July 30, 1963 P. H. CALDER ETAL 3,099,134

COMBUSTION CHAMBERS

Filed Dec. 27, 1960 2 Sheets-Sheet 1

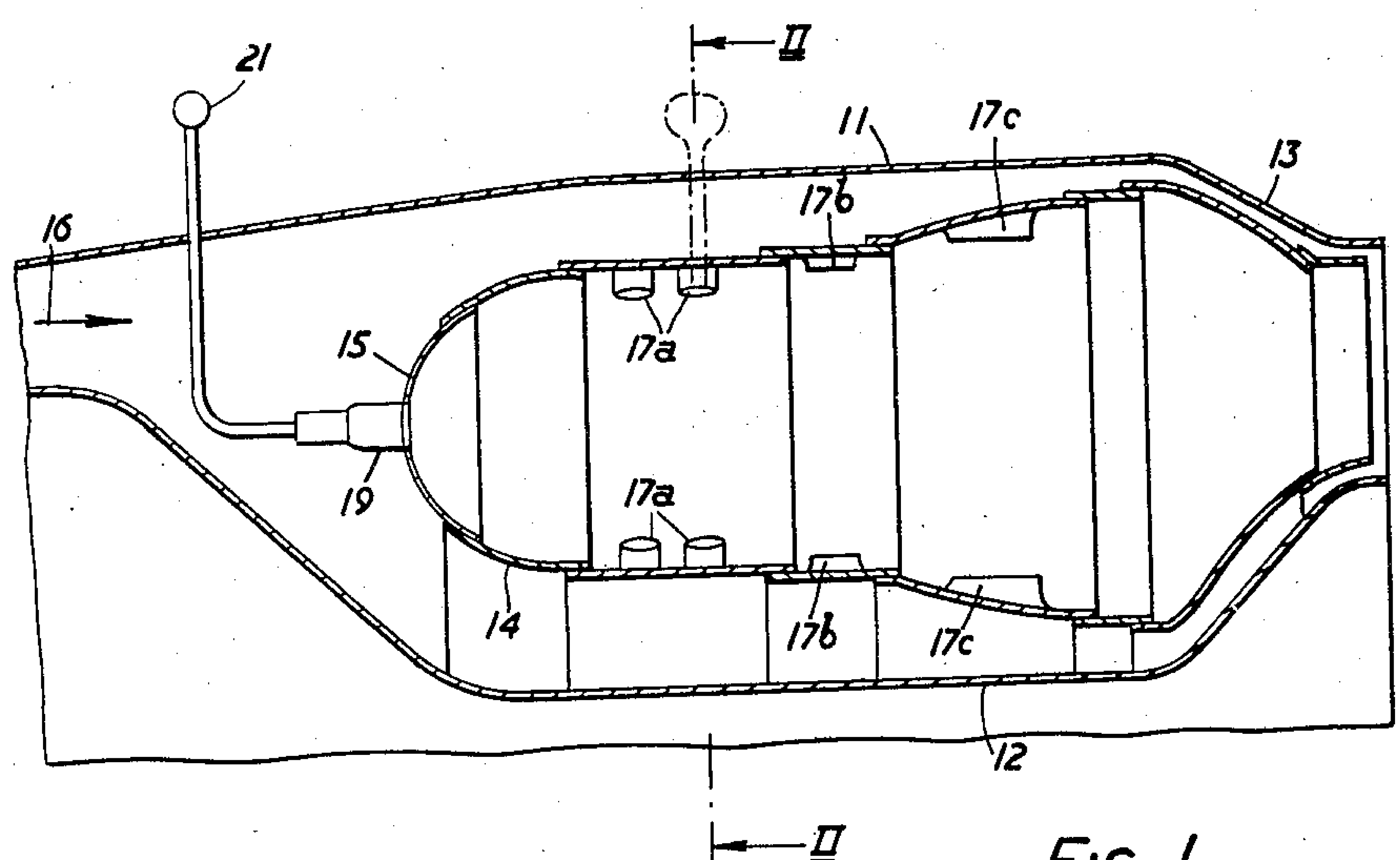


FIG. 1.

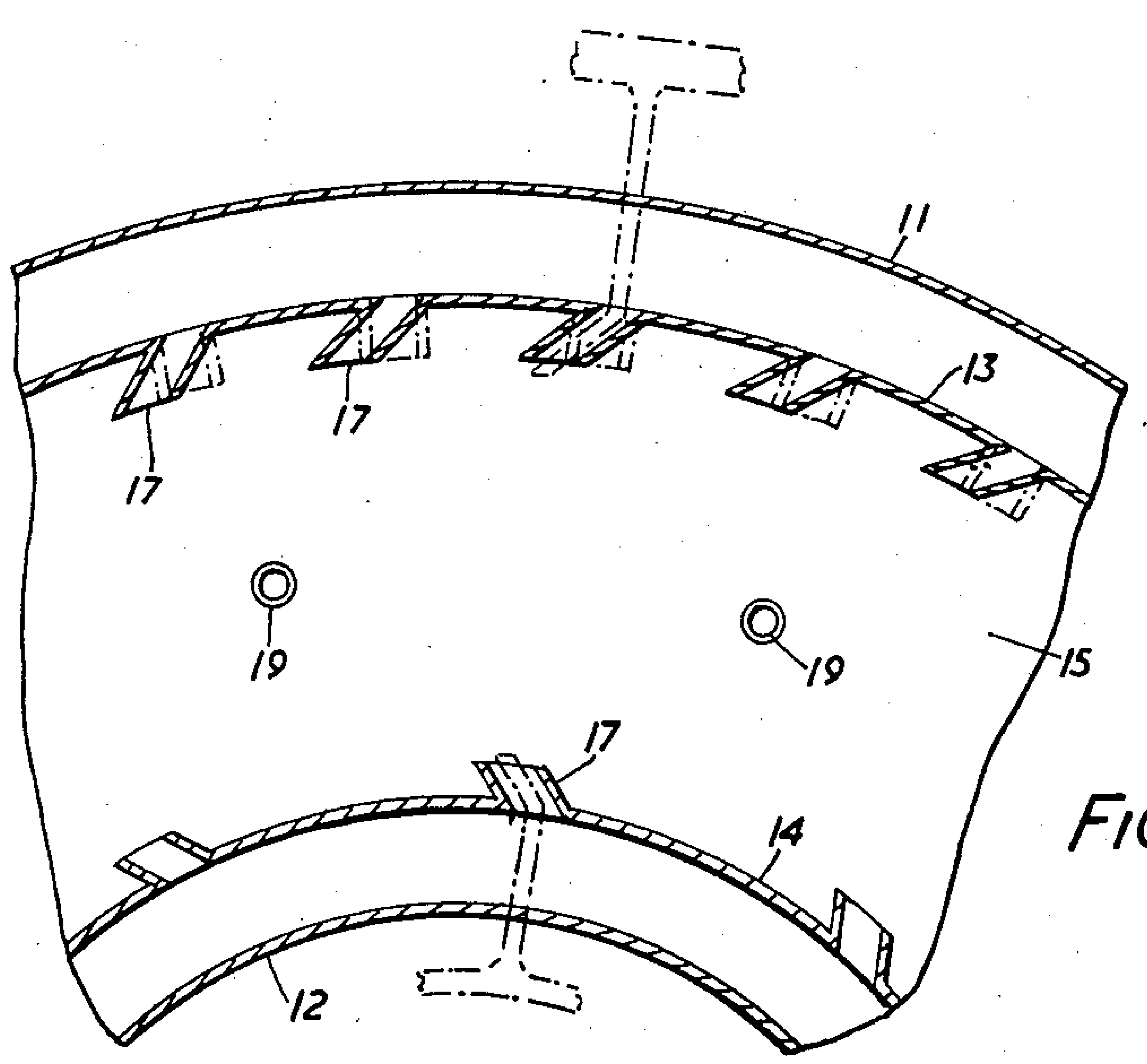


FIG. 2.

INVENTORS
PETER H. CALDER
JOHN S. LANCASTER

BY
Watson, Cole, Grindle & Watson
ATTORNEY

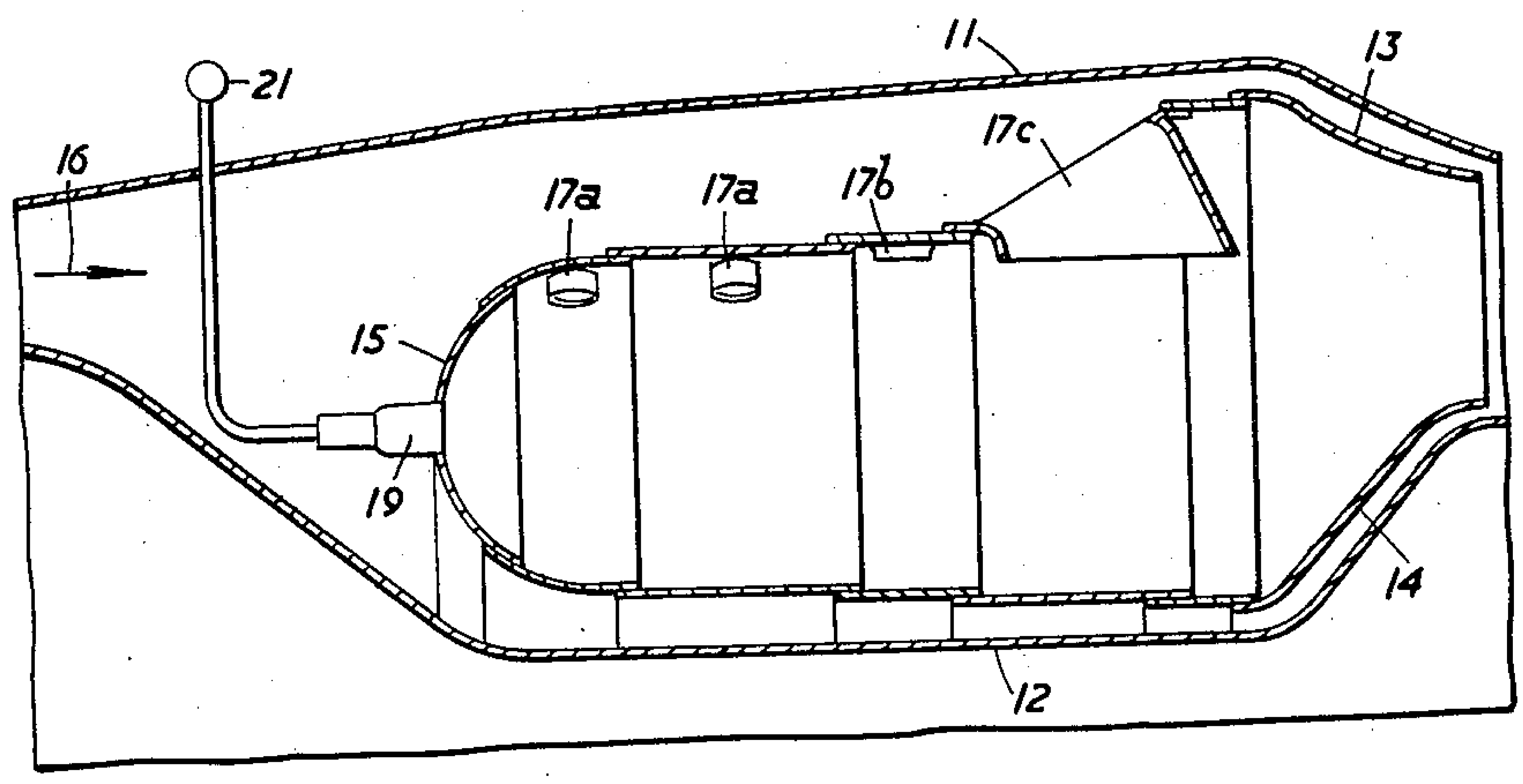


FIG. 3.

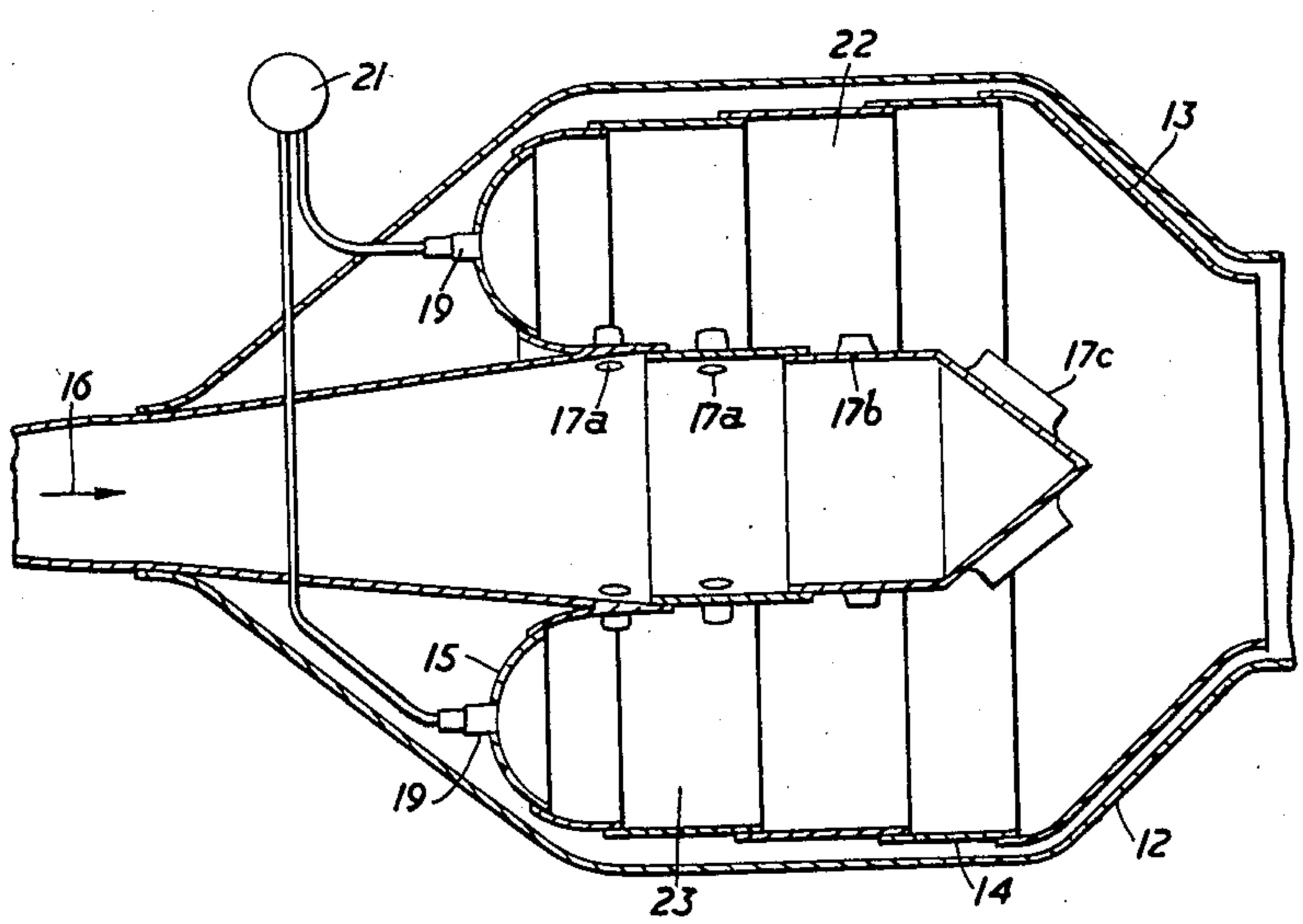


FIG. 4.

INVENTORS
PETER H. CALDER
JOHN S. LANCASTER

BY
Watson, Cole, Grindle & Watson
ATTORNEY

United States Patent Office

3,099,134

Patented July 30, 1963

1

3,099,134

# COMBUSTION CHAMBERS

Peter Henry Calder, London, and Derek John Stansfield Lancaster, Radlett, England, assignors to The De Havilland Engine Company Limited, Leavesden, Hertfordshire, England, a British company

Filed Dec. 27, 1960, Ser. No. 78,352
Claims priority, application Great Britain Dec. 24, 1959
3 Claims. (Cl. 60—39.65)

This invention relates to annular combustion chambers for use in gas turbines, for example for aircraft, industrial, or marine applications.

In conventional annular combustion chambers the gases pass through the combustion chamber travelling to the turbine nozzle ring in a substantially axial direction. This has various disadvantages and more particularly if the gas temperature is not uniform around the whole turbine nozzle ring, the nozzle ring or the turbine may be overheated at localised areas. The flow pattern in the combustion chamber may be very susceptible to changes in compressor outlet pressure distribution, and if any change in operating conditions occurs, the flame may go out or the radial temperature distribution may be such that the turbine rotor blades are severely overheated in highly stressed regions.

In all gas turbine combustion chambers the flame in the primary zone is stabilised by the recirculation of hot gases to give continuous piloting of incoming fuel/air mixture. In annular chambers this flow recirculation usually takes the form of a number of toroidal vortices spaced around the circumference of the annulus. Each toroid is usually maintained by combination of airflows from a swirler and from both the outer and the inner flame tubes. The symmetry and the balance of the flow in the toroid is dependent upon careful matching of swirler and flame tube airflows. Minor changes to swirler airflow distribution or to the pressure drops across outer and inner flame tubes can cause major distortion in the primary zone flow recirculation. Such distortions are caused by variations in compressor outlet flow distribution due to changes in engine operating conditions. Primary zone flow distortions cause drastic changes in combustion chamber outlet temperature distribution and can easily result in turbine blade failure due to overheating at critically-stressed sections.

The principal object of the present invention is to devise a primary zone flow recirculation which is less sensitive to the effects of compressor outlet flow distribution changes and which is basically stable.

Now according to the present invention, an annular combustion chamber for a gas turbine engine, includes air inlet apertures spaced around radially inner and/or outer walls defining an annular combustion space, as distinct from the end walls, and arranged to impart a velocity to the gases within the combustion space in a direction having a substantial circumferential component around the annular combustion chamber.

The bodily rotation of the combustion gases within the combustion chamber provides several advantages. In the first place the rotation of the air will assist in obtaining a good mixing and distribution of the fuel-air mixture in the combustion zone and this will result in a stable flame, secondly the rotation will give good mixing of the combustion gases and will tend to give a uniform gas exit temperature. Thirdly the rotational movement of the air and of the combustion gases will result in a flow path of increased length which in turn will result in more complete combustion of the fuel before the gases reach the turbine. In some cases it may be possible in some instances to shorten the length of the combustion unit.

2

The flow distribution may be basically stable by virtue of the combined effect of the rotation of the air in the primary zone circumferentially, and a subsidary vortex flow of air through the inlet aperture towards the upstream end of the combustion space due to the low pressure there, and thence out of the combustion space along the other side of the flame tube.

Conveniently, at least certain of the inlet apertures extend with axes at a substantial angle to the radius of the combustion space in order to impart the circumferential velocity.

It is preferred that substantially all the air enters the combustion chamber through the said air inlet apertures in the inner and outer walls. A certain amount of air will be used conventionally to cool the fuel nozzles and the combustion space walls.

It is also preferred that there is no swirler through which air enters the combustion space. This means that the flow path in the primary zone is substantially dependent on air directed into the primary zone from the flame tube walls. Changes in mass flow distribution between outer and inner annular passages supplying air respectively to the inner and outer flame tube may then cause the velocity and mixture strength in the primary zone to change without altering the flow path.

The inlet apertures may be only in the inner wall, or only in the outer wall defining the combustion space, in order that the air from the compressor does not have to be divided into two or more flow paths before entering the combustion space. On the other hand, in some cases, stability can be achieved by having air inlet apertures in both the inner and outer walls, of which at least some of the apertures in the inner wall or the outer wall only are arranged to direct the air radially, rather than with a circumferential component.

In one form of the invention, the combustion chamber comprises two co-axial annular combustion spaces radially spaced apart with an air supply duct between them from which air enters both the combustion spaces through inlet apertures in the inner wall of the outer combustion space, and the outer wall of the inner combustion space.

It is preferred that the fuel, or some of the fuel is supplied to the combustion space through nozzles in the end wall, but it is also possible to supply some or all of the fuel through other nozzles, for example nozzles which lie within the air inlet apertures, and which may be directed radially, or with a circumferential component.

The invention may be carried into practice in various ways, and certain embodiments will now be described by way of example as applied to an annular combustion chamber arranged to be connected between a compressor and a turbine to receive air from the compressor and to deliver to the nozzle ring of the turbine the products of combustion.

Reference will be made to the accompanying drawings, in which:

FIGURE 1 is a diagrammatic section of a part of one embodiment of combustion chamber,

FIGURE 2 is a transverse section on the line II—II in FIGURE 1,

FIGURE 3 is a diagrammatic section corresponding to FIGURE 1, of a second embodiment of combustion chamber in which the air enters only through the outer wall, and

FIGURE 4 is a section corresponding to FIGURES 1 and 3 of a third embodiment of combustion chamber having two radially-spaced concentric annular combustion spaces.

The combustion chamber comprises inner and outer generally cylindrical pressure resisting casings **11** and **12**, defining an annular chamber, together with an annular flame tube within this chamber and spaced from the walls **11** and **12**. The flame tube comprises outer and inner generally cylindrical, or part-conical walls **13** and **14**, and an end wall **15** at the upstream end, which wall is of semi-circular profile as seen in FIGURE 1, and is connected to the upstream ends of the inner and outer walls.

Air enters the annular chamber **11**, **12** from the compressor as shown by the arrow **16**, and divides into two streams radially outside and inside the annular flame tube **13**, **14**, **15**. The air enters the combustion space in the flame tube through air inlet apertures **17** in the outer and inner sidewalls **13** and **14**. The air entering through the upstream apertures **17***a* may be considered to be primary air. Air entering through apertures **17***b* further downstream may be considered to be secondary air, and air entering through down stream apertures **17***c* dilution air, although there is no strict distinction between primary and secondary air, and secondary and dilution air. The primary air through the upstream apertures **17** is responsible for maintaining the flame stable so that the incoming fuel is effectively piloted.

The apertures **17** comprise short open pipes or ducts, as shown in FIGURE 2. These all have a tangential or circumferential component so that the chage will tend to be bodily rotated circumferentially around the combustion space. There may also be even a slight axial component upstream or downstream if it is found to be necessary.

The general flow of the combustion gases around the flame tube and a continuous toroidal vortex which exists at the upstream end of the combustion space, have been found to give an air flow pattern in the combustion space which is extremely stable in spite of changes in conditions, and in particular in spite of variations in the compressor outlet pressure of flow distribution, so that the effective piloting of the incoming fuel, and a stable temperature pattern along the turbine blades can be achieved.

It was suggested above that all the apertures should be directed with a tangential component as shown in FIGURE 2, but in fact, in some cases, it may be that some apertures in the downstream rows **17***b* and **17***c* may be directed radially, and in some circumstances a more stable flow pattern still may be obtained if the rotation of the charge is achieved only by inclined apertures in the outer wall or in the inner wall, while the opposite apertures are radial. (This is shown dotted in FIGURE 2.)

In the embodiment shown in FIGURES 3, where similar parts have the same reference numerals as in FIGURES 1 and 2, the air inlet apertures through the wall of the flame tube lead only through the outer wall **13**, and almost all of the air from the compressor passes into the annular duct between this wall **13**, and the outer pressure resistant wall **11** of the combustion chamber. The upstream rows of air inlet apertures **17***a* are inclined tangentially in a manner similar to that shown in FIGURE 2, while the downstream rows are directed radially. Once again, the fuel is supplied through a ring of nozzles such as **19** arranged in the end wall of the flame tube



from an annular fuel gallery **21** surrounding the combustion chamber.

In the embodiment of FIGURE 4 the flame tube is formed to define two co-axial radially-spaced combustion spaces, **22** and **23**, leading to a common exhaust manifold **24**, and the air from the compressor at **16** is led to a central annular duct **25** radially between the spaces **22** and **23**. Air enters the outer combustion space **23** through the inner wall only, and enters the inner combustion space **23** through the outer wall only, and once again the apertures **17***a* in the upstream rows are inclined with a circumferential component. Fuel from a common supply gallery **21** enters the flame tubes through rings of fuel nozzles **19** in the respective end walls.

The embodiments of FIGURES 3 and 4 have the advantage that the air from the compressor does not have to be split into two or three ducts with bends around which energy is lost, but is fed principally into a single straight duct only. This gives better diffusion of the air.

It has been said that the air enters the combustion space only through the side walls, but it is pointed out that in making this remark no notice has been taken of small quantities of air supplied primarily for cooling the fuel nozzles or the flame tube walls through small apertures in the conventional manner.

It is also possible that fuel may be supplied in other ways, for example through radially-directed or circumferentially inclined nozzles leading through certain of the air apertures **17**, but it is preferred that the fuel enters through the end wall as shown.

By supplying the air only through the side walls, and with a circumferential component and through no swirler, it has been found that very stable flame patterns can be achieved in spite of considerable variations in compressor characteristics.

What we claim as our invention and desire to secure by Letters Patent is:

1. An annular combustion chamber for a gas turbine engine, including air inlet apertures spaced around both the radially inner and radially outer walls defining an annular combustion space, as distinct from the end walls, the air inlet apertures comprising a series of primary air apertures at the upstream end of the combustion chamber and a series of secondary air apertures further downstream of the primary air apertures, the primary air apertures in one of said walls being directed in a plane transverse to the axis of the combustion chamber, but with a substantial circumferential component of direction to establish a rotating burning charge and the primary air apertures in the other of said walls being arranged to direct the air radially rather than with a circumferential component, and fuel nozzles for directing fuel directly into the rotating burning charge in the combustion space.

2. A combustion chamber as claimed in claim 1 comprising two co-axial combustion spaces radially spaced apart with an air supply duct between them from which substantially all the air enters the combustion spaces through inlet apertures in the inner wall of the outer combustion space, and the outer wall of the inner combustion space.

3. An annular combustion chamber in combination with means defining an annular discharge path from an air compressor and walls defining an annular region connected through the annular discharge path, and embracing the annular combustion chamber, including air inlet apertures spaced around at least one of the radially inner and radially outer walls defining an annular combustion space, as distinct from the end walls, the air inlet aperture comprising a series of primary air apertures at the upstream end of the combustion chamber, which apertures are directed substantially in a plane transverse to the axis of the combustion chamber, but with a substantial circumferential component of direction to establish a recirculating annularly rotating burning charge and a series of secondary air apertures further downstream of

the primary air apertures, and fuel nozzles for directing fuel directly into the rotating burning charge in the combustion space.


References Cited in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 2,576,046 | Scarth | Nov. 20, 1951 |
| 2,579,614 | Ray | Dec. 25, 1951 |
| 2,588,728 | Hundstad | Mar. 11, 1952 |
| 2,627,719 | Stalker | Feb. 10, 1953 |
| 2,637,974 | Nathan | May 12, 1953 |
| 2,659,201 | Krejei | Nov. 17, 1953 |
| 2,718,757 | Bloomer | Sept. 27, 1955 |
| 2,930,192 | Johnson | Mar. 29, 1960 |
| 2,951,339 | Benson | Sept. 6, 1960 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 512,723 | France | Oct. 21, 1920 |