openings, or cracks. Also, the bell liners are preferably of a thin-walled construction so as to prevent the formation of cracks in the assembly due to thermal gradients. The materials from which the bell liners, tubulation, grate, and sleeve are formed depend primarily upon the amount of heat employed in the pressing operation. For example, with the aforementioned structures formed of alumina, working temperatures of 1,700° C. may be readily achieved. Conversely, if graphite is employed in the fabrication of these structures, temperatures in the neighborhood of about 3,000° C. may be employed. Other refractory or ceramic materials such as beryllia, zirconia, and the like may be similarly employed for the construction of the bell assembly. It may also be desirable to construct the hearth of material similarly resistant to high temperatures.

In order to better illustrate the thermal insulating properties of the present invention there is shown in FIG. 4 a cross section of the bell assembly extending from the working chamber 22 to the water cooled wall of the pressure vessel. As indicated in the data in this FIG., the temperature within the working zone is approximately 1,704° C., but by the time the heat flow reaches the vessel wall the temperature is down to about 9° C. The steady-state heat loss in a gas autoclave of the aforementioned patented configuration, when modified to incorporate the improved bell assembly of the present invention, is about 152,000 Btu./hr., or 44.7 kw., with an operating temperature of 1,700° C. and a pressure of 20,000 p.s.i. For the purposes of this illustration the bell liners are formed of the refractory alumina. Also, while the bell assembly of the present invention is shown with three liners, it will appear clear that a greater or lesser number of liners may be readily employed if desired.

As various changes may be made in the form, construction, and arrangement of the parts herein without departing from

the spirit and scope of the invention and without sacrificing any of its advantages, it is to be understood that all matter herein is to be interpreted as illustrative and not in a limiting sense.

We claim:

1. In an improved apparatus for hot-isostatically pressing materials by employing a fluid as the material heating and stressing medium and comprising a pressure vessel having a cavity therein, a bell assembly disposed in the cavity and having wall portions defining an end wall and sidewalls of a chamber, a hearth disposed in said cavity for defining another end wall of said chamber and supporting the bell assembly, a vertically oriented tubulation disposed within the chamber at a location laterally inwardly spaced from said sidewalls for defining an annular passageway therebetween and a material processing zone within the tubulation, passageway means adjacent opposite ends of the tubulation for placing the annular passageway in registry with said zone, and heating means carried by said hearth and disposed in said zone at a location spaced from the first-mentioned end wall for heating a fluid to produce thermal convection currents therein and thereby effect fluid flow in a recirculatory and successive manner through said zone and the annular passageway; the improvement being in the bell assembly wherein the latter comprises a shell defined by a cylinder having an end wall adjacent to and enclosing one end thereof, and a plurality of cuplike members disposed in said shell in a nesting spaced-apart relationship with one another with the cuplike members each being defined by elongated sidewalls enclosed at one end by an end cap with the latter being disposed in the shell adjacent to the end wall enclosing the cylinder.

2. The improved apparatus claimed in claim 1, wherein the outermost cuplike member is inwardly spaced from said shell, and wherein the spaces between the outermost cuplike member and said shell and the spaces defined by the spaced-apart cuplike members contain a portion of said fluid when the fluid is in said chamber.

3. The improved apparatus claimed in claim 2, wherein ring means are carried by the cylinder adjacent the end thereof opposite the end wall enclosing said one end of the cylinder and laterally inwardly projecting into said chamber for supporting said cuplike members, and wherein sealing means are

disposed intermediate the bell assembly and the hearth for inhibiting the passage of fluid from said chamber.

4. The improved apparatus as claimed in claim 3, wherein said hearth has a peripherally extending skirt at a location thereon spaced from said heating means, a further ring means is carried by said cylinder at a location thereon separated from the cuplike members by the first-mentioned ring means, said further ring means projecting inwardly into said cavity from said shell and overlapping a portion of said skirt, and wherein the sealing means are disposed between the further ring means and the skirt.

5. The improved apparatus claimed in claim 4, wherein the sealing means comprise an annular flange carried by the further ring means on a portion thereof overlying said skirt and projecting towards the latter, and an annulus of resilient thermal insulating material carried by the skirt at a location between the latter and said flange for intercepting the flange and effecting a seal therewith.

6. The improved apparatus claimed in claim 5, wherein further sealing means are disposed between the first-mentioned ring means and said further ring means, said further sealing means comprising a further flange carried by the first-mentioned ring means and projecting towards said further ring means, and an other annulus of resilient thermal insulating material carried by said further ring means for intercepting the further flange and effecting a seal therewith between the ring means.

7. The improved apparatus claimed in claim 1, wherein said cuplike members are fabricated of at least one of the materials selected from the group consisting of graphite and refractories.

8. The improved apparatus claimed in claim 2, wherein sealing means are disposed intermediate the hearth and the bell assembly for inhibiting the flow of fluid from said chamber, said sealing means comprising an annular flange carried by the bell assembly at a location thereon adjacent to said hearth and projecting towards a peripherally disposed portion of the latter, and an annulus of resilient thermal insulating material carried by said hearth and disposed between the latter and said flange for effecting the seal when contacted and deformed by said flange.

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