United States Patent

[11] 3,537,411

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[21] Appl. No. **791,225**
[22] Filed **Jan. 15, 1969**
[45] Patented **Nov. 3, 1970**

[54] **DOUBLE SHELLED CHIMNEY STACK**
33 Claims, 18 Drawing Figs.

[52] **U.S. Cl.** **110/184,** 98/60
[51] **Int. Cl.** **F23j 11/00**
[50] **Field of Search** 110/184; 98/60, 61

[56] **References Cited**

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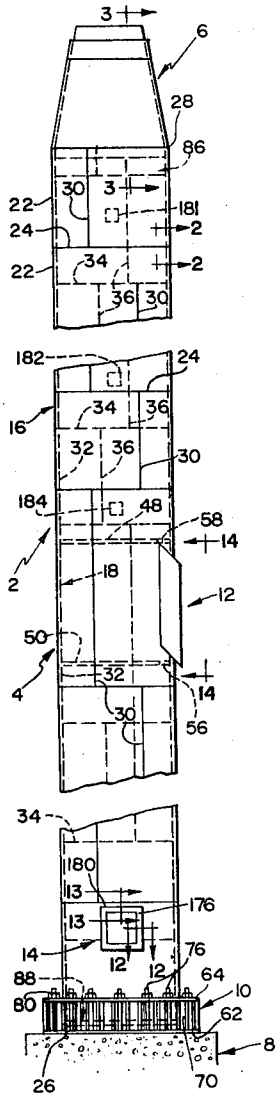
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Primary Examiner—Edward G. Favors
Attorney—Kenway, Jenney and Hildreth

ABSTRACT: A double shelled metal chimney stack made up of a substantially integral load-bearing metal outer shell and a substantially integral and substantially nonload-bearing, gas-conveying metal inner shell, the hermetically sealed annular air space between the shells providing insulation. Each shell comprises an integral, unitary welded structure substantially over its length, with the inner shell being slidable axially with respect to the outer shell in response to differential thermal expansion and contraction of the shells. A plurality of axially spaced annular spacers are located between the shells. The top of the stack is provided with a frustroconical cap for increasing the velocity of the gases.



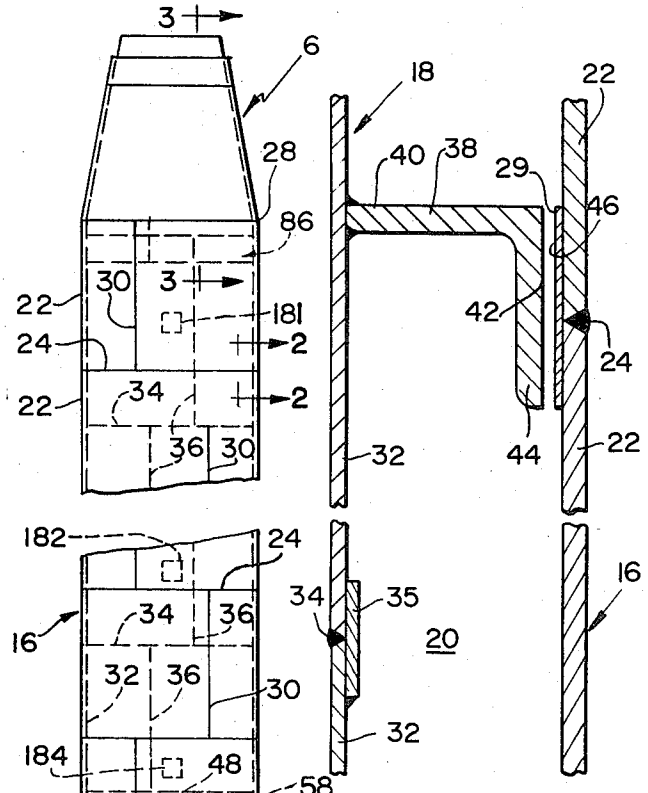


FIG. 1

FIG. 2

FIG. 2A

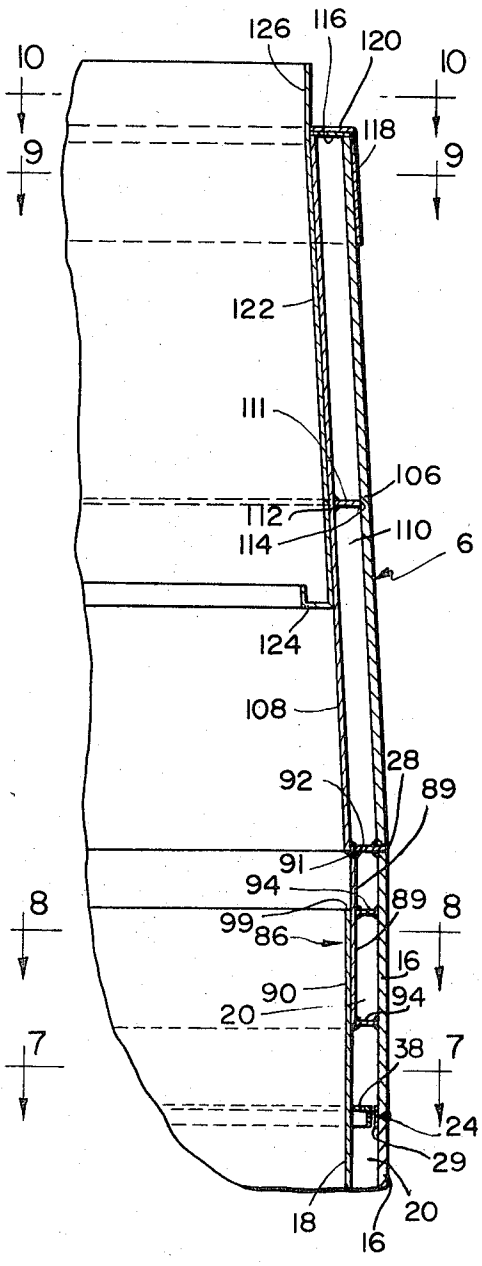


FIG. 3

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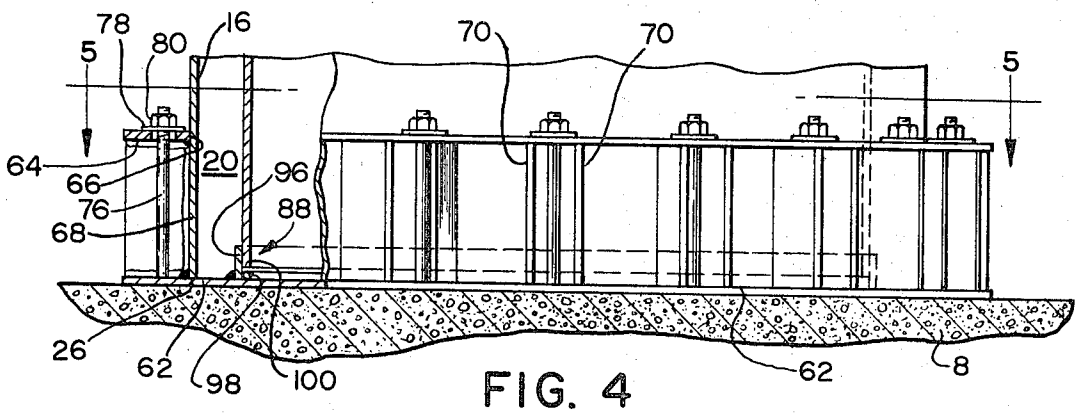


FIG. 4

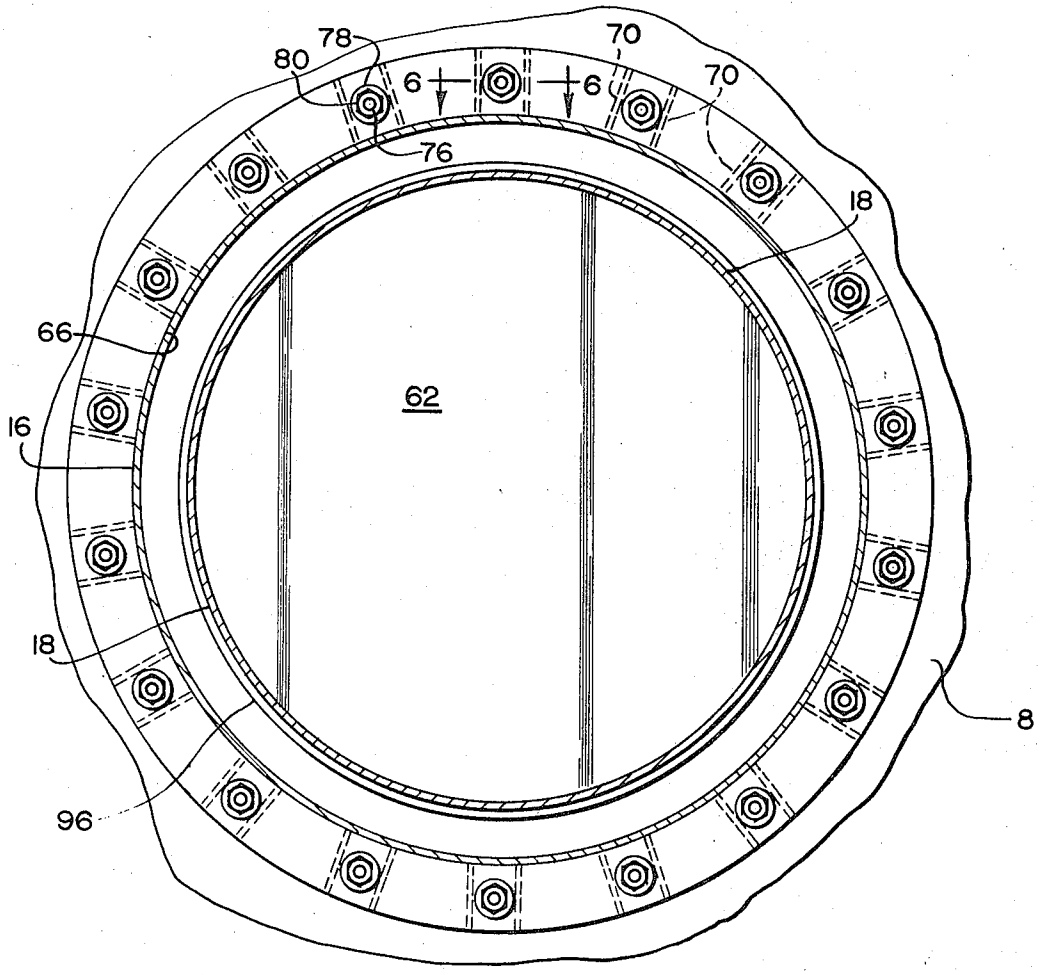


FIG. 5

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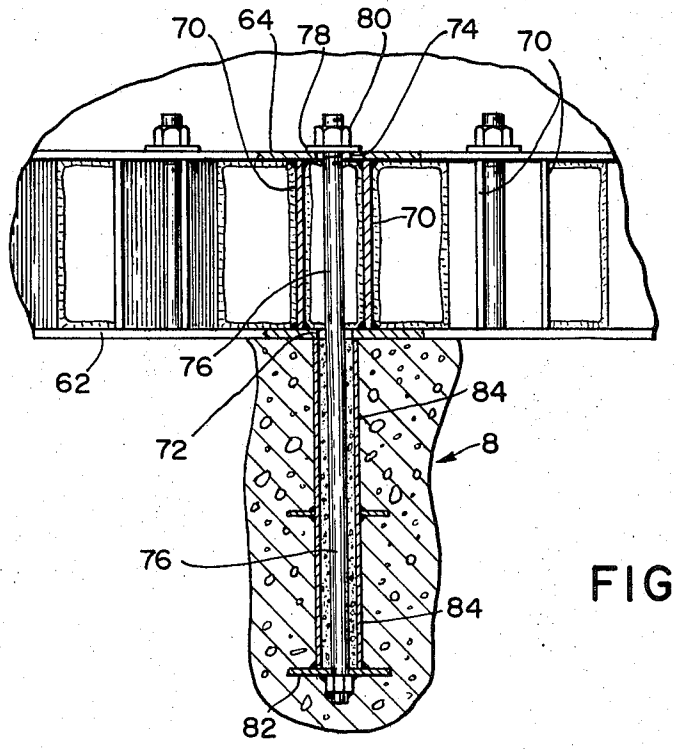


FIG. 6

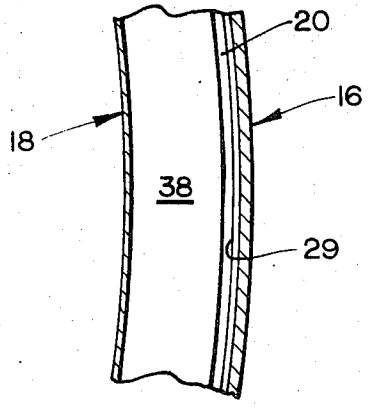


FIG. 7

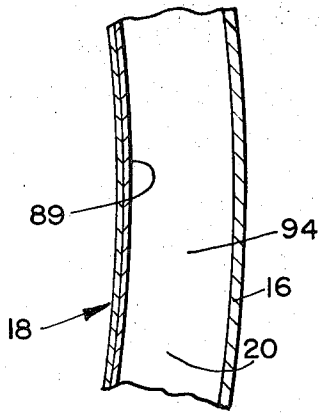


FIG. 8

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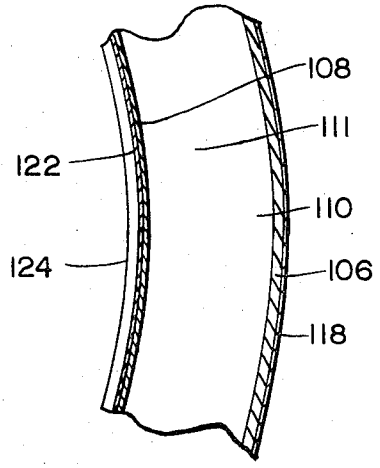


FIG. 9

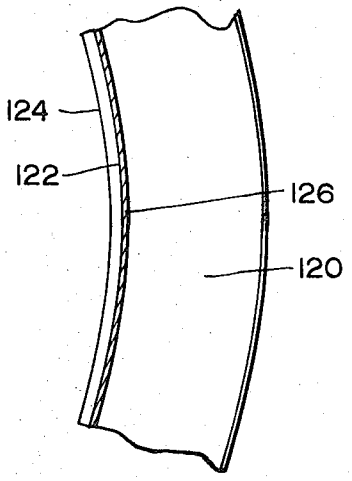


FIG. 10

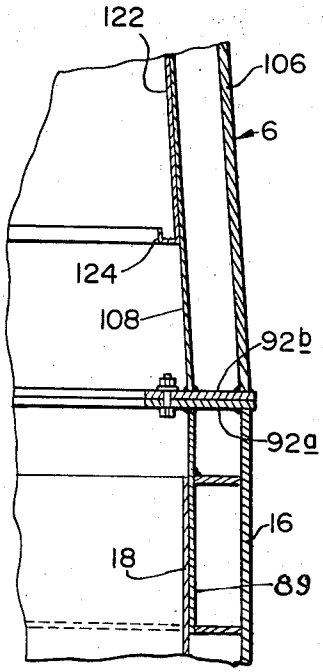


FIG. 11

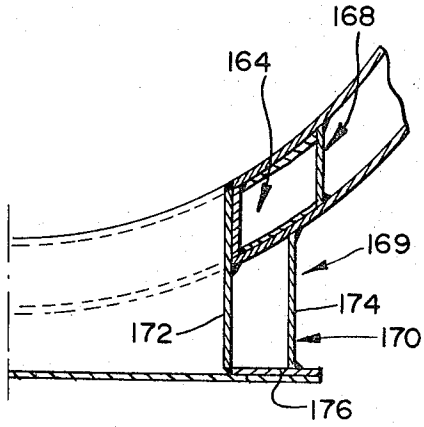


FIG. 12

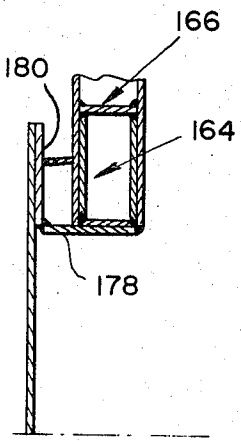


FIG. 13

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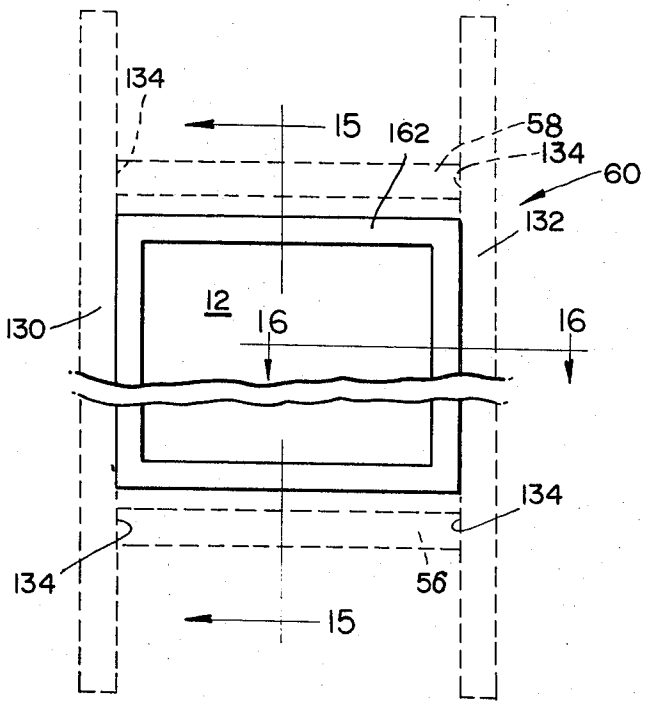


FIG. 14

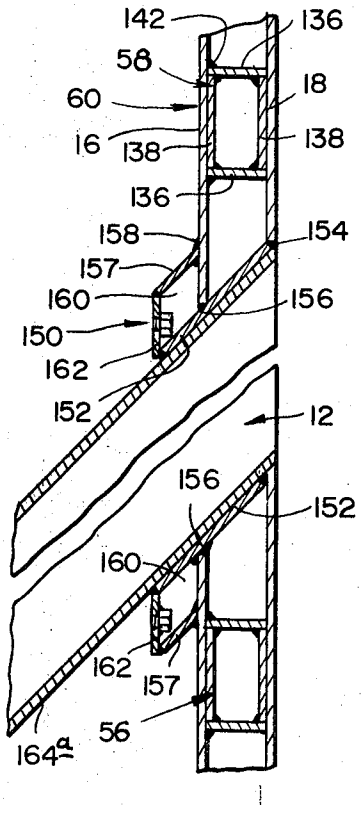


FIG. 15

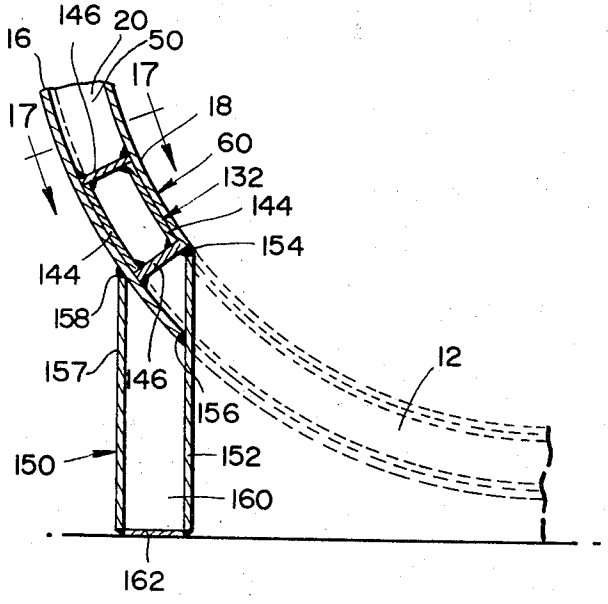


FIG. 16

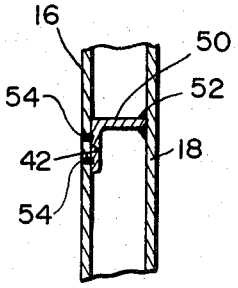


FIG. 17

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DOUBLE SHELLED CHIMNEY STACK

SUMMARY OF THE INVENTION

The present invention relates to industrial chimney stacks.

Because of the high material and labor costs and massive weight of large concrete and brick chimney stacks, it has been proposed to use metal, *e.g.* steel, tubular stacks, which can be prefabricated in part and which are much less expensive and are much easier to erect compared to concrete or brick stacks.

However, a serious problem with chimney stacks of metal, which has a high coefficient of heat transfer, has been condensation on the inner walls of water containing highly corrosive sulfur compounds, which badly corrode the metal in a short time.

In order to reduce such corrosion it has been suggested to use a double shelled stack with a dead air space between the inner and outer shells to insulate the inside of the inner shell against heat loss to thereby reduce corrosion. See J. Inst. Fuel, Vol. 35, pages 389—392, 1962, and British Pat. No. 942,002.

These publications, as well as U.S. Pat. Nos. 3,368,506; 3,302,599 and 3,363,591 disclose double shelled metal chimney stacks made from a plurality of separate tubular sections, which are joined together end-to-end by bolted flanges secured to opposite ends of each section. Each section consists of individual inner and outer shell sections, which are rigidly secured together as a unitary structure, and has an individual expansion joint to compensate for differential expansion and contraction of the inner and outer shells of the section. These bolted flanged joint constructions, which require an individual expansion joint for each section, are complex and expensive and present problems of cost, of wind loading, of tension, compression and shear loading and of erection. Each flanged joint must be analyzed for maximum compression and tension and large massive bolts are required for safety since these stacks are in many instances over 100 feet tall and must safely withstand high winds. Furthermore, with these constructions, the inner shell bears a substantial part of the loads, *e.g.* stresses, compression, shear and tension, to which the stack is normally subjected. Consequently the inner shell must be made relatively strong so as to safely withstand these loads. This limits the material and wall thickness which can be used for the inner shell so that metals, which have optimum resistance to corrosive attack by the hot gases but which are structurally weak, cannot be used. Also when the inner shell is weakened by inevitable corrosion thereof the strength of the stack is weakened to thereby sharply decrease the safe and useful life of the stack.

Accordingly, an object of the invention is to provide a double-shelled metal chimney stack which avoids these disadvantages.

This is achieved in accordance with the invention by providing a double-shelled metal chimney stack made up of a load-bearing outer shell and a substantially nonload bearing inner shell, each shell being made by integrally joining, *e.g.* by welding, end-to-end a plurality of tubular metal sections so that it is a continuous and integral unitary structure substantially from one end to the other, by making the inner shell slidable axially with respect to the outer shell in response to differential thermal contraction and expansion of the two shells and by providing a simple and inexpensive telescopical slip joint at the upper end of the inner shell, and, if desired, also at the lower end of the inner shell, to permit such differential expansion and contraction.

This slip joint is formed by terminating the upper end of the inner shell short of the upper end of the stack, *i.e.* short of the upper end of the outer shell, by providing a nesting or retaining cup secured to the upper end portion of the outer shell and by providing a snug, telescopical sliding connection between the nesting cup and the upper end of the inner shell to compensate for differential thermal axial expansion and contraction of the two shells.

If a second slip joint is used at the lower end of the inner shell, it also is formed by terminating the lower end of the inner shell short of the lower end of the stack, *i.e.* short of the lower end of the outer shell, by providing a nesting or retaining cup secured to the lower end portion of the outer shell, *e.g.* through the metal base plate on which the stack is supported, and by providing a snug, telescopical sliding connection between the nesting cup and the lower end of the inner shell to compensate for differential thermal axial expansion and contraction of the two shells.

Although in a sense the aforesaid nesting cups are a part of the inner shell, because they are quite short, *e.g.* 10 to 18 inches in the case of the upper nesting cup and 1 to 2 inches in the case of the lower nesting cup for stacks having an overall height of from 100 to 150 feet with the vertical distance between the upper end of the cold main inner shell and the top of the cold stack and between the lower end of such cold inner shell and the bottom of the cold stack being between 6 inches and a foot in the case of the upper nesting cup and between one-fourth inch and one and one-half inches in the case of the lower nesting cup, the inner shell may be considered to be a continuous and integral unitary structure substantially from end-to-end.

The aforesaid relative slidability of the inner and outer shells with respect to each other is achieved by the aforesaid slip joint or joints coupled with a plurality of axially spaced, annular spacers located in the hermetically sealed, annular dead air space between the shells, each spacer being secured to one of the shells and having an annular bearing surface for the other shell. Each bearing surface is slidable axially with respect to the other shell to permit the aforesaid differential expansion and contraction and each spacer is preferably located opposite and straddles a joint of the outer shell joining adjacent sections.

Preferably, each of the spacers is rigidly secured to the inner shell and provides a slidable, annular bearing surface for the inside of the outer shell, which annular bearing surface is located opposite a joint joining together adjacent sections of the outer shell, and an annular bearing and friction ring is provided between the bearing surface and the outer shell, which bearing ring is secured to such outer shell over the aforesaid joint so that the bearing surface and inner shell are slidable with respect to such bearing ring and outer shell. Such bearing ring preferably functions as a welding back-up ring for the aforesaid outer joint and when the outer shell is assembled in the field, it prevents the weld used to join adjacent outer sections from rigidly securing the inner shell to the outer shell.

With this arrangement, the two shells may be designed so that the outer shell bears substantially all of the loads to which the stack is normally subjected with the inner shell comprising substantially a nonload bearing member. Because of this, it may be designed primarily to resist heat and corrosion without consideration of its strength so that it can be made quite light in weight and of weak materials. Also, because of this, assembly of the stack is greatly simplified.

Thus, in a preferred embodiment, the walls of at least the lower sections of the outer shell are made quite thick compared to the thickness of the wall of the inner shell, the thickness of such outer shell sections preferably decreasing from the bottom (where the greatest strength is required) to the top of the outer shell.

The two shells may be entirely separate, *i.e.* with no rigid connection therebetween, or they may be rigidly secured together only at their bottom ends. In either case, each shell is free to expand and contract as a substantial unitary structure relative to the other over substantially their entire lengths by virtue of the slip joint at the upper end of the inner shell. However, if greater rigidity is required, the two shells may be rigidly secured at an area intermediate their ends with the aforesaid slip joint at the lower end of the inner shell being provided in addition to the slip joint at the top of the inner shell to take care of differential expansion and contraction below the rigid connection. In such case, the two shells are still

free to expand and contract substantially as unitary structures along substantially their entire lengths above and below the intermediate area of connection.

Another disadvantage of presently available double-shelled chimney stacks is that outside air, together with rain and snow and sleet tends to enter the top of the stack, particularly with strong winds. Deposition of such rain and snow on the inner surfaces of the inner shell together with condensation of the hot gases by the cool air entering the top of the stack causes serious corrosion and efficiency problems.

Accordingly, it is another object to avoid these disadvantages.

This is achieved by securing to the top of the stack a double-shelled frustoconical cap, which functions as a venturi throat to increase the velocity of the hot gases emerging from the top of the stack, and by providing a single thin shell insert secured within the cap and protruding upwardly beyond the upper end of the cap a sufficient distance so that eddy currents, caused by the wind blowing against the relatively thick upper end of the double-shelled cap, will not cause air, snow, rain and sleet to flow into the open top of the cap. Since the insert comprises a single, annular, relatively thin metal shell, *i.e.* a single wall, the aforesaid eddy currents are not created by wind blowing against the upper end of such insert. It is the thickness of the end of the double wall construction which causes the eddy currents.

The use of the aforesaid insert, even without the cap, is helpful in preventing eddy currents from causing air to enter the top of the stack.

The cap may be either rigidly attached to the top of the stack or may be removably bolted thereto by cooperating flanges on the bottom of the cap and top of the stack. In either case, the upper end of the annular space between the two stack shells is closed by an annular end plate secured to the tops of the inner and outer stack shells and which, when bolted flanges are used, may be the connecting flange at the top of the stack.

The upper nesting cup for the inner shell, which provides the slip joint, is preferably secured to this end plate, and accordingly is secured to the upper end of the outer shell so that such nesting cup moves upwardly and downwardly with the top of the outer shell and relative to the inner shell. Since the cap is secured to such end plate, it also moves upwardly and downwardly with the upper end of the outer shell also.

In the case where the cap is removably bolted to the top of the stack by cooperating flanges attached to the top of the stack and bottom of the cap, each of the stack shells may still be considered to be a substantially integral unitary structure from end-to-end since the cap is relatively short compared to the length of the stack. For example, in a 99 foot stack the cap may be 5 or 6 feet in height, *i.e.* about 6 percent of the total stack height, and in a 150 foot stack the cap may be 9 or 10 feet in height and at most 10 or 15 percent of the total stack height.

In a preferred embodiment, the horizontal section-joining joints of the outer shell are vertically staggered with respect to the horizontal, section-joining joints of the inner shell and the vertical joints of the sections of the outer shell are circumferentially staggered with respect to the vertical joints of the sections of the inner shell, each section of each shell being made by rolling a metal plate into a tubular section and welding the abutting edges of such section to form the aforesaid vertical joints.

It is another object of the invention to provide an improved base construction for the stack.

In accordance with the present invention, a combined metal base plate and parallel ring construction (the base plate lies on top of a supporting foundation and the ring is spaced vertically above the base plate) is provided, which is secured to the top of the foundation by means of bolts passing upwardly from the foundation through circumferentially spaced and aligned holes around the outer margins of the base plate and ring. Vertical, circumferentially spaced and radially extending gusset plates are located between adjacent holes and are rigidly secured to the ring and base plate. In accordance with the invention, the lower end portion of the outer shell fits snugly within the center opening of the ring and is welded to the edge of said opening and the radially inner ends of the gusset plates with its lower end welded to the base plate. Also, in accordance with the invention, the bolt holes in the ring and base plate are oversized to facilitate assembly and the end of each bolt protruding above its bolt hole in the ring passes through a washer in which it snugly fits and which is welded to the top of the ring. A nut threaded over the end of each bolt protruding above its washer, secures the plate and ring assembly to the foundation.

It is yet another object of the invention to provide an improved breeching opening construction in a double-shelled chimney stack by providing a bracing structure around such opening and located in the space between the two shells. The bracing structure is made up of two horizontally extending, arcuate hollow beams above and below the opening and rigidly secured to at least one of the shells (preferably the stronger outer shell) and two vertically extending hollow beams on either side of the opening and rigidly secured to at least one of the shells (preferably the outer shell), the horizontal and vertical beams being rigidly secured together to form a rigid hollow frame around the breeching opening. Preferably, the cross-sectional shape of each beam is a parallelogram, more preferably a rectangle. All the beams fit snugly between the inner and outer shells with the inner walls engaging and contoured to the outer surface of the inner shell and the outer walls engaging and contoured to the inner surface of the outer shell to thereby brace the shells around the opening.

Further advantages and objects will be apparent from the following description and accompanying drawings of preferred embodiments of the invention.

DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1** is a view in elevation with portions broken away of a chimney stack embodying the present invention;

FIG. **2** is a section of the stack of FIG. **1** at the section lines **2–2** of FIG. **1** showing one of the spacers between the inner and outer shells;

FIG. **2A** is a view like FIG. **2** showing another embodiment of the spacer for spacing the inner and outer shells;

FIG. **3** is a section of the stack and its cap or cone at the section lines **3–3** in FIG. **1**;

FIG. **4** is an enlarged view, in elevation and partially in section, of the base plate and ring of FIG. **1**;

FIG. **5** is a view taken along the line **5–5** of FIG. **4**;

FIG. **6** is a vertical section taken along the line **6–6** of FIG. **5**;

FIG. **7** is a horizontal section taken along the line **7–7** of FIG. **3** through the stack;

FIG. **8** is a horizontal section taken along the line **8–8** of FIG. **3** through the slip joint;

FIG. **9** is a horizontal section taken along the line **9–9** of FIG. **3** through the cap;

FIG. **10** is a horizontal section taken along the line **10–10** of FIG. **3** through the insert;

FIG. **11** is a view like FIG. **3** but showing the cap removably bolted to the top of the stack rather than welded thereto as in FIG. **3**;

FIG. **12** is a horizontal section taken along the line **12–12** in FIG. **1**;

FIG. **13** is a vertical section taken along the line **13–13** in FIG. **1**;

FIG. **14** is a view in elevation taken along the line **14–14** in FIG. **1**;

FIG. **15** is a vertical section taken along the line **15–15** in FIG. **14**;

FIG. **16** is a section taken along the line **16–16** in FIG. **14**;

FIG. **17** is a section taken along the line **17–17** in FIG. **16**.

DETAILED DESCRIPTION

With reference to the drawings, 2 represents a metal chimney stack embodying the invention. It is made up of the metal cylindrical stack 4 with a metal frustoconical shaped cap 6 secured to the top thereof. It is supported on a concrete foundation 8 to which it is secured by virtue of the metal base construction 10 and has a breeching opening 12 and an access door 14.

The stack is made up of an outer cylindrical metal shell 16 and a concentric inner metal shell 18 with an annular hermetically-sealed insulating air space 20 therebetween.

The outer shell 16 is made from a plurality of tubular metal sections 22 which are fusion welded together end-to-end at weld joints 24 to form a continuous and integral unitary shell structure from the lower end 26 thereof (FIG. 4) to the upper end 28 thereof (FIG. 3).

An annular stainless steel bearing and friction and welding backup ring or plate 29 is located around the inside of each annular and horizontal joint 24 and is secured to the inside of the outer shell by the weld of the joint.

Each section 22 is made from a plate of atmospheric corrosion resistant high strength steel, *e.g.* that sold under the name COR-TEN by the United States Steel Company or that sold under the name MAYARI-R by the Bethlehem Steel Company, which is rolled into the shape of a cylinder after which its abutting edges are shop-welded together at the joint 30 (FIG. 1) which forms a vertical joint or seam in the stack.

These vertical seams 30 of adjacent sections 22 are staggered circumferentially as shown in FIG. 1 to increase the strength of the stack.

Also, each of these vertical seams or joints 30 may have a vertically disposed welding backup plate (not shown) along the inside thereof and secured thereto by the weld of the vertical joint during the welding operation.

Since the outer shell 16 is the load-bearing shell, it is made much stronger than the inner shell 18 and the lower sections 22, which must bear a greater load, have a greater wall thickness than the upper sections. Preferably, the wall thickness of each section or group of sections of the outer shell is smaller than the one below it to which it is joined. Thus, for example in a 150 foot commercial stack made up of five groups of sections 22, the lowest group had a wall thickness of one-half inch, the next highest a wall thickness of seven-sixteenths inch, the next highest a wall thickness of three-eighths inch, the next highest a wall thickness of five-sixteenths inch and the next highest a wall thickness of one-fourth inch.

The inner shell 18 is also made of a plurality of tubular sections 32 also welded together end-to-end at weld joints 34 to form a continuous and integral unitary structure substantially from the lower end thereof to the upper end with an annular metal welding backup plate 35 located around the outside of each welded horizontal and annular joint 34 and secured to the outside of the inner shell by the weld of the joint.

As in the case of the outer shell, each of these sections are made from a plate of the same material as the outer shell, which is rolled into a cylindrical shape and the abutting ends shop welded together at 36 to form a vertical seam or joint in the stack. These seams are staggered circumferentially in adjacent sections, as shown.

Since, as aforesaid, the outer shell bears substantially all the load so that the inner shell is substantially a nonload bearing shell, it is made thinner and less strong than the outer shell. For example, in the aforesaid commercial 150 foot stack, the inner shell had a wall thickness of three-sixteenth inch. Although it may be made of the same non-corrosive steel as the outer shell, because it does not bear any substantial amount of the load, it can be made of much weaker materials, even plastic, which are highly resistant to heat and corrosion from the hot gases.

A plurality of annular spacer members 38 (FIG. 2) are vertically disposed along the length of the stack in the space 20 (in the aforesaid commercial stack, the width of this space is 3 inches) between the shells and function to space the two shells from each other, to retain their cylindrical concentric shapes and to stiffen the structure. Each annular spacer member 38 is L-shaped in cross section, as shown in FIG. 2. Each spacer 38 is disposed opposite and vertically straddles an outer joint 24. An end of the leg 40 of each annular spacer 38 is rigidly secured, *e.g.* by shop welding, to the outer surface of the inner shell 18 with the outer annular surface 42 (facing radially outwardly) of the other annular leg 44 located opposite the annular joint 24 so that a part of surface 42 is located above the joint 24 and a part is located below the joint. Actually, the annular bearing surface 42 is located radially opposite and vertically straddles the annular welding backing and bearing ring 29, the inner surface 46 of which also comprises a bearing surface for cooperating with the bearing surface 42 for axial sliding movement of one with respect to the other by differential axial expansion and contraction of the inner and outer shells.

In the drawings, the bearing surfaces 42 and 46 are shown spaced radially from each other a slight distance. This is how they are installed. The reason for the slight space is to permit radial thermal expansion of the two shells and spacers. During operation of the stack, the aforesaid radial expansion causes the two bearing surfaces to come into sliding contact with each other. In any event, this arrangement permits the two shells to be axially slidable with respect to each other in response to differential thermal expansion and contraction, the annular spacers 38 moving axially with the inner shell (to which they are secured) and with respect to the outer shell and the friction plates 29. Since the hot gases pass through the inner shell, it becomes hotter than the outer shell at a faster rate and consequently, the inner shell moves axially with respect to the outer shell.

Friction plates 29 are preferably made of stainless steel or copper and the inner faces thereof, as well as the bearing surfaces 42, are smooth to facilitate sliding movement therebetween.

The joints 24 are welded with the friction plates 38 in place to insure against the weld penetrating to the spacer members and thereby rigidly securing the outer shell to the spacer members.

The base construction 10 on which the stack is supported (FIGS. 1 and 4—6) comprises a circular steel base plate 62, supported on the upper surface of the concrete foundation 8, and a steel ring 64, which is spaced above and is parallel to the plate 62 and which has a central circular opening 66, which snugly receives the lower end portion 68 of the outer shell, as shown in FIGS. 4 and 5, with the lower end edge 26 of the outer shell resting on the top of the plate and rigidly secured thereto by welding.

The outer surface of the outer shell is also rigidly secured by welding to the edge of the central opening 66.

The plate 62 and ring 64 are rigidly secured together by a plurality of circumferentially spaced, radially and vertically extending steel gussets 70 welded to the upper and lower surfaces, respectfully, of the plate and ring. The radially inner edges of the gussets 70 are also welded rigidly to the outer surface of the outer shell 16. The plate 62 and ring 64 each has a plurality of circumferentially spaced, axially and vertically aligned oversize holes 72 and 74 (FIG. 6), respectively, each set of aligned holes receiving a massive steel bolt 76, which extends upwardly from the top of the foundation 8 through such oversize holes. The portion of each bolt 76 protruding upwardly out of each oversize hole 74 has a steel washer 78 fitted snugly around the bolt and welded securely to the top of ring 64 during erection to hold the bolt against sideways movement in the oversize holes. Nuts 80 are threaded tightly over the ends of the bolts to rigidly secure the base construction 10 to the foundation 8.

Bolts 76 are secured in the concrete foundation 8 in conventional manner. They are welded to the plate 82 within or on the underside of the concrete foundation 8. The bolts extend through concrete filled metal sleeves 84 within the concrete foundation 8 and which are welded to the plate 82.

The use of oversize holes 72 and 74 with washers 78, welded to the top of ring 64, facilitate erection of the stack, the washers being welded to the ring during erection after they have been placed over the bolts.

The two shells 16 and 18 are separated from each other (*i.e.* no rigid attachment) along their entire lengths except for being rigidly secured together by means of a pair of annular members 48 and 50 (FIGS. 1 and 17), each being located axially at levels immediately above and below the breeching opening 12, respectively. Each of these members has substantially the same cross-sectional L-shape as the spacer members 38 except that not only is the end of leg 50 secured to the outer surface of the inner shell 18 by welding at 52 (FIG. 17) but also the radially outer annular surface 42 is rigidly secured to the outer shell by plug welding at 54. Although the members 48 and 50 have been referred to as annular, they actually terminate circumferentially approximately above and below the vertical edges of the breeching opening 12, as best shown in FIG. 1. Continuing on around the circumference of the stack are a pair of circumferentially arcuate hollow beams 58 and 56 (FIGS. 1 and 14—16) which form part of a bracing structure 60 (this bracing structure will be described more fully hereinafter) and which are located above and below the breeching opening at the same levels as the connecting members 48 and 50, respectively.

The ends of members 48 and 50 are located adjacent the ends of the hollow beams 58 and 56, respectively, so that the member 48 and hollow beam 58 form a substantially annular stiffening structure and the member 50 and hollow beam 56 form another substantially annular stiffening structure.

Expansion joint 86 (FIG. 3) at the upper end of the inner shell 18 provides for differential thermal axial expansion and contraction of the entire lengths of the two shells 16 and 18 above the rigidly connected area 48—50 and expansion joint 88 (FIG. 4) at the lower end of the inner shell provides for differential thermal axial expansion of the entire lengths of the two shells below such rigidly connected intermediate area.

The upper expansion joint 86 (FIG. 3) comprises a slip joint formed by terminating the upper end 99 of the inner shell 18 short of the upper end of the stack, *i.e.* short of the upper end 28 of the outer shell, and providing an annular nesting or retaining cup 89 rigidly secured at its upper end to the upper end 28 of the outer shell 16 through the steel ring 92 to which the top of the nesting cup is welded and which is in turn welded to the upper end 28 of the outer shell. The upper end portion 90 of the inner shell 18 is snugly but slidably and telescopically received or nested within the nesting cup 89, as shown. It is apparent that with this construction the nesting cup 89 moves vertically upwardly and downwardly with the outer shell and with respect to the inner shell in response to differential thermal axial expansion and contraction. The telescopical fit between the nesting cup 89 and the inner shell is tight enough so that there is substantially no leakage of hot gases from within the inner shell into the space between the shells. Because the hot gases within the inner shell are lighter than the colder air in the space 20, they will not flow into the space in any event.

The annular steel ring 92 is located over and closes and seals the upper end of the annular space 20 between the inner and outer shells.

A pair of annular stiffening rings 94 are rigidly secured by welding to the inner surface of the outer shell and the other surface of the nesting cup 89, as shown in FIG. 3.

The lower expansion joint 88 (FIG. 4) is also a slip joint formed by terminating the lower end 100 of the inner shell 18 short of the lower end of the stack, *i.e.* short of the lower end 26 of the outer shell and providing an annular nesting or retaining cup 96 rigidly secured at its lower end to the lower end 26 of the outer shell 16 through the steel base plate 62 to which the lower end of the nesting cup is rigidly welded and which is in turn rigidly welded to the lower end 26 of the outer shell. The lower end portion of the inner shell is snugly but telescopically and slidably received within the nesting cup 96, as shown in FIG. 4. It is apparent that with this construction the inner shell is slidable axially with respect to the nesting cup 96, the plate 62 and the outer shell 16 in response to differential thermal axial expansion and contraction of the two shells.

A ring 98 of compressible, heat-resistant material, *e.g.* asbestos, is located below the lower end 100 of the inner shell so that when the inner shell expands axially during operation of the stack it compresses the asbestos ring to provide a seal. Although the fit between the nesting cup 96 and the inner shell is a snug one to provide a sealing effect, the asbestos ring is used because in most cases at the bottom of the stack the gases within the inner shell are not hot so that the temperature differential between the inside of the inner shell and the space 20 does not provide a natural sealing effect as in the case of the upper slip joint.

The base plate 62 closes and seals the lower end of the annular space 20 between the inner and outer shells.

In a sense the nesting cups 89 and 96 are part of the inner shell. However, since these nesting cups and the distances between the upper edge 99 of the inner shell and the upper end of the stack and between the lower end 100 of the inner shell and the lower end of the stack are each quite short relative to the total height of the inner shell, *e.g.* a cold nesting cup length of between 10 and 18 inches with a distance between the top of the cold inner shell and the top of the stack of between 6 inches and a foot in the case of the upper nesting cup and substantially less than that in the case of the lower nesting cup for a stack from 100 to 150 feet high, the inner shell, like the outer shell, may be considered as a substantially integral and continuous unitary structure from end-to-end.

Actually, it is preferred that the distance between the ends of the cold inner shell and the ends of the cold stack be made as small as possible so long as they are sufficient to compensate for the differential expansion for which they are designed.

As aforesaid, the upper expansion joint 86 provides for differential axial expansion of the major portion of the two shells above the rigid connection therebetween by the connecting member 48 and the lower expansion joint 88 provides for differential expansion of the minor part of the two shells below the rigid connection therebetween by the connecting member 50.

Since the height of the breeching opening 12, and hence the vertical distance between the connectors 48 and 50, is quite small in comparison to the height of the stack, *e.g.* 8 feet for a stack between 100 and 150 feet, the inner and outer shells may be considered as being rigidly secured at only a single small area intermediate the ends thereof and are otherwise separate from each other and free to move axially as unitary structures with respect to teach other in response to differential thermal axial expansion and contraction (the short distance between the two members 48 and 50 does not present any expansion or contraction problems). Actually, as aforesaid, the upper single and simple slip joint 86 provides for the major portion of the differential axial thermal expansion of the substantially unitary inner and outer shell structures.

It is pointed out that the rigid connectors 48 and 50 can be omitted together with the lower expansion joint 88, in which case the inner shell extends continuously to the base plate 62 with the lower end 100 thereof welded to the base plate in the same manner as the lower end of the outer shell. In such case, the two shells are rigidly joined together only at their lower ends, *i.e.*, by the welded connections between the ends thereof and the base plate, with the single upper expansion joint 86 providing for the entire differential expansion and contraction as two unitary structures of the entire lengths of the two shells.

By rigidly connecting the two shells by members 48 and 50 intermediate their ends and at the breeching opening, the structure is strengthened.

The frustoconical shaped cap 6 is rigidly secured at its lower wider end to the upper end of the stack by welding (FIG. 3). Actually, cap 6 is welded at its base to the annular ring 92.

Cap 6 consists of an outer tapered shell 106 and an inner concentric, parallel, tapered shell 108, the annular space 110 therebetween comprising an insulating dead air space. An annular spacer ring 111 is provided in the space 110, one edge of the ring 111 being rigidly secured to the outer surface of the inner shell by welding at 112. The outer edge 114 of the spacer 111 constitutes an annular bearing surface for the outer shell 106 and is slidable with respect to the outer shell to provide for differential thermal axial expansion and contraction of the cap shells.

The lower edge of each of the shells 106 and 108 is rigidly secured to the ring 92.

In the aforesaid 150 foot commercial stack, the thickness of the outer shell 106 and inner shell 108 of the cap was three-sixteenths inch and the shells were made of COR-TEN steel.

The upper end of the annular space between cap shells 106 and 108 is closed and sealed by a steel ring 116 rigidly secured to the top edges of the outer and inner cap shells 106 and 108 by welding.

The upper end portion of cap 6 has an annular reinforcing, thin, *e.g.* 16 gauge or .0625 inch, stainless steel band 118 therearound, the upper end portion 120 of which is turned inwardly over the ring 116.

The frustoconical cap functions as a venturi to increase the velocity of the hot gases in the inner shell as they exit from the stack. This reduces the tendency of outside air, rain, snow and sleet from entering into the top of the stack.

Rigidly secured within the upper smaller end of cap 6 by welding is a frustoconical shaped, hollow, single-shelled stainless steel insert 122, the upper end of which protrudes above the upper end 120 of the double-shelled cap sufficiently so that eddy currents created by the wind blowing against the thick top end 120 of the cap cannot cause outside air, rain, snow and sleet to enter the top of the cap. In commercial embodiments, the insert 122 protrudes from the top of the cap between 6 and 10 inches although it can protrude more. Without the insert, the aforesaid eddy currents are apt to cause entering of outside air, rain, snow and sleet into the top of the cap in spite of the increased gas velocity achieved by the venturi cap. These eddy currents, as aforesaid, are caused by the wind blowing against the thick upper end of the cap. Since the insert is made up of only one relatively thin shell, *e.g.* 16 gauge, no eddy currents are created by the wind blowing against the upper open end thereof.

The lower end of the insert 122 has an upturned lip 124 to catch any condensation or rain or sleet or snow which might be deposited on the inner surfaces of the insert.

If desired, the upper end portion 126 of the frustoconical insert 122 may be cylindrical in shape as it emerges from the top of the cap. It is noted that the portion of the insert within the cap fits snugly against the inner surface of the inner cap shell.

Since the cap 6 is rigidly secured to the outer shell 16, it moves upwardly and downwardly with the top of the outer shell 16.

The cap 6, rather than being welded to the top of the upper shell, may be removably secured to the top of the stack, as shown in FIG. 11, by replacing ring 92 with a pair of annular rings 92*a* and 92*b*, the former being welded to the upper ends of the outer shell 16 and nesting cup 89 and the latter being welded to the lower ends of the outer and inner shells 106 and 108 of the cap 6, both annular rings extending radially inwardly of the inner shells 18 and 108 and having a plurality of circumferentially spaced, axially aligned holes therein for receiving bolts for removably bolting the cap to the top of the stack. To the extent that the cap is removably bolted to the stack, the inner and outer shells from the bottom of the stack to the top of the cap are not each continuous and integral unitary structures. However, since the height of the cap is usually from 5 to 10 feet with a stack having an overall height of from 99 to 150 feet, *i.e.*, the cap is usually less than 10 percent of the overall height of the stack, the inner and outer shells of the stack may be considered as each being a substantially continuous integral unitary structure.

The bracing structure 60 (see FIGS. 14—16) around the breeching opening 12 comprises, in addition to the two horizontal hollow beams 56 and 58 located in the annular space 20 above and below the opening, a pair of vertical hollow beams 130 and 132 located in the annular space 20 on either side of the opening 12 and extending vertically upwardly above the upper horizontal beam 58 and vertically downwardly below the lower horizontal beam 56, as shown in FIG. 14. The ends of the hollow horizontal beams 56 and 58 are rigidly connected by welding to the vertical hollow beams 130 and 132 to form a rigid unitary bracing structure.

Each of the hollow beams 56 and 58 (FIG. 15) is rectangular in cross section and consists of a pair of oppositely disposed and parallel arcuate (from end-to-end) steel plates 138, one having the same contour as the inner surface of the outer shell and fitting snugly thereagainst and the other having the same contour as the outer surface of the inner shell and fitting snugly thereagainst, and a pair of oppositely disposed, parallel flat, arcuate steel plates 136 extending radially from the inner surface of the outer shell to the outer surface of the inner shell, these plates 136 and 138 being rigidly secured to each other by welding. These hollow beams are also welded to the outer shell at 142 but not to the inner shell, although they may be.

Each of the vertical hollow beams 130 and 132 (FIG. 16) is also rectangular in cross section and is made up of a pair of oppositely disposed and parallel steel plates 144, one of which is contoured to and snugly engages the inner surface of the outer shell and the other of which is contoured to and snugly engages the outer surface of the inner shell, and a pair of oppositely disposed and parallel steel plates 146 extending from the inner surface of the outer shell to the outer surface of the inner shell; these plates being rigidly welded together. The beams 130 and 132 are also welded to the inner surface of the outer shell but not to the outer surface of the inner shell, but they may be.

This bracing structure 60 greatly strengthens the stack around the breeching opening, which is usually weaker than the rest of the stack.

In the stack shown in the drawings, the breeching opening is rectangular and at an incline but it need not be.

Extending from the breeching opening is a double-shelled breeching duct receiving extension 150, the inner shell 152 of which extends through the breeching opening and is welded at its inner end to the edge of the breeching opening in the inner shell at 154. The inner shell also engages the edge of the opening in the outer shell and is welded thereto at 156.

The inner end of the outer shell 157 of the extension 150 is welded to the outer surface of the outer shell 16 of the stack at 158 around but spaced from the breeching opening as shown.

The outer end of the space 160 between the shells 152 and 157 is closed by plates 162.

The breeching duct 164*a* is snugly received within the extension 150.

This bracing structure 60 and extension 150 provides an exceedingly strong breeching opening at low cost.

The square (it need not be square) access door opening 14 (FIGS. 1 and 12 and 13) also has a hollow bracing structure 164 located within the annular space 20 around the opening. Bracing structure 164 is like bracing structure 60 in that it is made up of rigidly connected hollow beams 166 and 168 having a parallelogram cross section and which are contoured to and engage the inner and outer shells to strengthen the structure around the opening. Bracing structure 164 comprises a pair of hollow horizontal beams 166 located above and below the door opening and a pair of hollow vertical beams 168 located on either side of the door opening. Each beam is made of pairs of oppositely disposed parallel steel plates welded together as in the case of bracing structure 60.

The door opening is also provided with an outwardly extending square frame 169, the vertical walls 170 of which are double-shelled with the inner shell 172 extending and welded to the edge of the access door opening of the inner shell 18 of

the stack and being also welded to the edge of the recess door opening in the outer shell, as shown. The inner edge of the outer shell **174** of the frame **169** is welded to the outer surface of the outer shell spaced from the opening in the outer shell. The space between the two walls is closed by the plates **176** welded thereto.

The two horizontal walls **178** of the access door opening are also each double-shelled and each has a wall **180** secured to the outer edges of the double shell by welding.

The annular spacers **38** may be U-shaped in cross section, as shown in FIG. **2A**, in which the spacers are designated **38***a*. One annular leg **40***a* of the U is welded to the outer surface of the inner shell and the other leg **40***b* presents an annular bearing surface **42***a* for the outer shell.

The annular spacers may also be Z-shaped or H-shaped or T-shaped in cross section and in FIG. **2**, the leg **44** can be omitted so that the spacer comprises a flat annular ring, the radially outer annular edge of which comprises a bearing surface. This is the form of the spacer **111** in the cap **6**, shown in FIG. **3**.

Although the stack shown in the drawings is cylindrical in shape, it may be oval or square in cross-sectional shape or may have any other cross-sectional shape.

An alarm system is located in the stack to warn when the hot gases drop below a certain minimum at which condensation might occur. The alarm system comprises conventional type heat responsive sensors **181**, **182** and **184** (FIG. **1**) located at the top, middle and base of the stack, respectively, which are electrically connected in a conventional manner with conventional type warning lights and a warning horn (not shown) which are located in the control room (not shown) of the plant. When the alarm goes on, the operator knows that the temperature at one of the sensors has been reduced below the minimum. He can then turn on the conventional steam coil at the entry of the hot gases into the breeching duct to increase the temperature to the proper temperature. He will also know that when this happens something is wrong with the system which can be taken care of while the steam coils are in operation.

In larger stacks, the annular spacer members **38** may be rigidly secured to the inner surface of the outer shell and slidable axially with respect to the inner shell, in which case it is preferred for the larger annular bearing surface **42** to face the outer surface of the inner shell and the end of the leg **40** to be welded to the inner surface of the outer shell. In such case, the bearing surface of each spacer member is located opposite and straddles a seam **34** of the inner shell and its backup plate **35**.

In the aforesaid 100 foot commercial stack, each of the inner and outer shells were made from twelve tubular sections **32** and **22**, respectively, of MAYARI-R steel, the lower four sections of the outer wall having a wall thickness of one-fourth inch and the remaining sections of the outer wall having a wall thickness of three-sixteenths inch.

In the aforesaid 150 foot stack, the diameter of the stack is 23 feet.

If desired, a thin reflective liner, *e.g.* stainless steel, aluminized steel, aluminum, etc., may be secured to the outer surface of the inner shell **18** or the inner surface of the outer wall **16** to better insulate the inner shell. Also the space **20** may be partially or fully filled with insulation.

It is not intended that the invention be limited to the above description and accompanying drawings but only to the constructions covered by the following claims and their equivalents.

I claim:

1. A double-shelled chimney stack comprising an outer metallic shell and a coaxially disposed inner gas-conveying shell through which gases are adapted to flow, the annular space between said shells providing insulation to reduce condensation within said inner shell, said stack being supported on a base structure secured to and located on the top of a foundation having bolts extending from the top thereof for bolting said base structure to said foundation, said base structure comprising a flat base plate and a parallel vertically spaced ring above said plate, the ring having a central opening therein in which the lower end of said double-shelled stack is received with the lower end of said outer shell supported on and secured to said base plate, said plate and ring having a plurality of circumferentially spaced, vertical gussets secured therebetween, said plate having a plurality of oversized, circumferentially spaced holes located between adjacent gussets for receiving said bolts, a washer welded to said upper ring above each hole therein and fitting snugly around the end of each of said bolts protruding above the ring and a nut threaded over each of said protruding bolt ends above said washer, said outer shell fitting snugly in and secured to said opening in said ring.

2. A double-shelled metal chimney stack comprising an outer metallic shell and a coaxially disposed inner gas-conveying shell through which gases are adapted to flow, the annular space between said shells providing insulation to reduce condensation within said inner shell, each of said inner and outer shells being formed from a plurality of tubular sections which are integrally joined at their ends to form a plurality of axially spaced joints, the wall thicknesses of said sections making up the outer metallic shell decreasing from the lower end to the upper end of said stack, the wall thickness of at least the lower section of said outer shell being substantially thicker than the wall thickness of said inner shell.

3. A double-shelled chimney stack comprising an outer metallic shell and a coaxially disposed inner gas-conveying shell through which gases are adapted to flow, the annular space between said shells providing insulation to reduce condensation within said inner shell, said stack having a breeching opening for receiving a breeching duct, said opening having a hollow brace structure around the periphery thereof and between said inner and outer shells, said brace structure comprising a pair of rigid hollow horizontal beams of parallelogram cross section located above and below said opening and conforming to the contour of said shells and a pair of rigid hollow vertical beams of parallelogram cross section located on either side of said opening and conforming to the contour of said shells, said horizontal and vertical beams being rigidly secured together to form a rigid structure surrounding said opening, said horizontal and vertical beams being rigidly secured to said stack.

4. A stack according to claim **2**, said metallic tubular sections of said outer shell being joined end to end by fusion welds substantially fully penetrating the thickness of said section walls.

5. An insulated chimney stack having, in combination:

a load bearing tubular metal outer shell formed as a fused integral structure continuously over a height measured from a base end to a top end thereof;

means to secure said base end to a foundation;

a substantially nonload bearing, tubular inner shell within and in annularly spaced relation to the outer shell and formed as an integral structure continuously from a lower end thereof adjacent said base end to an upper end thereof open to the atmosphere and adjacent said top end;

supporting means for the inner shell secured to the outer shell and to a region of the inner shell, said region being located a substantial distance longitudinally from said upper end and having a longitudinal extent that is small in relation to said height; and

sealing means for the annular space between said shells and having provision to accommodate differential thermal longitudinal expansions and contractions of said shells at said upper end.

6. A chimney stack according to claim **5**, in which said supporting means is secured to only one said region of the inner shell.

7. A chimney stack according to claim **6**, in which said region is located intermediate the ends of the shells, said sealing

means including provison at both ends of the shells to accommodate differential thermal longitudinal expansions and contractions of the shells.

8. A chimney stack according to claim 7, in which said upper end terminates below said top end and said lower end terminates above said base end to permit both ends of the inner shell to move longitudinally within the ends of the outer shell.

9. A chimney stack according to claim 8, including a ring of compressible heat resistant material below said lower end.

10. A chimney stack according to claim 7, having a breeching located in said region.

11. A chimney stack according to claim 6, in which said lower end is secured with said base end to the foundation.

12. A chimney stack according to claim 5, in which said sealing means include a member extending from one of said shells and having telescopically slidable engagement with the other shell at said upper end.

13. A chimney stack according to claim 5, in which the inner shell is metallic and formed as a fused integral structure continuously from said lower end to said upper end thereof.

14. A chimney stack according to claim 5, including a plurality of spacers each attached to one shell and slidably engaging the other, said spacers being mutually spaced longitudinally between said base and top ends.

15. A chimney stack according to claim 14, said spacers being rings of L-shaped cross section.

16. A chimney stack according to claim 14, said spacers being rings of Z-shaped cross section.

17. A chimney stack according to claim 14, said spacers being rings of U-shaped cross section.

18. A chimney stack according to claim 14, in which the outer shell is formed of a plurality of tubular sections joined end-to-end by fusion welds, and including annular metallic welding backing and bearing rings straddling said welds, said spacers being attached to the inner shell in positions for slidably engaging said rings.

19. A chimney stack according to claim 18, in which the inner shell is formed of a plurality of tubular sections joined end-to-end by fusion welds longitudinally staggered with respect to said welds on the outer shell.

20. A chimney stack according to claim 18, in which each of said sections is formed from plate stock into a tubular shape with the abutting edges integrally joined to form a longitudinally-extending joint, the longitudinally-extending joints of adjacent sections being circumferentially staggered.

21. A chimney stack according to claim 5, in which the outer shell is formed of a plurality of tubular sections joined end-to-end by fusion welds substantially fully penetrating the thickness of the section walls.

22. A chimney stack according to claim 5, said inner shell having a slip joint located at the upper end thereof and formed by terminating the upper end of said inner shell short of the top end of the outer shell and providing a nesting cup for said upper end of said inner shell with one of said cup and said upper end of said inner shell being telescopically and snugly received in the other for sliding movement with respect to each other, said cup being secured to the top portion of said outer shell to move axially therewith and with respect to said inner shell in response to differential thermal axial expansion and contraction of said shells.

23. A stack according to claim 22, said shells being rigidly connected together at a region intermediate their ends, said slip joint compensating for differential thermal expansion of said shells above said rigid connection, the lower end of said inner shell also having a slip joint formed by terminating the lower end of said inner shell short of the base end of said outer shell and providing a lower nesting cup for said lower end of said inner shell with one of said lower nesting cup and said lower end of said inner shell being telescopically and snugly received within the other for sliding movement with respect to each other, said lower nesting cup being rigidly secured to the base portion of said outer shell so that said inner shell can move axially with respect to said lower nesting cup and said outer shell in response to differential thermal axial expansion of said shells below said intermediate rigid connection.

24. A stack according to claim 23, including a ring of compressible, heat resistant material below the lower end of said inner shell.

25. A stack according to claim 24 supported on a metal base plate, said ring of compressible material being between said lower end of said inner shell and said base plate, the lower end of said lower nesting cup and the base end of said outer shell being secured to said base plate.

26. A stack according to claim 23, said stack having a breeching opening, said shells being rigidly connected to each other in the vicinity of said opening, the portion of said inner shell above said rigid connection and below said upper slip joint being free to move upward with respect to the outer shell in response to temperature changes and the portion of said inner shell below said rigid connection and above said lower slip joint being free to move downwardly with respect to said outer shell in response to said temperature changes.

27. A stack according to claim 22, said stack having a plurality of longitudinally-spaced, annular spacer rings within said space and between said shells, each of said spacer rings being secured to one of said shells and having a cylindrical bearing surface for, and axially slidable with respect to, the other shell for said longitudinal sliding movement of said shells with respect to each other.

28. A chimney stack according to claim 5, the upper end of said stack having a tapered cap, which tapers inwardly as it extends upwardly from the upper end of said stack and which comprises an inner tapered cap shell and outer tapered concentric cap shell, whereby the velocity of said gases is increased.

29. A chimney stack according to claim 28, said double-shelled cap having the shape of a truncated cone.

30. A stack according to claim 29, said outer shell of said stack being substantially integral from the base end thereof to the top end thereof from which said cap extends, said inner shell of said stack having a slip joint located at the upper end thereof and formed by terminating the upper end of said inner stack shell short of the top end of said outer stack shell and providing a nesting cup for said upper end of said inner stack shell with one of said nesting cup and the upper end of said inner stack shell being telescopically and snugly received within the other for sliding movement with respect to each other, said nesting cup being affixed to the top portion of said outer stack shell to move therewith and with respect to said inner shell in response to differential thermal axial expansion and contraction of said stack shells.

31. A stack according to claim 29, the upper end of said cap having an annular end wall closing the space between said inner and outer cap shells.

32. A stack according to claim 29, including a thin, tubular single wall insert extending upwardly from within the upper end of said cap beyond the upper end of said cap a sufficient distance to prevent eddy currents created by the wind blowing against the upper end of said double-walled cap from causing outside air to enter the top of said stack, said insert being secured to the top of said cap.

33. A stack according to claim 22, the inner end of said insert within said cap having an inturned and upturned lip forming a trough for collecting any liquid deposited on the inner surface of said insert.

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,537,411 Dated November 3, 1970

Inventor(s) John R. Roy

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

Column 14, line 65, cancel "22" and substitute --32--

SIGNED AND
SEALED
MAR 9 1971

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents