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2,617,255

COMBUSTION CHAMBER FOR A GAS TURBINE

Filed March 3, 1948

3 Sheets-Sheet 1

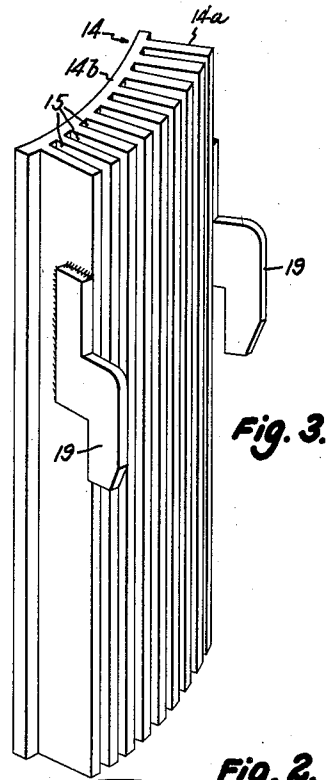
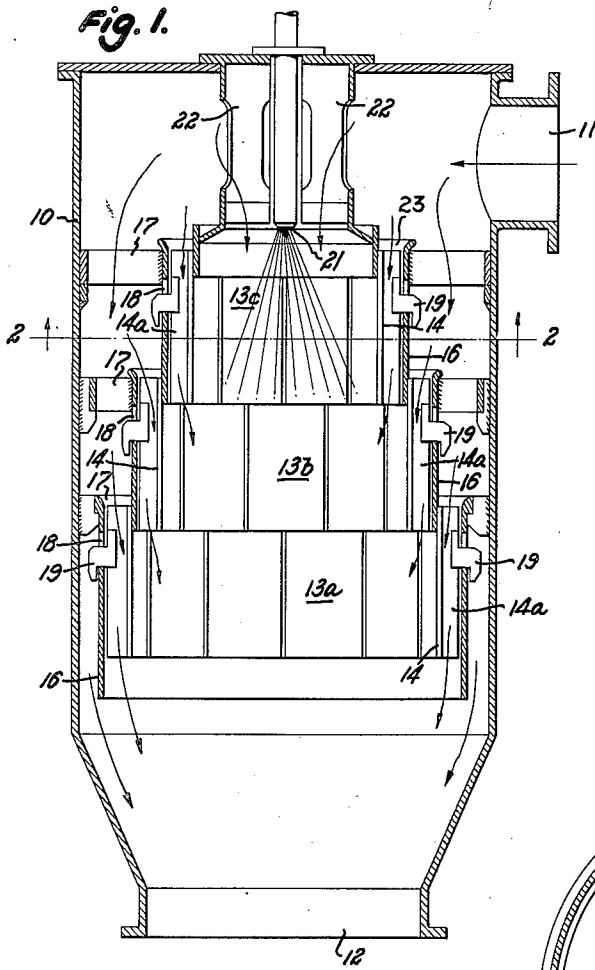


Fig. 3.

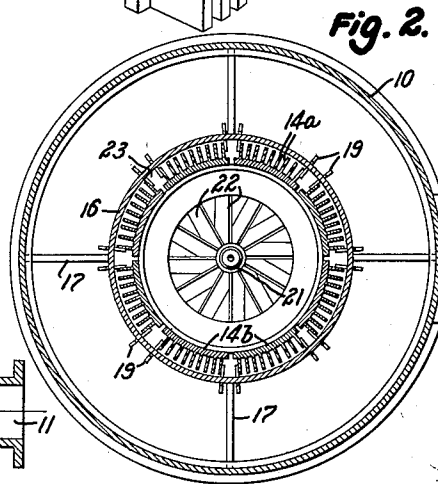


Fig. 2.

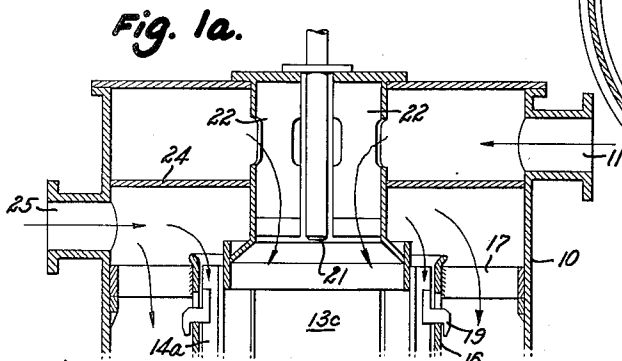


Fig. 1a.

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3 Sheets-Sheet 2

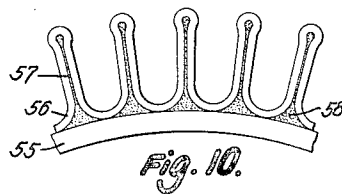
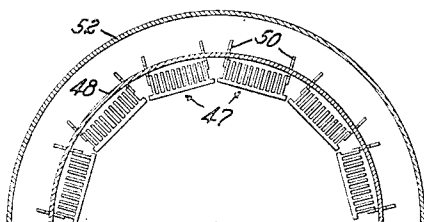
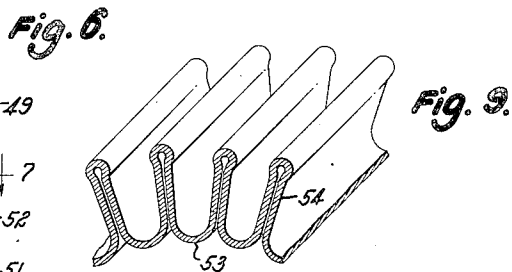
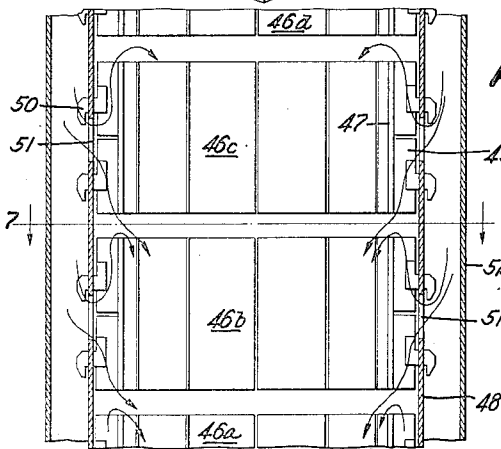
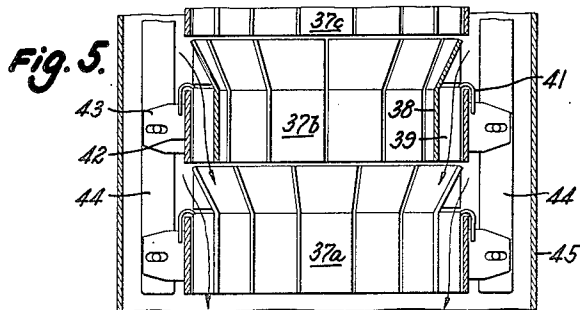
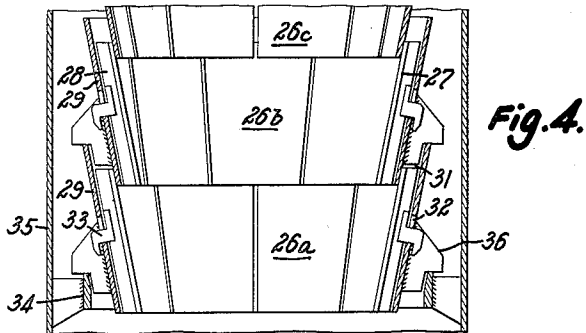
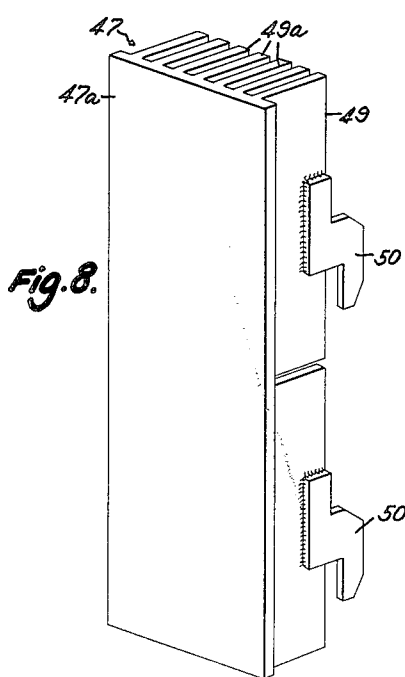


Fig. 7.

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Fig. 12.

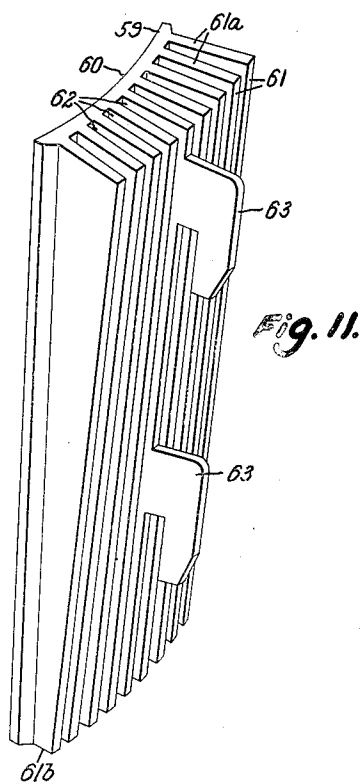
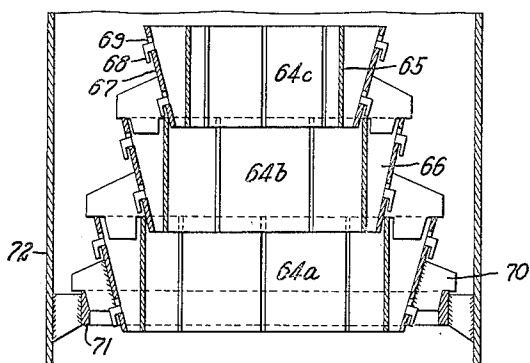


Fig. 11.

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UNITED STATES PATENT OFFICE

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COMBUSTION CHAMBER FOR A GAS TURBINE

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Application March 3, 1948, Serial No. 12,722
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14 Claims. (Cl. 60—39.65)

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This invention relates to combustion chambers and in particular to those designed for use with gas turbine plants for heating the driving gases. These chambers are customarily located between the compressor outlet and the turbine inlet and the driving gases such as compressed air are heated by introducing fuel into the chamber and burning it in the presence of the compressed air. A portion of the latter is used for combustion of the fuel and the remainder used for cooling the chamber and lowering the gas temperature to the maximum value at which it can be admitted to the turbine without running the risk of damaging the turbine blades by overheating.

One of the more serious problems arising in connection with the design of the combustion chamber has been the prevention of overheating the chamber walls. No alloys now available are capable of withstanding the high temperatures prevailing in the chamber without resorting to some type of forced cooling and much has been done towards improving the rate at which the chamber walls are made to give up the enormously high heat to which they are subjected.

One type of construction now in use employs a pair of concentric cylindrical shells spaced radially to provide an annular passageway therebetween. The inner shell serves as the combustion chamber proper and is made from a metal which will best withstand the high combustion temperature. A portion of the driving gas such as compressed air is delivered to the inner shell where it is mixed with the burning fuel to form hot combustion gases, and the remainder is passed through the annular passageway between the shells to take heat from the wall of the inner shell and thereby keep its temperature down. The cooling air is thereafter combined with the gases leaving the combustion chamber and delivered directly to the gas turbine.

Another type of construction utilizes a third cylindrical shell between the double shell structure described above, the added shell being bathed on both sides by cooling air and serving to protect the outermost shell from absorbing any appreciable amount of heat.

With the foregoing two types of construction, it has been found necessary to drive the cooling gases through the annular passageway at high speeds in order to maintain an adequate degree of heat transfer from the outer surface of the combustion chamber wall. While satisfactory cooling is thus effected, it is obtained at the expense of a decrease in the overall efficiency of the gas turbine plant since high gas speeds en-

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tail a correspondingly high energy loss. That is, the higher the gas speed the higher is the power required to circulate it through the system.

In the interest of reducing the energy loss in the gases, it has also been proposed to construct the combustion chamber proper in the form of a plurality of frusto-conical wall sections arranged axially in spaced relation and overlapping so as to provide annular passageways therebetween through which the cooling gases flow to the interior of the chamber. By so dividing up the combustion chamber wall into relatively shorter air flow paths along it, the resistance to flow of the cooling air is correspondingly lowered.

The general object of this invention is to still further improve upon the cooling of a combustion chamber and specifically so by increasing the amount of surface on the cooling side of the combustion chamber wall in heat exchange relation with the cooling gas.

The greatly enlarged surfaces available for the transfer of heat from the combustion chamber wall makes it practical to circulate the cooling gases at a relatively much lower and more economical speed and still assure adequate cooling. Furthermore, the pressure drop of the gases between the inlet and outlet sides of the combustion chamber is kept at a low value by dividing the cooling gases into a plurality of parallel streams, each of which is required to cool only a short section of the combustion chamber wall, the gas streams then being admitted into the combustion chamber where they mix with the products of combustion.

Another object is to provide a combustion chamber made up from a plurality of easily renewable wall sections. The latter are also preferably slightly spaced from each other to allow their free expansion in all directions, and are also supported so that they can be replaced easily and quickly when necessary.

A further object is to provide a combustion chamber made up from a plurality of closely spaced wall sections, all sections being of like size which not only simplifies storage of replacement parts but also lowers the maintenance cost in replacing any burned out wall section since only one size need be kept on hand.

Several different structural embodiments of the invention are possible and a few of these are illustrated in the accompanying drawings. With reference to the latter,

Fig. 1 is a vertical axial section through a construction in which the combustion chamber proper is constituted by a plurality of cylindrical wall

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sections of stepped diameter spaced axially in overlapping relation; and Fig. 2 is a transverse section taken on line 2—2 of Fig. 1.

Fig. 1a is a view similar to Fig. 1 with the top portion of the outer surrounding casing modified to provide a second inlet for gas.

Fig. 3 is a perspective of one of the arcuate plate sections which when assembled form a completely cylindrical wall of the chamber.

Fig. 4 is also a vertical axial section through a slightly different construction in which the several wall sections are frusto-conical shells of like size rather than cylindrical shells of stepped sizes.

Fig. 5 is likewise a vertical axial section through a construction in which the several axially spaced wall sections forming the complete combustion chamber proper are cylindrical shells of uniform diameter with their upper ends flared outwardly.

Fig. 6 is an axial section through still another form of the invention featuring open-ended shells of like size, each of which is constituted by an assembly of flat-sided wall sections that form a combustion chamber of polygonal cross section; Fig. 7 is a half-transverse section taken on line 7—7 of Fig. 6; and Fig. 8 is a perspective of one of the wall sections used in the Fig. 6 construction.

As to the various constructions shown in Figs. 4, 5 and 6, it is to be understood that upper and lower ends of the exterior casing are made in the manner shown in either Figs. 1 or 1a. Complete axial sections through the entire structure were decided against in the interest of eliminating a needless repetitive showing of details already presented.

Figs. 9, 10, 11 and 12 are views of still other constructions for the wall of the combustion chamber within the scope of the present invention.

Referring now to the drawings, and in particular to the construction shown in Figs. 1-3, the combustion chamber in general includes an outer gas-pressure resistant casing 10 having an inlet 11 at the top for gas which, in an application of the combustion chamber to gas turbine plants, would lead to the high pressure outlet of the air compressor unit, not shown. The bottom end 12 of casing 10 is open and, again assuming the same application, would lead to the inlet side of the gas turbine unit, also not shown, that drives the useful load and the compressor unit.

The combustion chamber proper is comprised of an assembly of open-ended cylindrical shells 13a, 13b, 13c of stepped and decreasing diameter mounted one above the other in overlapped relation inside of casing 10. Each shell, as shown by the transverse sectional view Fig. 2, is sectionalized peripherally so as to be constituted by a plurality of arcuate wall sections 14 arranged in side-by-side relation, one of which is shown in perspective in Fig. 3. The side edges of these wall sections extend longitudinally of the axis of the combustion chamber and the confronting side edges of adjacent sections are spaced slightly apart to allow for free expansion in all directions. The exterior surface of each wall section is ribbed in an axial direction at 14a to provide longitudinal grooves or passageways 15 for cooling gas which takes on the heat from the plate portion 14b and thus serves to keep its temperature down to a safe level.

Surrounding closely each of the inner shells 13a-13c is an outer open-ended cylindrical shell

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16 made in one piece. Each of the latter is secured in place by attachment to a spider 17 that is in turn supported at the wall of the outer casing 10. Each of the outer shells supports its associated inner shell and for this purpose has slots 18 for receiving the toe portion of hook type hangers 19 secured to the end ribs 14a of each wall section 14.

As will be seen from Fig. 1, each of the outer shells underlaps and lies in contact with the interior surface of the inner shell next below it. Hence as shown by the arrows, cooling air entering the top of any of the annular ribbed passageways 23 passes out of the lower end of the passageway into the interior of the inner shell next below it along the interior surface of the latter.

Located at the top of the uppermost inner shell 13c is a nozzle 21 by which fuel is admitted into the chamber defined by the three overlapped shells 13a-13c. Air for combustion also enters the topmost shell through a plurality of fixed and curved vanes 22 which give it a swirling motion. The remainder of the air passes downwardly through the outer casing 10 entering the three annular ribbed passageways 23 formed by the three sets of inner and outer shells and subsequently passing into the combustion chamber proper where it combines with the products of combustion. The latter and the air used for cooling then pass out of the bottom opening 12 in casing 10 and enter the gas turbine.

The construction shown in Fig. 1 has many advantages. The axially extending ribs 14a at the exterior surface of the wall sections 14 greatly enlarge the area available for surface contact with the cooling air and thus materially improve the rate at which heat is transferred from the hot interior surface of the overlapped inner shells that are subjected to the extremely high combustion temperatures. This makes it possible to keep the temperature of the inner shells down to a safe level without resorting to high velocities of air flow along the ribs which, for reasons already stated, should be avoided in the interest of high efficiency operation. Furthermore by arranging the combustion chamber proper in sections such that the cooling air is divided into a plurality of parallel streams each of which is used to cool a relatively short axial section of the entire hot chamber wall and thereafter enters the chamber to then mix with the hot combustion gases, the pressure difference required to send the cooling air along the ribbed walls will be approximately the same as the pressure drop in the combustion air as it passes through the vanes 22.

Fabricating each of the inner shells 13a-13c from a plurality of wall sections 14 is also of advantage, for replacement of one or more of the sections in the event of a burn-out is obviously far more economical than would be the case were the entire shell to be renewed. The hook-and-slot type support for the plate sections makes replacement a simple and brief task and, what is equally important, each of the wall sections is able to expand freely in all directions.

The construction shown in Fig. 1a is quite similar to that of Figs. 1-3. The only differences are that the upper end of the outer casing 10 is blocked off by a transverse partition 24 so that all of the air delivered at the inlet 11 passes through the vanes 22 into the upper shell 13c, and a second gas inlet 25 is provided immediately beneath partition 24 that communicates

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with the spaces between the outer casing 10 and the shells 13a-13c and 16. This type of combustion chamber is especially suited for use in the production of heating gas for a steam boiler plant or as a superheater. Air for combustion would be supplied to air inlet 11 from a blower, the air entering through vanes 22 and serving to support combustion of fuel discharged into the combustion chamber shells 13a-13c from nozzle 21. Flue gas would be introduced through inlet 25, the latter passing downwardly along the ribbed plate section 14 for cooling the latter and entering the combustion chamber proper as in the case of the construction shown in Fig. 1.

Fig. 4 illustrates a modified embodiment of a combustion chamber incorporating the invention that permits all of the inner and outer shells to be of the same construction and dimensions. This is an advantage in manufacture since it reduces the number of different parts required. It also simplifies replacement and storage problems in that only one size of outer shell and inner wall section need be stocked. In Fig. 4, each of the inner shells 26a, 26b and 26c is comprised of a frusto-conical assembly of closely spaced wall sections 27 the exterior surfaces of which are ribbed axially at 28 as in Fig. 1. An outer one-piece frusto conical shell 29 closely surrounds each of the inner shells to form an annular gas pasageway 31 that is likewise of frusto cone form. Each of the shells 29 is provided with slotted apertures 32 which receive the support hooks 33 of the associated inner wall sections 27.

A ring 34 welded or otherwise secured in place inside the outer cylindrical casing 35 is provided to support the vertical assembly of inner and outer shells. To this end each of the outer shells 29 is provided with a plurality of circumferentially spaced lugs 36. Lugs 36 for the lowermost outer shell 29 rest upon ring 34 and the lugs of each of the remainder of the outer shells 29 rest upon the upper end face of the shell next below it. As will be seen clearly from the drawings, the support lugs 36 are so placed upon the outer shells 29 that the latter and the inner shells overlap as in the Fig. 1 construction. Also when the combustion chamber is assembled, each of the outer shells lies adjacent the interior surface of the inner shell next below it so that the cooling gas upon leaving one of the annular passageways 31 will move into the combustion chamber along the interior surface of the next inner shell below it in the assembly.

Another constructional form of the invention which affords a near maximum space for combustion inside the casing and also permits the superposed shell assembly to be made from sections of like dimensions is illustrated in Fig. 5. Here each of the inner shells 37a, 37b, 37c, which are positioned one above the other in spaced rather than in telescoping relation, is cylindrical and composed of an assembly of arcuate wall sections 38 having ribs 39 on their exterior surface and hooks 41 for hanging each of the sections in position over the upper end of the closely surrounding outer and one piece cylindrical shell 42. The latter which are all of like diameter are provided with a plurality of radially extending ears 43 for attachment to vertical supports 44 placed within the cylindrical casing 45. In order that the cooling gas may be directed into each of the inner shells after passing along the outer ribbed surface of the inner shell next above it, the top portion of each wall section 38 is turned outwardly so that when assembled to form the in-

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ner shell, the latter will have a flared opening at its upper end positioned immediately below the inner shell right above it in the assembly. Furthermore the internal diameter of the shell at its upper flared end is made substantially the same as the exterior diameter measured at the outer edges of the ribbed exterior surface along the main body portion of the shell so that cooling air flowing along the ribbed passageway of one of the inner shells will pass into the flared opening of the shell next below it and thence into the combustion space.

Still another form of combustion chamber making full use of the interior of the enclosing pressure resistant outer casing, and affording economy of repair by using wall sections of like dimension in the several shells which go to make up the combustion chamber proper in shown in Figs. 6, 7 and 8. Here each of the inner shells 46a-46d is constructed in polygonal form from a group of flat, externally ribbed wall sections 47, there being one plate section to each side of the polygon. The inner shells are all supported in spaced relation one above the other by a closely surrounding one piece outer shell 48 which can be cylindrical, the latter being provided with slots to receive the hangers 50 at each side of each wall section. As will be evident from Figs. 6 and 8, the ribs 49 which make up the outer channeled surface of each inner shell are interrupted at a point substantially midway between the ends and a peripheral opening 51 is provided in the outer shell 48 at each of these levels to allow cooling air to enter from the space between the outer casing 52 and shell 48. As shown by the arrows, the incoming cooling air divides about in half, one half passing upwardly along the ribbed outer surface of the inner shell and thence over the upper edge into the combustion space, and the other half passing downwardly along the ribbed surface of the shell and thence into the inner shell next below. The reason for providing an interruption in the ribbed exterior surface of the inner shell becomes apparent when one considers the fact that the large temperature drop transversely across the ribs results in different expansion characteristics at different points along the ribs as measured in this direction. The very hot plate portion 47a expands much more than does the outer and much cooler edge 49a of the ribs so that the whole ribbed body tends to twist lengthwise. The longer the rib the more the twist; hence by interrupting the ribs at least at one point such as at the middle of the shell, the tendency of the section towards twisting is reduced considerably.

In all of the various forms of combustion chambers that have been described, the ribbed wall sections are illustrated as being formed from a solid body, the ribs themselves being milled out for example. Because of the extremely high temperatures prevailing within the combustion chamber proper, a material having a high degree of resistance to heat is preferred and chromium steel has been found suitable. Instead of machining grooves in solid material to form the ribs and wall portions of each wall section, one can start from a flat plate of chromium steel and by folding it reversely back and forth upon itself as shown in Fig. 9 produce a substantially arcuate or flat wall portion 53 as the case may require, and ribs 54 between which the cooling air will flow.

Another practical construction for the wall sections of each of the inner shells is shown in Fig.

10. Here the wall portion proper is comprised of a relatively thick plate 55 of chromium steel to which is attached on the exterior surface a much thinner steel plate 56 bent back and forth upon itself to form hollow cooling ribs 57. The hollow ribs 57 are then cast full of copper 58 or some other material likewise notable for its high heat conduction characteristic.

Still another construction of a plate section and of an assembly of such plate sections in a combustion chamber is illustrated in Figs. 11 and 12. The plate section 59 with the arcuate plate portion 60 carries ribs 61 on the exterior surface, the inlet end 61a of which is higher than the outlet end 61b. This means that the cross-section of the longitudinal grooves 62 is greater at their inlet end than at their outlet end. The velocity of the cooling air increases as it flows through the grooves and, although its temperature increases also, the rate of heat transfer can be maintained. In this way, and by choosing appropriate groove cross-sections, it is possible to lower the maximum temperature of the plate portion 60 and to obtain an equal temperature over the entire inner plate surface of a section. Fig. 11 further illustrates a construction with hooks 63 located on the middle rib, a feature which facilitates free lateral expansion of the plate sections. The assembly shown in Fig. 12, using plate sections as illustrated by Fig. 11, is substantially the same as in Fig. 4. The plate sections 64a, 64b and 64c, consisting of plates 65 and ribs 66 with decreasing height, are held by frusto-conical rings 67 by means of hooks 68 and slots 69. The lowermost conical ring, by means of lugs 70, rests on a ring 71 attached to the inside of the outer cylindrical casing 72; the upper conical rings rest upon the upper end faces of the rings next below them by means of similar lugs.

In conclusion, it is to be understood that while preferred embodiments of the invention have been described and illustrated various other changes in the construction and arrangement of parts may be made without departing from the spirit and scope of the invention as expressed in the appended claims.

I claim:

1. A combustion chamber comprising inner and outer shell members spaced from each other to provide a passageway therebetween for cooling gases, said inner shell member being sectionalized peripherally into a plurality of wall sections the side edges of which extend longitudinally of the chamber, said wall sections being arranged in side-by-side relation with the side edges of adjacent wall sections spaced from each other, each said wall section being provided with ribs extending longitudinally along the outer surface thereof, hanger means individual to each of said wall sections supporting the latter independently in said spaced relation upon said outer shell member to thereby permit said spaced wall sections to expand independently of the other wall sections adjacent thereto, and means for admitting fuel and a combustion supporting medium into said inner shell member for combustion.

2. A combustion chamber as defined in claim 1 wherein said ribs on each wall section are interrupted at at least one place along their length to reduce longitudinal distortion.

3. A combustion chamber as defined in claim 1 wherein each of the wall sections comprising said inner shell member is made from metallic plate material and said ribs are produced by folding

successive portions of said material back and forth upon itself.

4. A combustion chamber as defined in claim 1 wherein each of the wall sections comprising said inner shell member is comprised of metallic plate material having high heat resistant characteristic and the ribs thereon are constituted by a ribbed shell attached to said plate and filled with material having a high heat conductivity characteristic.

5. A combustion chamber as defined in claim 1 wherein the hanger means individual to each of said wall sections is constituted by a pair of spaced hooks each having a toe extending through and engaging the edge portion of a corresponding slot in the wall of said outer shell member.

6. A combustion chamber as defined in claim 1 wherein the wall sections constituting said inner shell member are arcuate.

7. A combustion chamber as defined in claim 1 wherein the wall sections constituting said inner shell member are flat.

8. A combustion chamber as defined in claim 1 wherein the height of the ribs on said wall sections in a direction transverse to the flow of the cooling gases is greater at the gas inlet end than at the gas outlet end.

9. A combustion chamber comprising a casing, a plurality of open ended inner shells arranged in spaced relation one above the other in said casing, each of said shells being constituted by a peripheral assembly of wall sections the side edges of which extend longitudinally of said casing, said wall sections being arranged in side-by-side relation with the side edges of adjacent wall sections spaced from each other, each said wall section having ribs extending longitudinally along the outer surface thereof, means for introducing fuel and a combustion supporting medium into the space enclosed by said inner shells for combustion, an outer shell closely surrounding each of said inner shells to provide a passageway for leading cooling gases along the surfaces of said ribs, and hanger means individual to each of said wall sections supporting the latter independently in said spaced relation upon the surrounding outer shells to thereby permit the spaced wall sections constituting each inner shell to expand independently of the other wall sections adjacent thereto.

10. A combustion chamber comprising a casing having a top air inlet and a bottom air outlet, a plurality of open-ended inner shells of stepped cross section arranged one above the other in said casing in partly telescoped relation, said shells decreasing in cross-section in the direction of the air inlet to said casing, each of said inner shells being comprised of a peripheral assembly of wall sections the side edges of which extend longitudinally of said casing, said wall sections being arranged in side-by-side relation with the side edges of adjacent wall sections spaced from each other, each said wall section having ribs extending longitudinally along the outer surface thereof, an open-ended outer shell closely surrounding each of said inner shells to form a plurality of stepped gas passageways therebetween each of which receives cooling air at the upper end and discharges the same at the lower end inside the next lower inner shell, hanger means individual to each of said wall sections supporting the latter independently in said spaced relation upon the surrounding outer shells to thereby permit the spaced wall sections constituting each inner shell to expand independently of the other wall sec-

tions adjacent thereto, and means for admitting fuel and air into the space enclosed by said inner shells for combustion.

11. A combustion chamber comprising an outer casing, an inlet for cooling gas at the upper end of said casing, a gas outlet at the lower end of said casing, a plurality of open-ended cylindrical inner shells of stepped diameters assembled one above the other in said casing, said shells decreasing in diameter in the direction of the air inlet to said casing and overlapping one another, each of said inner shells being comprised of a peripheral assembly of wall sections the side edges of which extend longitudinally of said casing, said wall sections being arranged in side-by-side relation with the side edges of adjacent wall sections spaced from one another, each said wall section having ribs extending longitudinally along the outer surface thereof, an open-ended outer shell closely surrounding each of said inner shells and which extends into the inner shell next below adjacent its interior surface to establish an annular passageway between each inner and outer shell for downward flow of cooling gas in said casing along the ribbed surface of one inner shell into the inner shell next below, hanger means individual to each of said wall sections supporting the latter independently in said spaced relation upon the surrounding outer shells to thereby permit the spaced wall sections constituting each inner shell to expand independently of the other wall sections adjacent thereto, and means for introducing fuel and a combustion supporting medium into the space enclosed by said assembly of inner shells for combustion.

12. A combustion chamber comprising a casing, an inlet for gas at the upper end of said casing, a plurality of like open-ended inner shells arranged one above the other in said casing in partly telescoped relation and tapered outwardly in the direction of said gas inlet, each of said inner shells being comprised of a peripheral assembly of wall sections the side edges of which extend longitudinally of said casing, said wall sections being arranged in side-by-side relation with the side edges of adjacent wall sections spaced from each other, each said wall section having ribs extending longitudinally along the outer surface thereof, an open-ended outer shell closely surrounding each of said inner shells to form gas passageways therebetween, each said passageway receiving cooling gas at the upper end and discharging the same at the lower end inside of the next lower inner shell, hanger means individual to each of said wall sections supporting the latter independently in said spaced relation upon the surrounding outer shells to thereby permit the spaced wall sections constituting each inner shell to expand independently of the other wall sections adjacent thereto, and means for admitting fuel and a combustion supporting medium into the chamber defined by said inner shells for combustion.

13. A combustion chamber comprising a casing, a plurality of open-ended inner shells uniform in cross-sectional area arranged in spaced relation one above the other in said casing, each of said inner shells being comprised of a peripheral assembly of wall sections the side edges of which extend longitudinally of said casing, said wall

sections being arranged in side-by-side relation with the side edges of adjacent wall sections spaced from each other, each said wall section having ribs extending longitudinally along the outer surface thereof, an outer shell spaced inwardly from said casing and closely surrounding said inner shells to provide a passageway for cooling gas admitted to said casing, said outer shell being provided with a peripheral opening adjacent the middle of each inner shell for admitting cooling gas part of which flows upwards and part downwards along the ribbed surface into the interior of said inner shells through the spaces therebetween, hanger means individual to each of said wall sections supporting the latter in spaced relation upon the surrounding outer shell to thereby permit the spaced wall sections constituting each inner shell to expand independently of the other wall sections adjacent thereto, and means for admitting fuel and a combustion supporting medium into the chamber defined by said inner shells for combustion.

14. A combustion chamber comprising an outer casing having an inlet for cooling gas at the upper end and a gas outlet at the lower end, a plurality of open-ended inner shells arranged in spaced relation one above the other in said casing, each of said inner shells being comprised of a peripheral assembly of wall sections the side edges of which extend longitudinally of said casing, said wall sections being arranged in side-by-side relation with the side edges of adjacent wall sections spaced from each other, each said wall section having ribs extending longitudinally along the outer surface thereof and the upper portion of each said wall section being flared outwardly in the direction of said gas inlet to provide a mouth portion for receiving cooling gas flowing between the ribs of the shell next above, an open-ended outer shell closely surrounding each of said inner shell, hanger means individual to each of said wall sections supporting the latter independently in said spaced relation upon the surrounding outer shells, hanger means individual to each of said constituting each inner shell to expand independently of the other wall sections adjacent thereto, and means for admitting fuel and a combustion supporting medium into the space defined by said inner shells for combustion.

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