June 5, 1951 W. GARBER 2,555,965

END CAP FOR FLUID FUEL COMBUSTORS

Filed March 24, 1950

Fig. 1.

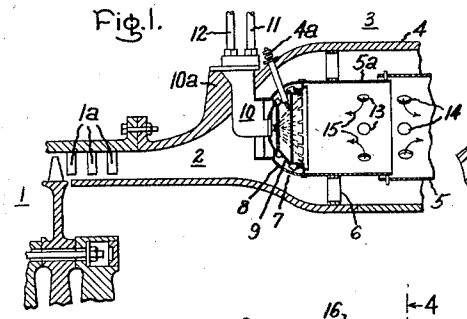


Fig. 4.

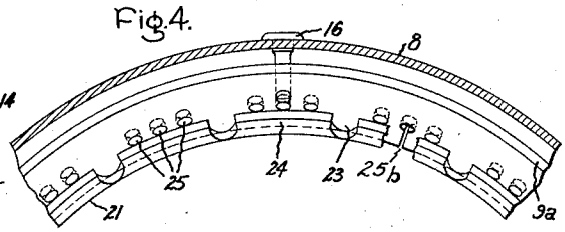


Fig. 2.

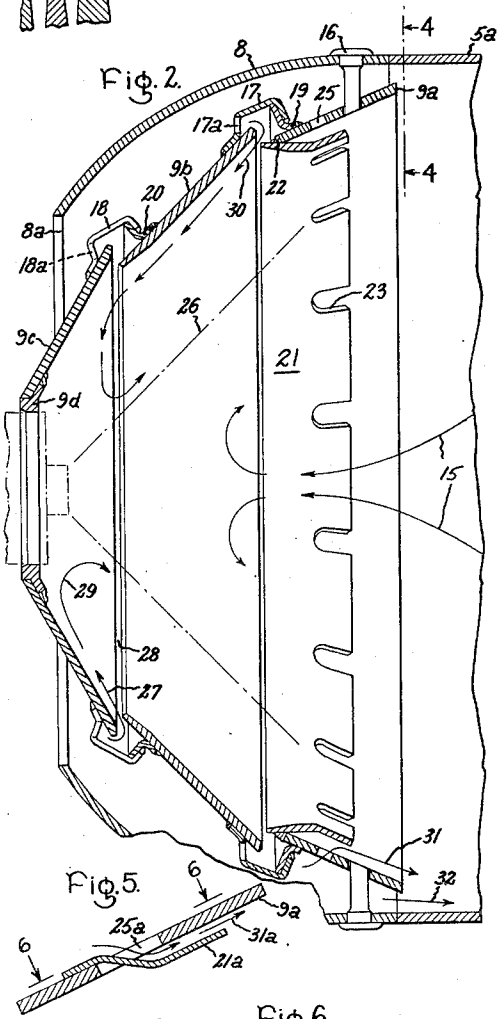


Fig. 3.

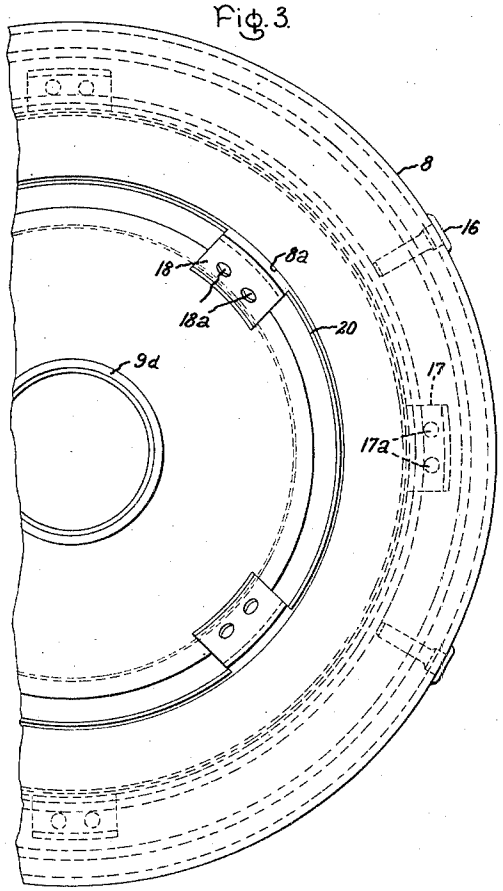
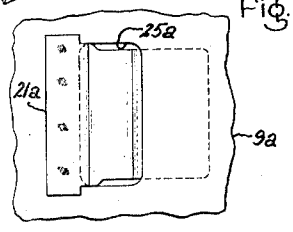


Fig. 5.

Fig. 6.



Inventor:
William Garber,
by Ernest C. Britton
His Attorney.

Patented June 5, 1951

2,555,965

UNITED STATES PATENT OFFICE

2,555,965

END CAP FOR FLUID FUEL COMBUSTORS

William Garber, Schenectady, N. Y., assignor to General Electric Company, a corporation of New York

Application March 24, 1950, Serial No. 151,651

8 Claims. (Cl. 60—44)

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This invention relates to combustor structure for burning liquid or gaseous fuels, particularly to the mechanical details of the "end cap" or dome which forms the end closure for the liner defining the combustion space.

In the high performance combustion chambers or "combustors" developed in recent years for the efficient production of hot motive gases as required in gas turbine powerplants, experience has indicated that the thin sheet metal walls defining the actual combustion space are the components requiring most frequent inspection, servicing and replacement. The primary requirement for such a device is of course that the flow of the combustion-supporting air into the combustion space be precisely as required in order to effectively promote the combustion process. Once the cylindrical liner forming the side walls of the combustion space, and the end dome or cap forming the closed end of the space, are designed for producing proper combustion characteristics, then the most important considerations are appropriate mechanical design to permit the differential thermal expansions which occur during operation without creating excessive local stresses tending to cause failures in the metal, effective and uniform cooling to prevent "hot spots" and the resulting thermal stresses, and provision for a cooling and insulating film of pure air on the inner surfaces of the liner and end cap to prevent the deposition of carbonized fuel particles.

Producing an integrated design which effectively takes into account these various and sometimes conflicting requirements is often extremely difficult. The purpose of the present invention is to provide an improved combustor end cap, which has been found to possess outstanding characteristics from the standpoint of long life and trouble-free operation.

This combustor end cap is intended specifically for use in the so-called "Nerad type" combustor, as described in application Serial No. 750,015, filed May 23, 1947, in the name of Anthony J. Nerad and assigned to the same assignee as the present application. More specifically, this end cap is a further improvement of that disclosed in the co-pending application of Walter L. Blatz, Serial No. 644,888, filed February 1, 1946, also assigned to the same assignee.

More specific objects and advantages will be apparent from the following description taken in connection with the accompanying drawings, in which Fig. 1 is a diagrammatic representation of a portion of a gas turbine powerplant showing

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the relation of the combustor end cap to other components; Fig. 2 is a sectional detail view of the end cap by itself; Fig. 3 is a rear view of the end cap; Fig. 4 is a front view of a portion of the cap taken on the plane 4—4 in Fig. 2; Fig. 5 is a sectional detail view of an alternate form of the outer circumferential segment; and Fig. 6 is a view taken in the direction 6—6 in Fig. 5.

This novel end cap consists generally of a plurality of annular segments held together by special supporting means in a particular relation one to another so as to define continuous annular orifices for directing an insulating and cooling film of combustion supporting air over the inner surfaces of the respective segments. Special cooling arrangements are provided for the circumferential portion of the cap, which is ordinarily most subject to overheating.

Referring now more particularly to Fig. 1, this end cap is shown mounted in the combustion system of a gas turbine powerplant, in which a compressor of any suitable type, indicated generally at 1, supplies air at a suitable pressure, for instance 75 lbs. per sq. in. gage, through a diffusing and transition passage 2 to the combustor indicated generally at 3. The combustor includes an outer housing 4 surrounding and spaced from an inner liner assembly 5, which latter defines the combustion space proper. The liner may be supported from the outer housing by any suitable means, for instance suitable resilient loops or brackets 6. The end cap assembly is indicated generally at 7 as comprising an outer cowl portion 8 surrounding and spaced from the inner segmental cap structure 9.

For introducing liquid fuel in a finely atomized spray into the end cap, a nozzle 10 is provided. This may be of any suitable type, but is preferably as shown in the co-pending application of B. O. Buckland and D. C. Berkey, Serial No. 62,634, filed November 30, 1948, and assigned to the same assignee as the present application. Of course, when using gaseous fuels, other types of known nozzles might be used. As will be apparent from Fig. 1, this nozzle is secured to a mounting boss 10*a* formed integral with the outer housing wall 4, and is adapted to project a conical spray of atomized fuel particles into the end dome. For igniting the resulting fuel-air mixture, an electric spark-plug 4*a* or the equivalent is secured to the outer housing wall and projects through the cowl 8 and the middle segment of the end cap 9 so the electrodes define a spark gap located approximately in the fuel spray pattern. Obviously, the igniter may be lo-

cated otherwise, and ignition devices of other types may be employed. An appropriate fuel is supplied to the nozzle 10 through a conduit 11. If the nozzle 10 is of the so-called "air-atomizing type," disclosed in the above-mentioned Buckland and Berkey application, atomizing air at a suitable pressure is supplied through conduit 12.

The exact details of the compressor, combustor liner, fuel nozzle and other components shown in Fig. 1 are not essential to an understanding of the present invention; however it may be noted that an important characteristic of the Nerad type of combustor is that the combustion supporting fluid is injected through circumferential rows of openings 13, 14 with such pressure and velocity as to form strong discrete jets which persist all the way to the axis of the liner 5, diametrically opposed jets meeting at the axis of the liner to produce a resultant velocity back towards the end cap 8, this reverse circulation being represented by the air-flow arrows 15.

The end cap 9, to which this invention particularly relates, is shown only diagrammatically in Fig. 1; the details being shown more clearly in Figs. 2–4.

Fig. 2 illustrates a longitudinal sectional view through the axis of the end cap and cowl. The cowl 8 is a generally hemispherical shell stamped, spun, or otherwise formed of comparatively thin sheet metal, perhaps on the order of $\frac{3}{32}$ inch thick. At the left-hand or rearward end, cowl 8 defines a central opening 8*a* which cooperates with the cap structure proper to form an annular air inlet orifice, as described more particularly hereinafter. At its forward outer circumferential portion, cowl 8 may be welded or otherwise secured to the adjacent section of the liner wall 5*a*. The liner 5 and outer housing 4 may be arranged in accordance with the co-pending application of B. O. Buckland, Serial No. 62,333, filed November 27, 1948, now Patent No. 2,547,619, granted April 3, 1951 and assigned to the same assignee as the present application.

The segmented end cap 9 is supported coaxially within the cowl 8 by a plurality of circumferentially spaced radial pins 16, which may be pressed, tack-welded, or otherwise secured in holes in the rim portion of the cowl 8, and project freely through holes in the outer segment 9*a* of the end cap.

The three segments 9*a*, 9*b*, 9*c* of which the end cap is composed are each in the form of a frustum of right circular cones of different altitudes. Together, the three segments define a substantially hemispherical primary combustion and mixing space. In accordance with the present invention, these segments are secured together by a plurality of circumferentially spaced, bent sheet metal clips shown at 17, 18 in Fig. 2, the plan view of these clips being indicated in Fig. 3. At the upstream side, each clip is provided with a plurality of cooling air inlet holes 17*a*, 18*a*, the function of which will be described more particularly hereinafter. The left-hand or upstream ends of these clips may be spot-welded or otherwise secured directly to the next adjacent segment, while the downstream sides are secured to ring members 19, 20, which rings extend entirely around the respective segments 9*a*, 9*b*, and serve as dams or deflectors for directing the flow of cooling air, as described more particularly hereinafter. The central portion of the inner segment 9*c* defines a central opening with a bushing portion 9*d* adapted to slip freely over the cylindrical end portion of the fuel nozzle 10.

Because the outer circumferential segment 9*a* corresponds to the portion of the cap previously found most subject to thermal stresses, "hot spots," and short life due to "burn-out," special mechanical and aerodynamic means are provided for shielding and cooling this segment. This comprises a separate "louver ring" 21 welded at 22 to the rearward edge of outer segment 9*a*. The forward half of louver ring 21 is provided with a plurality of circumferentially spaced slots or cut-outs 23, the portions between which define tongues 24 which are bent outwardly so as to lie generally parallel with the surface of segment 9*a*. The ring 9*a* is provided with circumferentially spaced sets of orifices or nozzles 25 cooperating with the respective tongues 24. As may be seen better in Fig. 4, there are three of these nozzles 25 associated with each of the tongues 24.

The flow of air through and around the various parts of the combined cowl and end cap assembly is as follows. In the first place, it should be noted that the fuel spray pattern is in the form of a hollow right circular cone coaxial with the end cap, as indicated by the dotted lines 26 in Fig. 2. As shown, the nozzle is selected so as to have an "intrinsic spray angle" not greater than 90°, which means that the fuel spray misses the louver ring 21 by a safe margin. In actual operation, this spray angle will vary somewhat because of changes in the effects of various rates of air flow on the spray 26. Specifically, the reverse air flow indicated by the arrows 15 in Figs. 1 and 2 has a tendency to flatten out the spray cone so that the spray 26 would tend to approach the louver ring more closely. Naturally this tendency increases as the strength of the reverse air flow 15 increases. On the other hand, the specially arranged air inlet openings in the end cap provide another reverse flow on the outside of the spray pattern which has a tendency to cause the spray angle to collapse, as described hereinafter. Thus two reverse flows of combustion air formed on opposite sides of the spray cone 26 have opposing tendencies, so that the spray pattern is ordinarily kept from contacting directly the louver ring 21.

The flow of combustion supporting air through the end cap louvers and nozzles is as follows. Air from the compressor 1 approaches the end cap assembly at a high velocity and in as nearly an axial direction, and with as great uniformity, as can be provided by the guide vanes 1*a* in the diffusing and transition passage 2 (Fig. 1).

The desirable condition is that air shall enter the annular opening 8*a* into the cowl 8 in as nearly an axial direction as possible and with as perfect uniformity as can be obtained circumferentially around the cowl. This air entering the cowl almost immediately encounters the annular dam ring 20 projecting from the surface of middle segment 9*b*; and this dam has the effect of deflecting a portion of the air through almost a 180° angle, as indicated by the flow arrow 27 in Fig. 2. It will now be noted that the outer circumference of the innermost segment 9*c* is somewhat greater in diameter than the left-hand edge of the middle segment 9*b*, and that the clips 18 support these two edges in spaced relation so as to define an annular air inlet orifice 28. The left-hand edge of the middle segment 9*b* cooperates with the dam ring 20 to form a curved annular deflector for this sheet of air 27. As described more fully in the above-identified Blatz application, this air 27 forms a thin film flowing

along the inner surface of segment 9c so as to cool it and insulate it from contact with partly burned fuel particles. The design of the parts and the supply of air to the cowl are such that this inwardly sweeping film of air 27 flows across the exposed end portion of the fuel nozzle and then is directed into contact with the outer surface of the fuel spray cone, as indicated by the flow arrow 29. In cooling the segment 9c, and by reason of radiation from the flame in the combustion space, this air 27, 29 becomes appreciably preheated by the time it reaches the fuel spray pattern, so that it readily vaporizes the fuel particles as it mixes with them. As described in the above-identified Blatz application, this has a very beneficial effect on the combustion characteristics of the apparatus.

It will be obvious from Fig. 2 that the outer circumferential edge of segment 9b is likewise spaced radially from the adjacent left-hand edge of segment 9a so that, in cooperation with the dam ring 19 an annular orifice is provided for creating a reverse flow of air indicated by arrow 30. This sweeps across the inner surface of segment 9b to cool it and prevent carbon deposition thereon.

The purpose of the small ports 17a, 18a in the clips 17, 18 is to reduce or prevent any discontinuity in the annular jets of air 27, 30 which might otherwise be introduced by the presence of the supporting clips.

The sets of nozzles 25 formed in the outer segment 9a serve to cool the tongue portions 24 of louver ring 21, also providing an annular film of cooling and insulating air along the inner surface of ring 9a, as indicated by arrow 31 in Fig. 2.

Attention is directed to the fact that several provisions are made in this design for permitting differential thermal expansion between the respective parts of the assembly without setting up dangerous thermal stresses. First, the basic idea of dividing the generally hemispherical end cap into three separate segments separated by somewhat resilient clips permits the outer and middle segments 9a, 9b to expand and contract differentially with respect to each other and relative to the much cooler central segment 9c. Furthermore, the cut-outs 23 permit the right-hand half of louver ring 21, which is the part most subject to contact with burning gases, to expand and contract relative to the left-hand half of ring 21, which is rigidly welded to the ring 9a, without setting up differential expansion forces tending to break the weld or deform the ring. To facilitate free differential expansion of the left-hand portion of ring 21, the outer ring 9a may be slit from the weld 22 into the central hole of each group of holes 25. One such slit is shown at 25b in Fig. 4. It will be understood that such a slit may be made at each group of holes 25. This permits expansion of ring 21 without overstressing the weld 22. Also, the louver ring 21 constitutes a radiation shield between the flame in the combustor and a substantial portion of the outer segment 9a, serving also to protect ring 9a from impingement of fuel particles and forming the insulating air film 31 to further protect ring 9a. Thus the most vulnerable portion of the end cap structure receives protection in a number of ways. As noted previously, the radial supporting pins 16 permit the segment 9a to freely expand and contract relative to the supporting cowl 8.

A few additional points pertaining to the relation between cowl 8 and the end cap structure 9 may be noted. The central opening 8a in the cowl is made of such a size as to provide an annular entrance passage which will admit only that quantity of air required to form efficient jets for forming the flow pattern described above. As will be appreciated by those skilled in the art, too small a flow of air into the cowl will result in failure to produce jets strong enough to produce the air flow patterns described; whereas too much air may produce an excessive cooling effect in the primary mixing and combustion space within the end cap, or fuel-air mixtures too lean for good combustion characteristics. Thus the designer must proportion the size of the air entrance into cowl 8 so as to provide just the right flow of air, taking into consideration the number and size of the various orifices and nozzles in the end cap. Furthermore, once the air enters the space between cowl and end cap segments, the effective cross-section area of this passage should be designed so that the velocity of the air over the outer surfaces of the segments 9b, 9a is adequate to provide effective cooling thereof. Lastly it may be noted that a certain portion of the air entering the cowl is directed through the annular orifice defined between the right-hand outer circumferential edge of segment 9a and the adjacent inner surface of liner 5a, to form a layer of cooling and insulating air indicated by flow arrow 32.

This novel end cap structure has been found to produce outstanding improvements in the cooling of the parts of the assembly, particularly around the outer circumference represented by the segment 9a. Furthermore, it has been found possible to introduce the same, or a greater amount of cooling air, as compared with prior art end domes of the general type described in the Blatz application, without adversely affecting the desired air flow pattern within the end cap. Thus better cooling of the end cap parts has been procured, with equally good or even improved combustion characteristics. Also, the continuous annular slots forming the jets 27, 30 provide a stronger reverse flow inwardly towards the fuel nozzle which, as will be suggested by the arrow 29 in Fig. 2, tends to collapse the fuel cone so as to prevent contact of fuel particles with the cap parts. Thus the main reverse air flow circulation indicated by arrows 15 can be made stronger, in order to obtain good combustion characteristics, without causing the fuel spray pattern 26 to flatten out so that the flame directly impinges on the outer cap segment 9a.

A dramatic indication of the extent of the overall improvement effected by the invention may be seen from the fact that, whereas previous designs had a life of less than 100 hours without servicing or replacement, combustor end caps in accordance with the present invention have operated in gas turbine powerplants for as long as 500 hours without difficulty.

It will, of course, be appreciated by those skilled in the art that many changes in mechanical design might be made. For instance, the form of the louver ring 21 shown in Fig. 2 may be altered. Another arrangement is illustrated in Figs. 5 and 6. Here instead of a continuous annular louver ring, substantially the same functions are performed by a plurality of circumferentially spaced cut-outs 25a in the outer segment 9a. Each of these cut-outs takes the place of one set of three orifices 25 (Fig. 4). Instead of a single louver ring 21, a plurality of separate deflector plates 21a are provided, one deflector being associated with each cut-out 25a. As will

be seen in Fig. 5, each deflector 21*a* is of Z-shaped cross-section with an outer portion spot-welded or otherwise secured to the outer surface of segment 9*a*, while the other end portion is flat and spaced parallel with the inner surface of segment 9*a*. Thus air flowing through the cut-out 25*a* is caused to flow in a thin film over the inner surface of segment 9*a*, this flow 31*a* obviously corresponding to the flow 31 in Fig. 2. Air deflectors of this general type have previously been disclosed in the above-mentioned Patent No. 2,547,619 to B. O. Buckland, also in an application filed in the name of Lowell J. Pierce, Serial No. 3,760, filed January 22, 1948, and assigned to the same assignee as the present application.

Still other modifications will be obvious to those skilled in the art, and it is, of course, desired to cover by the appended claims all such changes as fall within the true spirit and scope of the invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A substantially hemispherical end cap for a combustion chamber comprising three coaxial annular segments, each being a frustum of a right circular cone, the inner segment having a central opening adapted to receive the discharge end of fuel injection nozzle means, the intermediate segment having a minor edge diameter slightly smaller than the major diameter of the inner segment, a plurality of circumferentially spaced bracket means secured to the adjacent edge portions of the inner and intermediate segments respectively and adapted to support said edges in adjacent radially spaced relation to define a narrow annular orifice adapted to direct a thin film of cooling and insulating fluid along the inner surface of the inner segment inwardly toward the fuel nozzle opening, the outer segment having a minor diameter edge portion smaller than the outer diameter of the intermediate segment, a plurality of circumferentially spaced bracket means secured to the adjacent edge portions of the intermediate and outer segment and adapted to support said edges in adjacent radially spaced relation to define a second narrow annular orifice for directing a thin film of cooling and insulating fluid along the inner surface of the intermediate segment, the outer segment defining a plurality of circumferentially spaced nozzle openings, fluid deflector means secured to the outer segment and having portions cooperating with said nozzle openings for directing a thin film of cooling and insulating fluid radially outward along the inner surface of the outer segment, the resiliency of the respective connecting brackets permitting free differential thermal expansion between the respective segments.

2. A substantially hemispherical end cap for a combustion chamber comprising at least two coaxial annular segments, each being a frustum of a right circular cone, the inner segment having a central opening adapted to receive the discharge end of a fuel injection nozzle, the next adjacent segment having a minor edge diameter slightly smaller than the outer diameter of the inner segment, a plurality of circumferentially spaced bracket means secured to adjacent portions of the respective segments and supporting the adjacent edges thereof in radially spaced relation to define a narrow annular orifice adapted to direct a thin film of cooling and insulating fluid along the inner surface of the inner segment inwardly towards the fuel nozzle, the resiliency of the respective connecting brackets permitting free differential thermal expansion between the segments.

3. A substantially hemispherical end cap for a combustion chamber comprising at least two coaxial annular segments, each being a frustum of a right circular cone, the inner segment having a central opening adapted to receive the discharge end of a fuel injection nozzle, the next adjacent segment having a minor edge diameter slightly smaller than the outer diameter of the inner segment, a plurality of circumferentially spaced bracket means secured to adjacent portions of the segments respectively and supporting the adjacent edges thereof in radially spaced relation to define a narrow annular orifice adapted to direct a thin film of cooling and insulating fluid along the inner surface of the inner segment inwardly towards the fuel nozzle opening, whereby the resiliency of the connecting brackets permits free differential thermal expansion between the segments, the outer segment defining a plurality of circumferentially spaced nozzle openings and fluid deflector means secured to the outer segment and having portions cooperating with said nozzle openings for directing a thin film of cooling and insulating fluid radially outward along the inner surface of the outer segment.

4. A substantially hemispherical end cap for a combustion chamber comprising at least two coaxial annular segments, each being a frustum of a right circular cone, the inner segment forming a central opening adapted to receive the discharge end of a fuel injection nozzle, the next adjacent segment having a minor edge diameter slightly smaller than the outer diameter of the inner segment, a plurality of circumferentially spaced bracket means secured to adjacent portions of the respective segments and adapted to support the adjacent edges thereof in radially spaced relation to define a narrow annular orifice, an annular dam member secured to the outer surface of the second segment in spaced relation with the outer annular edge of the inner segment, said dam extending substantially normal to the surface of the second segment and adapted to deflect fluid flowing over the outer surface of the end cap through the annular orifice defined between the adjacent edge portions of said inner and second segments to form a thin film of cooling and insulating fluid flowing along the inner surface of the inner segment radially inwardly toward the fuel nozzle opening.

5. An end cap for a combustion chamber in accordance with claim 4 in which said spaced bracket means form at least one fluid inlet port at the upstream side of the bracket relative to the fluid flow over the exterior of the end cap, the flow of fluid through said port preventing any substantial discontinuity in the annular film of fluid flowing through the inwardly directed annular orifice defined by adjacent edge portions of the segments.

6. A substantially hemispherical end cap for a combustion chamber comprising three coaxial annular segments, each being a frustum of a right circular cone, the inner segment forming a central opening adapted to receive the discharge end of a fuel injection nozzle, the intermediate segment having a minor edge diameter slightly smaller than the outer diameter of the inner segment, a plurality of circumferentially spaced bracket means secured to adjacent edge portions of the inner and intermediate segments respectively and adapted to support said edges in adja-

cent spaced relation to define a narrow annular orifice for directing a thin film of cooling and insulating fluid along the inner surface of the inner segment inwardly toward the fuel nozzle opening, the outer segment likewise having a minor diameter edge portion smaller than the outer diameter of the intermediate segment with a plurality of circumferentially spaced bracket means secured to adjacent edge portions and adapted to support said edges in adjacent radially spaced relation to define a second narrow annular orifice for directing a thin film of cooling and insulating fluid along the inner surface of the intermediate segment, annular dam means secured to the outer surfaces of the intermediate and outer segments respectively, each of said dam rings extending substantially normal to the outer surface of the segment to which it is secured and spaced from the edge of the next adjacent smaller segment to direct fluid flowing over the outer surface of the cap into the respective annular orifices, the outer segment having a plurality of circumferentially spaced nozzle openings, and a louver ring disposed concentrically within the outer segment and having a rearward edge portion secured to a minor diameter edge portion of the outer segment, the forward edge portion of the louver ring being flared outwardly so as to lie substantially parallel with the inner surface of the outer segment and in spaced relation with said nozzle openings in the outer segment, the forward annular edge of said louver ring defining

a substantially annular orifice for directing a thin film of cooling and insulating fluid from said nozzle openings radially outward along the inner surface of the outer segment, said louver ring and the annular film of fluid formed by it serving to protect the outer segment from radiant heat and direct contact with burning fuel particles.

7. A combustor end cap in accordance with claim 6, in which the louver ring defines a plurality of cut-outs circumferentially spaced around the forward edge thereof, whereby said forward edge portion may freely expand relative to the rearward edge portion of the louver ring.

8. A combustor end cap in accordance with claim 6, in which the outer segment is secured to the rearward edge of the louver ring by an annular weld, and the outer segment defines a plurality of circumferentially spaced slits extending from the weld substantially to the nozzle openings in said segment, whereby the rearward portions of the louver ring and segment may expand freely without overstressing said weld.

WILLIAM GARBER

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