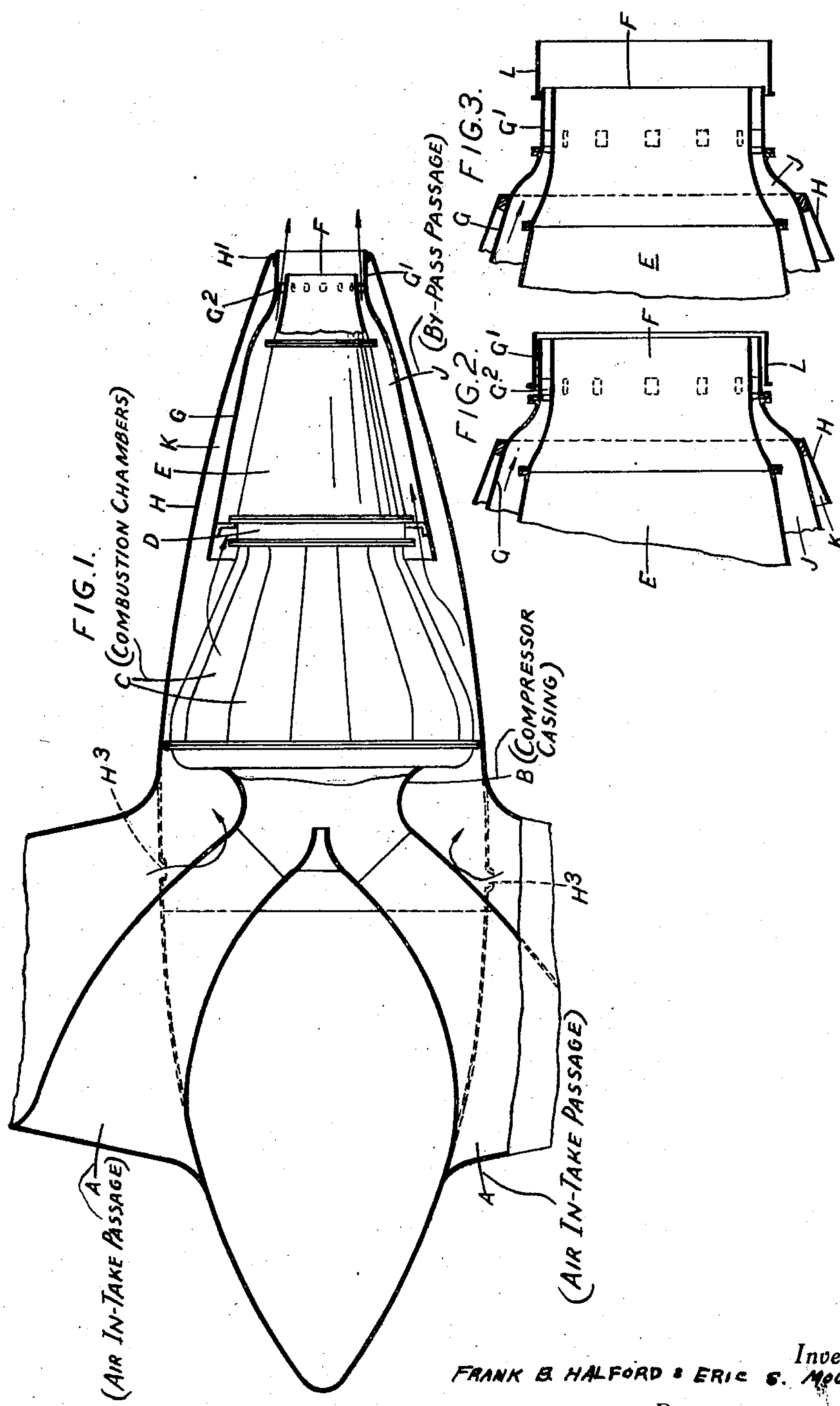
Sept. 29, 1953 F. B. HALFORD ET AL 2,653,445

TURBOCOMPRESSOR JET-PROPULSION APPARATUS AND ADJUSTABLE NOZZLE THEREFOR

Filed June 19, 1946 4 Sheets-Sheet 1



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By
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Attorneys

FIG.7.

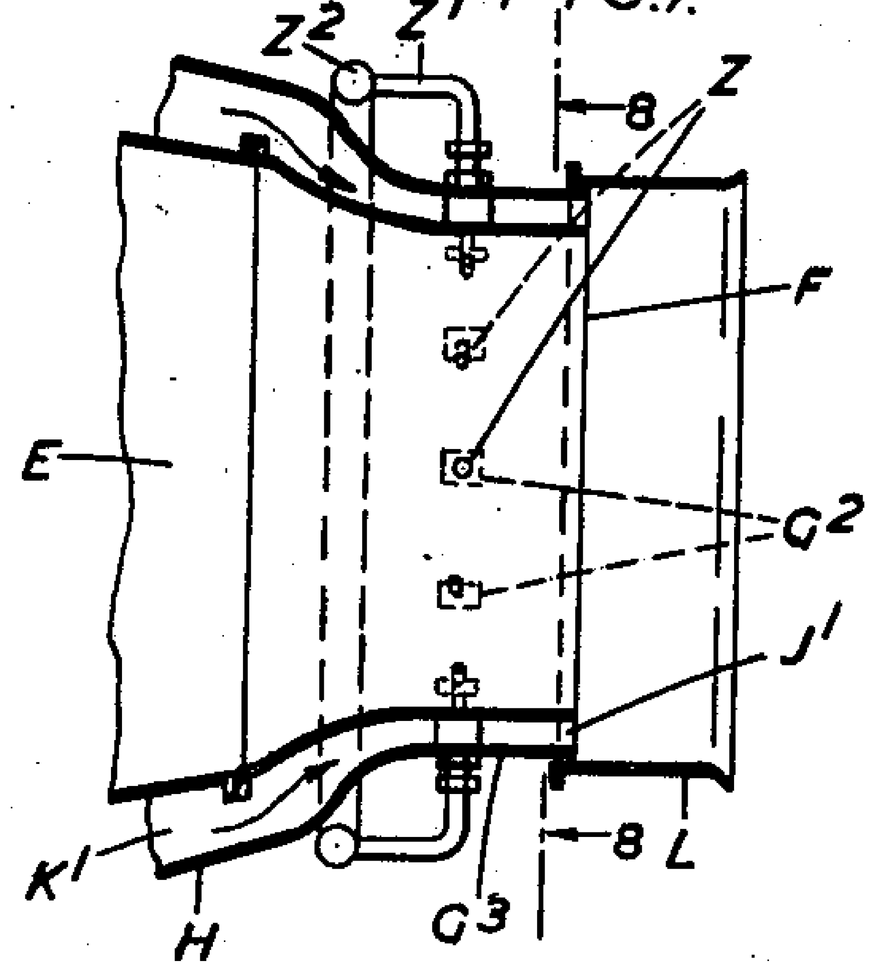

FIG.8.

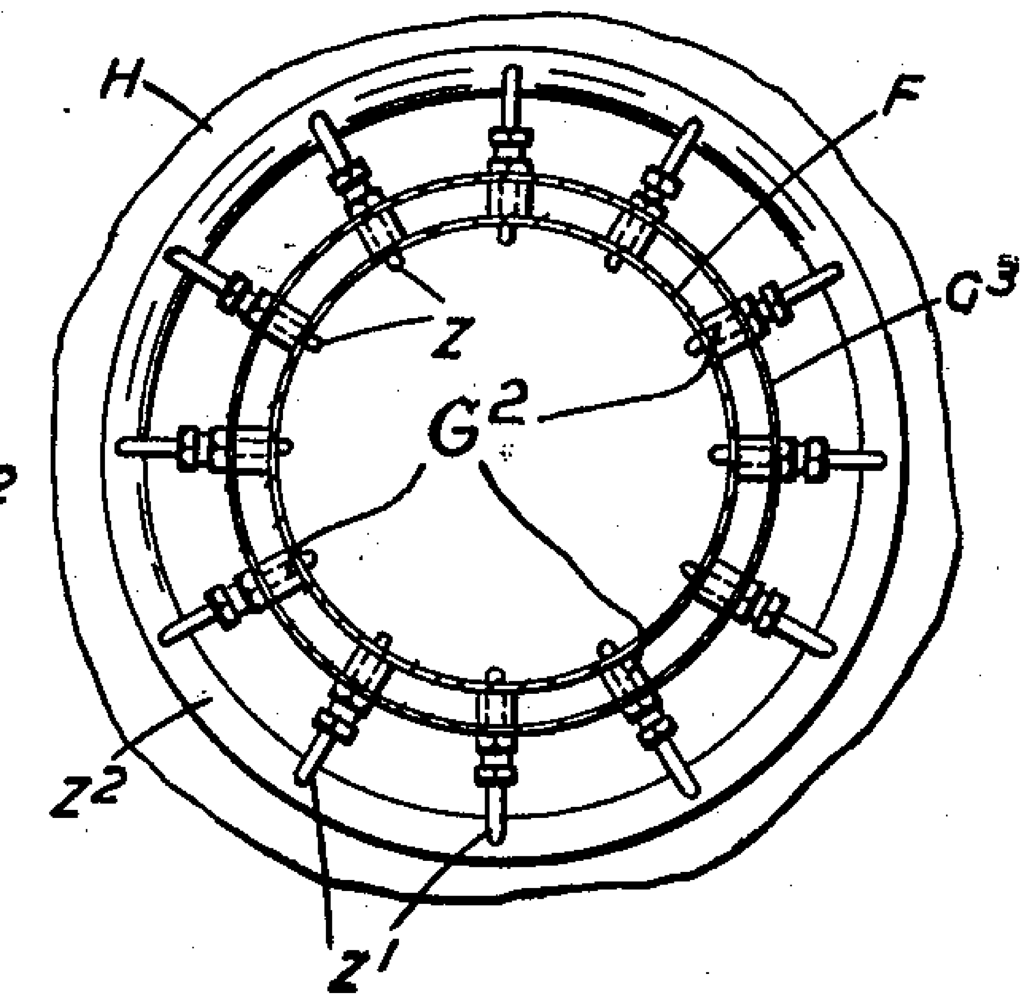

FIG.4.

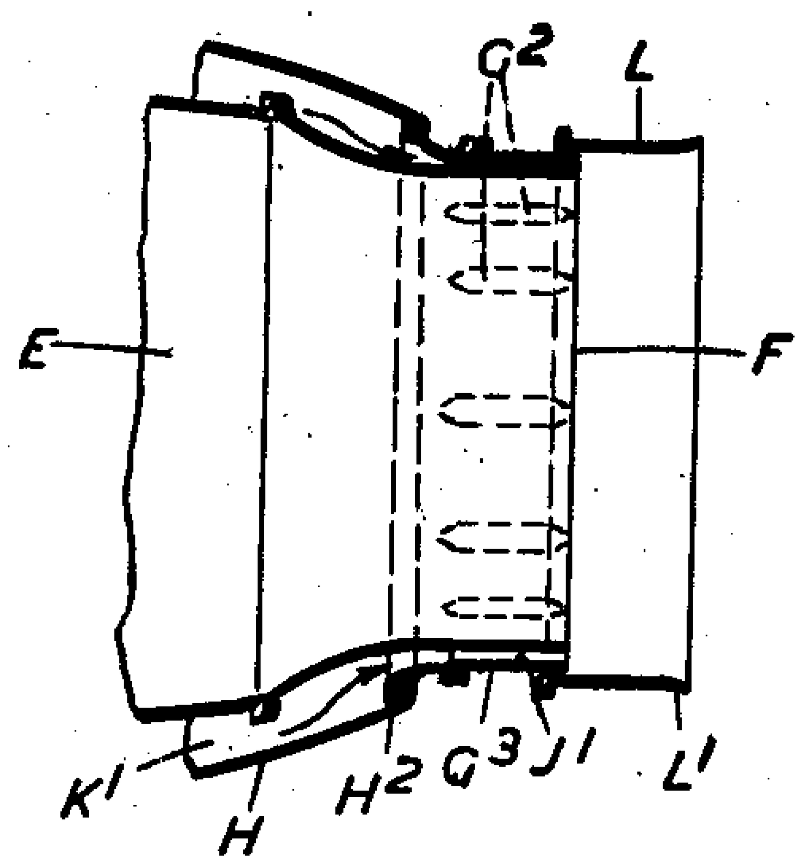

FIG.5.

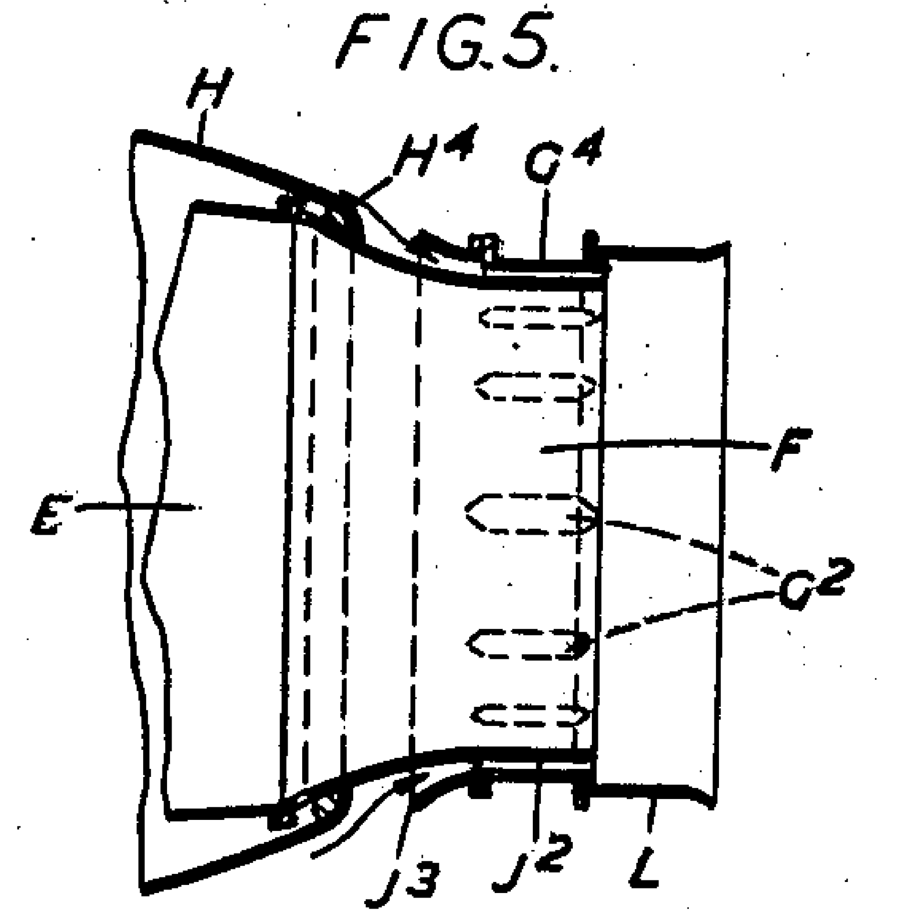

FIG.6.

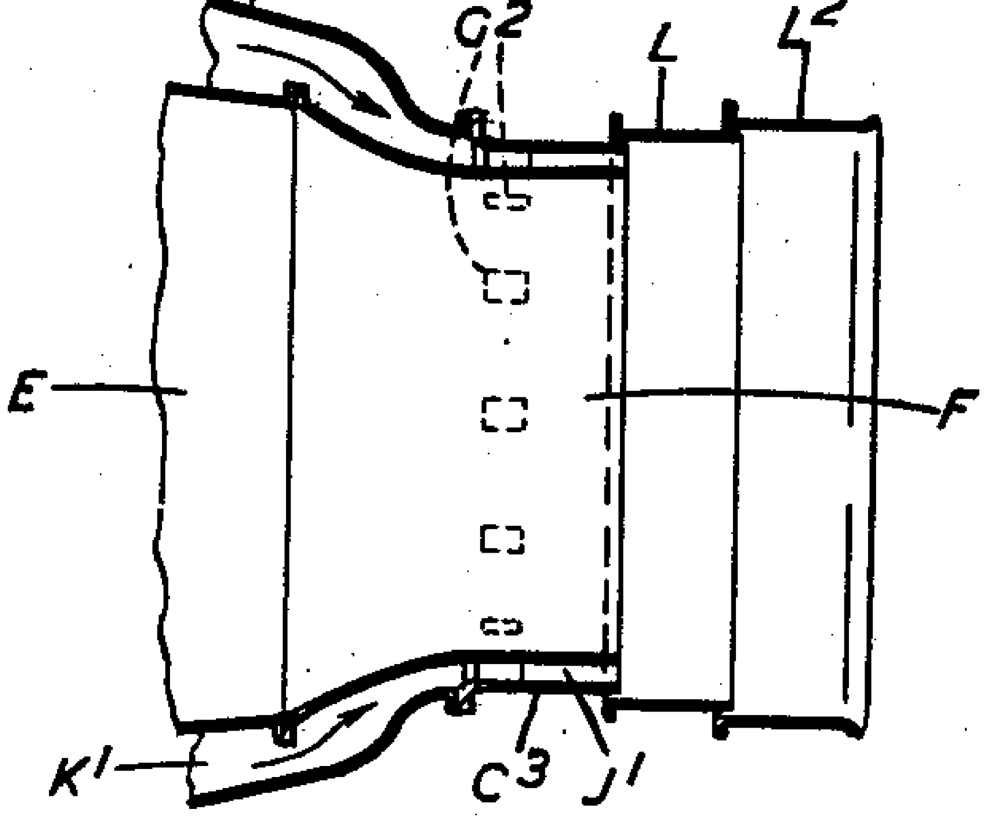

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FIG. 9.

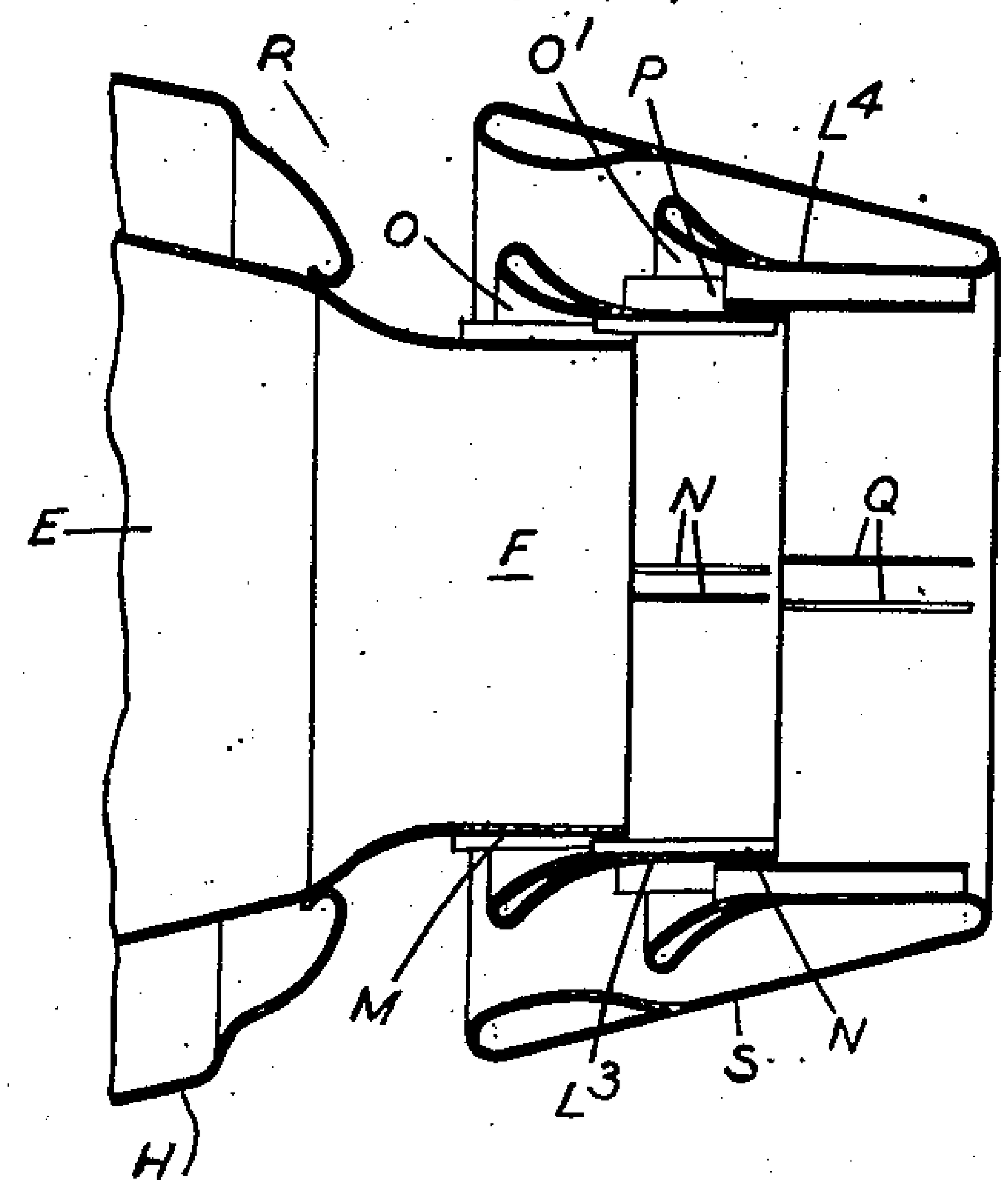

FIG. 10.

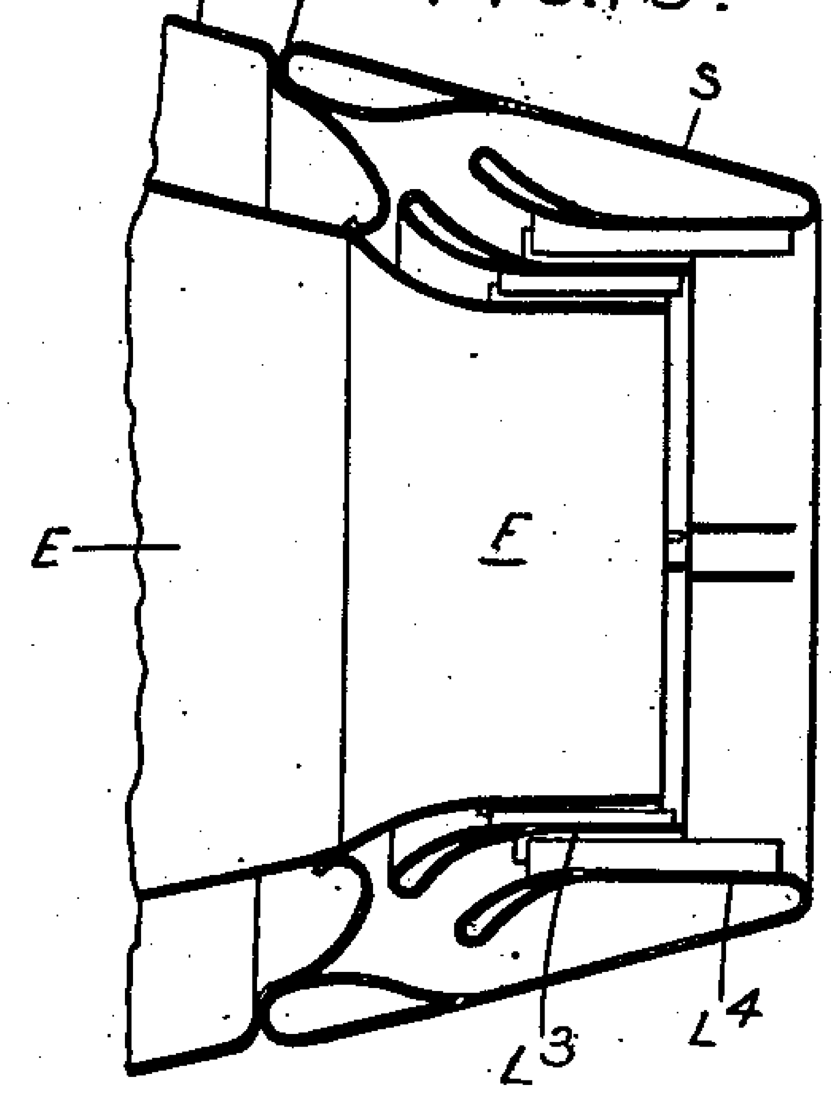

FIG. 11.

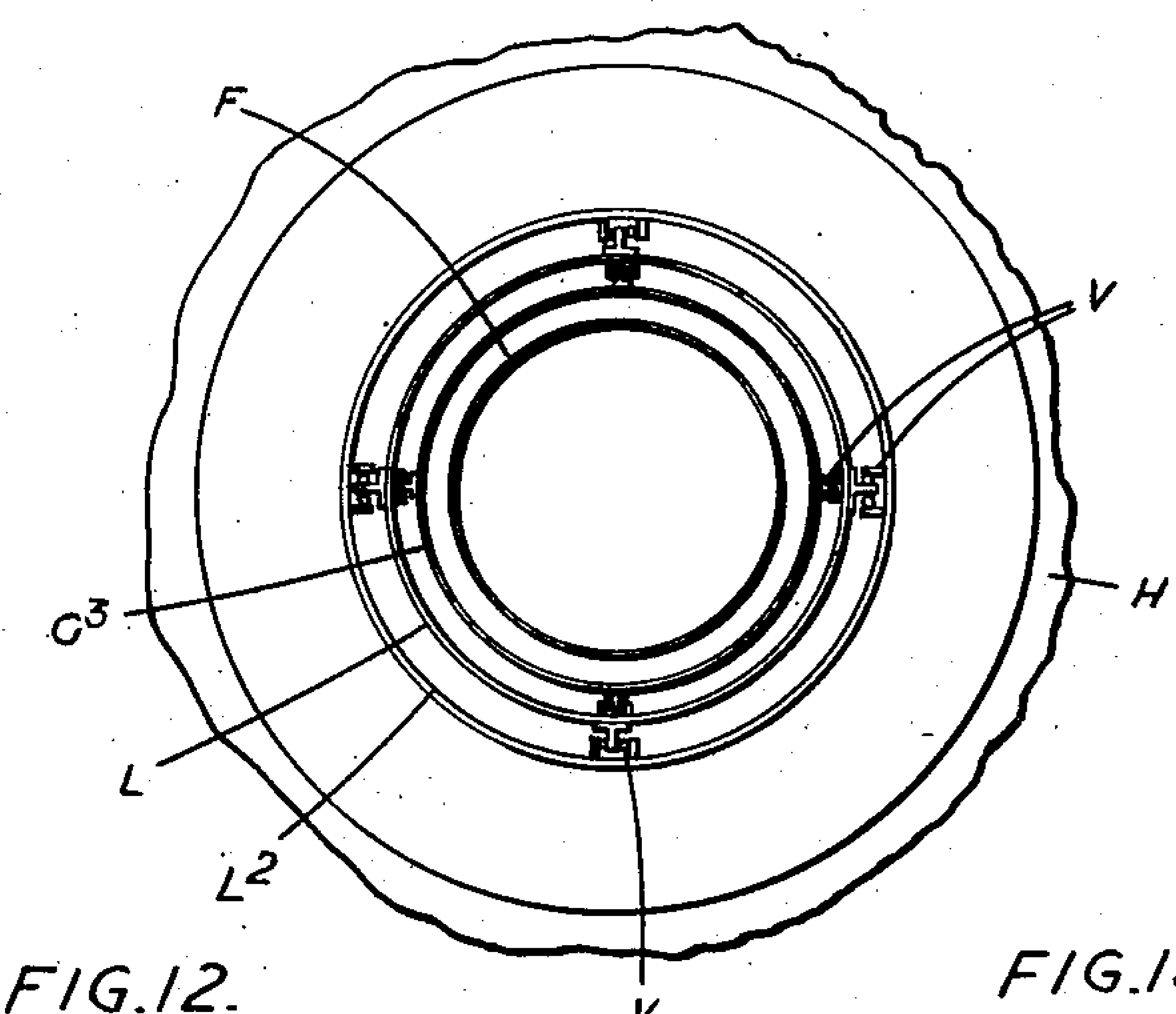

FIG. 12.

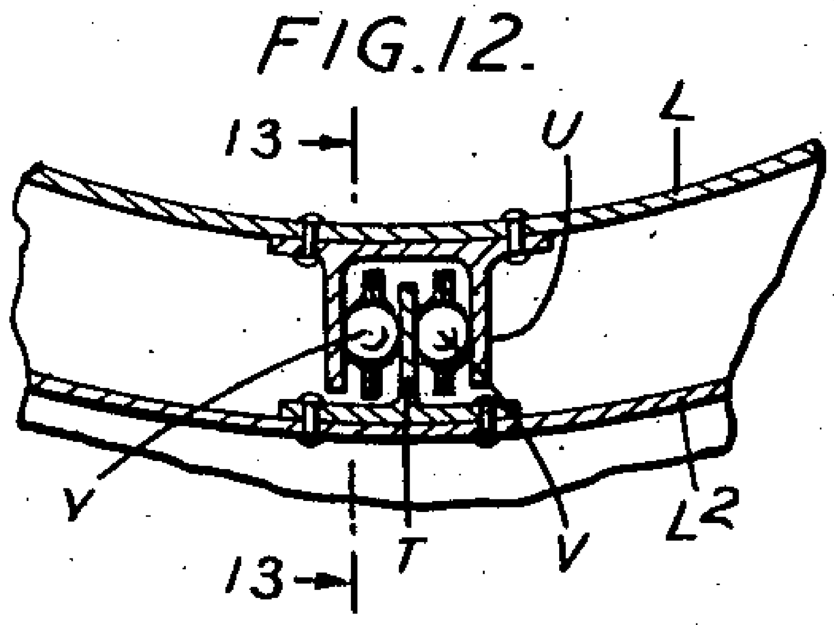

FIG. 13.

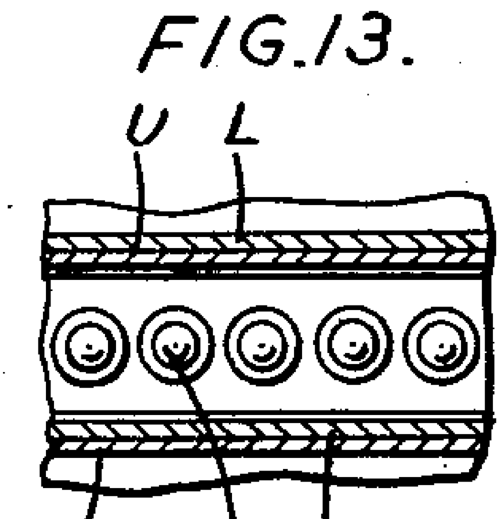

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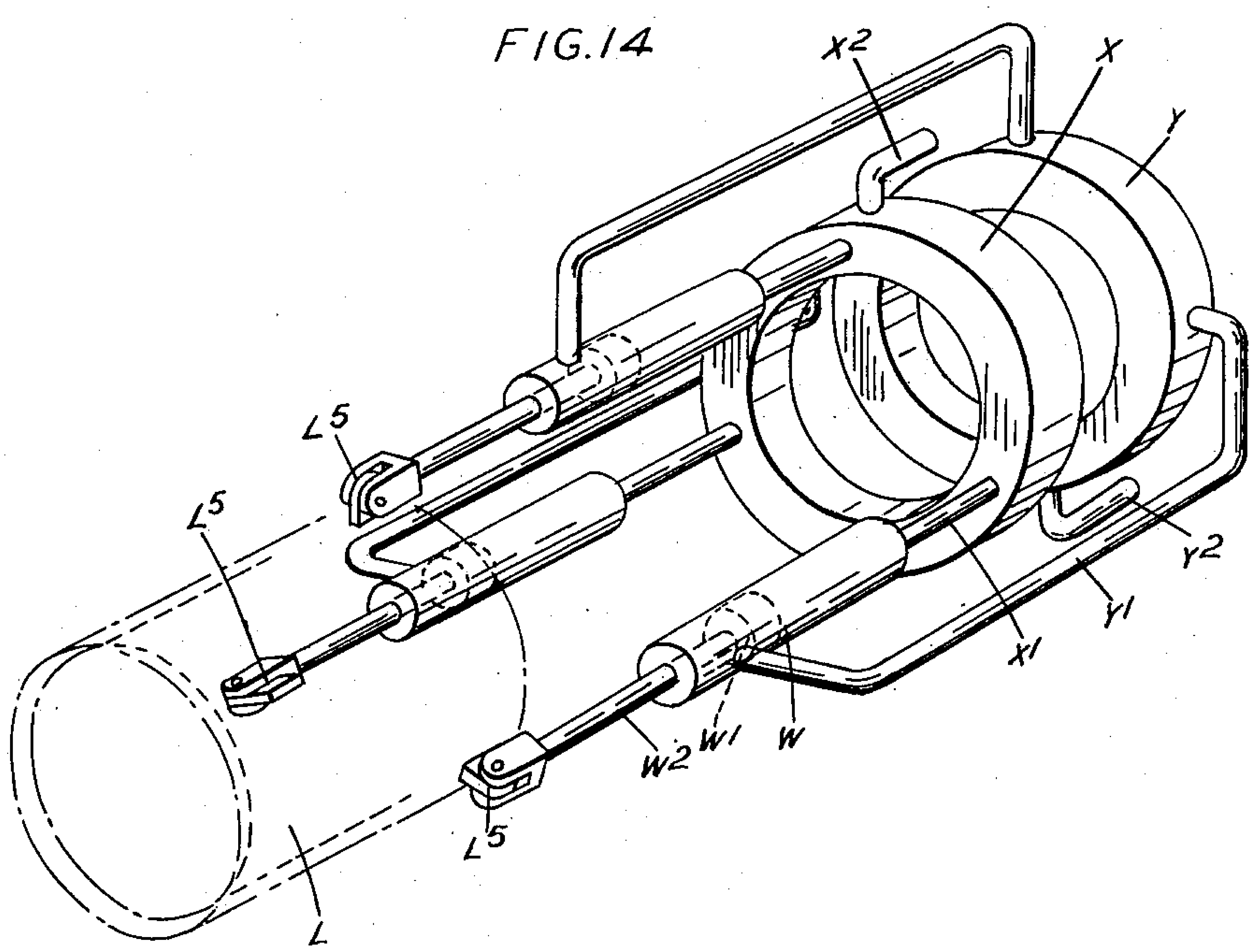
FIG. 14



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2,653,445

TURBOCOMPRESSOR JET-PROPULSION APPARATUS AND ADJUSTABLE NOZZLE THEREFOR

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Application June 19, 1946, Serial No. 677,695
In Great Britain May 11, 1945

Section 1, Public Law 690, August 8, 1946
Patent expires May 11, 1965

4 Claims. (Cl. 60—35.6)

This invention relates to jet propulsion apparatus embodying a turbo-compressor and as more especially intended for use in aircraft. The invention is applicable to various types of such apparatus in which it is desirable to vary the propulsive thrust of a jet reaction.

A type of this propulsion apparatus to which the invention is more particularly applicable comprises a compressor coaxial with and driven by a turbine from which it is spaced apart in the axial direction the compressor delivering air either into a single annular combustion chamber or into a series of separate tubular combustion chambers spaced apart circumferentially in an annular formation around the turbine shaft and between the compressor and the turbine to which the combustion products flow and cause its rotation before these gases issue with propulsive effect from a single nozzle which may either be coaxial with or have its axis inclined to that of the turbine shaft. The object of the invention is to provide means whereby the effective exit area of the nozzle through which the gases issue can be varied.

In a given propulsive unit of the type indicated above, a reduction in the area of the nozzle has the effect of giving increased thrust at the expense of increased temperature conditions, at a constant speed of rotation. Hence in a unit which is already operating at its maximum permissible speed, as limited by centrifugal stresses, reduction in the area of the nozzle provides a means of giving increased thrust for short periods during which the increase in temperature would not be harmful. Again if the temperature of the turbine falls when the aircraft is in flight, as usually occurs at a substantial altitude, the effective thrust of the jet can be increased by reducing the nozzle area.

It has been proposed to effect variation in the area of these nozzles in one case by the use of a stream-lined body mounted so that it can slide somewhat as a valve within a circular nozzle and along its axis. In another case where the nozzle has a polygonal orifice the side walls of the nozzle have been hinged or made flexible. Such devices being necessarily subjected to the full heat of the gases, are liable to distortion and consequent failure to operate.

According to this invention there is combined with the nozzle a sleeve which surrounds the nozzle from which it may be spaced apart in the radial direction so as to leave an annular passage between the sleeve and the nozzle, and means

for extending the length of the sleeve in the direction of the axis of the nozzle, whereby when thus extended the sleeve by reason of its having a diameter greater than the diameter of the nozzle will increase the effective exit area of the nozzle. This sleeve formed as a tubular member may be mounted so that it can slide in the direction of the axis of the nozzle so as to cause a part of the sleeve to project beyond the nozzle orifice. Alternatively the sleeve may be fixed with one or more tubular members mounted on it so that each of these members can slide in a telescopic manner on the sleeve or on each other and produce the effect of an extension of the sleeve with a consequent increase in the effective exit area of the nozzle. There may be two or more of these telescopically sliding members and means may be provided for moving them collectively or separately so that as they have different diameters there may be produced with them the effect of different diameters of nozzle. With this arrangement the sleeve is not excessively heated because of the flow of cool air drawn through the annular space between the sleeve and the nozzle so that risk of sticking due to distortion is minimised. It may also be remarked that a precise fit between the fixed and movable parts in contact, such as the sleeve and the members movable thereon, is not necessary since the passage of air between them merely adds to the cooling effect as this air flows through and mingles with the main air flow through the sleeve.

The end of the sleeve, if the whole sleeve is adapted for sliding, or the end of the tubular member which slides on the sleeve, or the end of the outermost of a set of telescopic members, may be flared.

If desired, additional fuel may be injected and burnt in the tail pipe leading to the nozzle thereby raising the temperature and velocity of the gases issuing from the nozzle. This device is more especially useful when combined with the above described means for varying the effective exit diameter of the nozzle.

The accompanying drawings illustrate diagrammatically and by way of example various ways in which the invention may be carried out in practice. In these drawings:

Figure 1 is a longitudinal part sectional plan of a jet propulsion apparatus which illustrates how, in a non-movable nozzle, the effective area of the jet nozzle may be increased in a simple manner so as to provide additional thrust.

Figure 2 is a sectional elevation of the jet nozzle in apparatus as seen in Figure 1 showing one arrangement for varying the effective exit area of the jet nozzle, the device being here adjusted so as to reduce the diameter of the nozzle.

Figure 3 is a view similar to Figure 2 but showing the device adjusted so as to increase the diameter of the nozzle.

Figure 4 is a view similar to Fig. 2 showing an alternative arrangement of the device as shown in Figures 2 and 3, in which the forward end of the fixed sleeve is connected to the nacelle.

Figure 5 is a view similar to Figure 2 showing yet another arrangement in which the forward end of the nozzle is connected to the nacelle.

Figure 6 illustrates by means of a like view an arrangement similar to that shown in Figure 4 but with the device constructed to enable a greater variation to be effected in the diameter of the jet nozzle.

Figure 7 is again a similar view showing means for introducing fuel which is burnt in the nozzle.

Figure 8 is a transverse section on the line 8—8 in Figure 7.

Figure 9 illustrates another arrangement of adjustable telescopic members for varying the effective exit diameter of the jet nozzle, the members being shown in their fully extended positions.

Figure 10 is a view similar to Figure 9 but showing the members telescoped inwards so as to reduce the size of the nozzle.

Figure 11 is an end view of an arrangement such as is shown in Figure 6 and illustrating how the telescopically sliding sections may be mounted on ball bearings.

Figure 12 is an enlargement of a part of Figure 11 showing the manner in which the ball bearings may be arranged.

Figure 13 is a section on the line 13—13 in Figure 12.

Figure 14 shows diagrammatically and by way of example one arrangement of apparatus for imparting the necessary sliding or telescopic movement to a tubular member for the purpose of varying the effective exit diameter or cross-sectional area of the nozzle.

The type of turbo-compressor propulsive apparatus in connection with which the present invention will be more particularly described is illustrated by way of example in Figure 1 and comprises the following principal features. Air is drawn in through twin intake passages A by the impeller of a compressor enclosed in a casing B and this air is delivered into a series of separate tubular combustion chambers C wherein fuel is burnt. The gases from these chambers flow to and act on a turbine disposed within a casing D and on leaving the turbine the gases pass through the tubular and somewhat conical casing E to issue from the nozzle F with propulsive effect. Around the turbine casing D and the jet pipe E and spaced radially out therefrom is a sleeve G and outside this sleeve and spaced therefrom is the engine nacelle H. There is thus an annular space J within the sleeve through which air drawn from the open atmosphere through the openings H^3 in the nacelle H below the wings can flow along the path indicated by the curved arrows in Figure 1 and constitute a lagging for the casing D and jet pipe E, and there is a similar annular air space K between the sleeve G and the nacelle H, but in this arrangement air is not free to flow through this latter space since the nacelle is connected at its after end at H^1 to the after end of the sleeve. The after end G^1 of the sleeve extends beyond the nozzle F on which it is conveniently supported by pads G^2. This extension of the sleeve has the effect of an enlargement of the diameter of the nozzle F and as will be seen it may be arranged so that the air may flow through the lagging space J within the sleeve G and thus issue around the nozzle F and mingle with the gases issuing from the nozzle.

According to this invention the extension of the sleeve G or of a corresponding part around the nozzle F is made adjustable as by providing one or more separate tubular members which can slide relatively and telescopically and thus enable the effective exit diameter of the nozzle to be enlarged or reduced as required. Such an arrangement is shown in a simple form in Figures 2 and 3. Here a single tubular section L is mounted on the end portion G^1 of the sleeve G so that this section can either be caused to slide outwards into the position in which it is shown in Figure 3 or moved inwards into the position in which it is shown in Figure 2. In the former and extended position the section L having a diameter which is larger than that of the nozzle F will have the effect of increasing the size of the nozzle, but when the section is withdrawn inwards onto the end G^1 of the sleeve the size of the nozzle will be reduced to that of the nozzle itself, when the end of the tubular section L will lie with its end substantially flush with the end of the nozzle F as can be seen in Figure 2. As will be seen the air flowing through the lagging space J will come out around the nozzle F and serve to cool the end G^1 of the sleeve and the sliding extension L. The outer end of the tubular member L may be slightly flared as shown at L^1 in Figure 4.

Referring to Figure 4, this shows the fixed sleeve G^3 as carried by pads G^2 on the nozzle F, but with its forward end connected at H^2 to the nacelle H. Air can flow through the annular space K^1 between the nacelle and the jet pipe E and issue through the annular space J^1 around the nozzle F. The arrangement of the nacelle H may be as shown in Figure 1 with openings H^3 in its forward part (not shown in Figure 4) through which the air can enter.

In the arrangement shown in Figure 5 the nacelle H is connected at H^4 to the end of the jet pipe E or forward end of the nozzle F so that air cannot flow through the space between the nacelle H and the jet pipe. Air can however flow through the space J^2 between the fixed sleeve G^4 and the nozzle F which carries the sleeve G^4 through the pads G^2, the air entering the space J^2 through the annular opening J^3 at the somewhat flared forward end of the sleeve G^4. The air entering here can thus flow out between the nozzle F and the tubular section L which can slide telescopically on the fixed sleeve G^4.

Referring now to Figure 6, this shows an arrangement in which there are two telescopically sliding tubular members L, L^2, the latter sliding on the tubular section L while this section can itself slide telescopically on the fixed sleeve G^3. This sleeve is here shown as mounted and arranged in the same way as shown in Figure 4, being supported by pads G^2 on the nozzle tube F and connected at its forward end to the nacelle H with an intervening annular space J^1, K^1, through which air can flow and issue around the nozzle F. The tubular sections L, L^2 can be moved separately and relatively to the fixed sleeve G^3 so that they may be either wholly withdrawn, so that the effective diameter or cross-sectional area of the nozzle will be that of the nozzle F itself, or each section L, L^2 may be extended so as to vary the effective exit diameter of the nozzle which will then be either the diameter of the end of the section L or the diameter of the outer section L^2. The effective exit diameter of the nozzle can thus be increased in steps or otherwise as desired and by suitable determination of the relative diameters of the telescopically sliding sections L, L^2 the difference in the effective exit diameters of the nozzle may be varied. The tubular sections L, L^2 may be so mounted one on the other that there will be an annular space for air flow between them and between the inner section L and the fixed sleeve G^3, as shown in Figs. 9, 10 and 11.

Referring to Figures 9 and 10, these show a modified arrangement of two telescopically sliding tubular members arranged so that when the members are extended air may flow through the annular spaces between them, or when the members are withdrawn the air flow within them can be shut off. In this case the inner member L^3 is carried on the nozzle tube F, the latter being provided with longitudinally extending guide members M which engage corresponding longitudinal guide members N within the tube L^3, these guide members M and N being spaced apart circumferentially and serving not only to guide the tube L^3 as it slides on the nozzle F but also to space it radially from the nozzle so as to leave an annular air passage O around the nozzle F through which air can flow. The second and outer sliding tubular member L^4 is similarly carried on the inner tube L^3, the latter having longitudinal guide members P which engage corresponding guide members Q within the tube L^4. There is thus an annular air passage O^1 between the tubular members L^3 and L^4. Air flowing through the annular spaces O, O^1 enters through an annular opening R between the after end of the nacelle H, which is connected to the end of the jet pipe E, and a conical casing S connected at its rearward end to the end of the sliding tube L^4. The annular air passage R is fully open when both the tubes L^3, L^4 are extended beyond the nozzle F, but if one of these tubes is withdrawn, the size of the air inlet R will be reduced, and if both tubes L^3 and L^4 are withdrawn, as shown in Figure 10, the air inlet R will be wholly closed by the forward end S^1 of the casing S coming into contact with the after end of the nacelle H. The part S then provides a continuous streamline surface with the contour of the nacelle H.

As an example of the manner in which the telescopically sliding tubular members may be mounted so as to facilitate their sliding, there may be adopted an arrangement such as shown in Figures 11, 12 and 13. In this case the tubes and associated parts are assumed to be as diagrammatically indicated in Figure 6, that is to say there is a nozzle F which carries a fixed sleeve G^3 on which in turn can slide the tube L while the outer tube L^2 can slide on the inner tube L. Since the arrangement to be described is similar as between the fixed sleeve G_3 and the inner sliding tube L and also between this tube and the outer sliding tube L^2, the following description will apply in each case. Ball bearings of the "ladder" type are employed and arranged in the manner shown in the enlarged views Figures 12 and 13. The outer tubular member, for example L^2, carries within it a T-section guide T of which the projecting rib lies between the lateral portions of a U-section guide U mounted on the exterior of the inner tubular section L. Between the interengaging parts of these guides lie two similar ball cages V. As shown in Figure 11, there are four of these ball races between the fixed sleeve G^3 and the inner sliding tube L, and similarly four races between the inner sliding tube L and the outer sliding tube L^2, all these races being equally spaced apart in the circumferential direction. These races serve to keep the tubular members concentric with the nozzle F and facilitate the relative sliding movement of the tubes L, L^2. Obviously if preferred there may be only three spaced ball races in one or each case. The guides indicated in Figures 9 and 10 and described with reference to these figures may carry such ball races.

The sliding movement of the single or multiple telescopic tubular members may be effected in various ways, but a simple example of how this may be effected is shown diagrammatically in Figure 14 in connection with the single sleeve L. This is here assumed to be slidably mounted on a fixed sleeve in the manner shown for example in Figures 2 and 3. On some adjacent fixed part such as G in Figures 2 and 3 but here omitted for the sake of clearness, there are mounted three hydraulic cylinders W equally spaced apart circumferentially and each containing a piston W^1 connected through a rod W^2 to a lug L^5 on the exterior of the sliding tube L. Two annular chambers X and Y are provided with piping connecting these chambers to the opposite ends of the cylinders W and to sources of supply not shown. Thus from the annular chamber X a pipe X^1 runs to one end of each cylinder W while from the second chamber Y a pipe Y^1 runs to the other end of each cylinder W. Thus if pressure fluid, either air or liquid, is admitted to the chamber X through a pipe X^2 it will flow into the inner end of each of the cylinders W and acting on the pistons W^1 will cause the tubular section L to be moved outwardly. At the same time through piping such as Y^2 the pressure fluid can flow from the chamber Y and thus through the piping Y^1 from the outer ends of the cylinders W. On the other hand if the tubular section L is to be withdrawn, pressure fluid is admitted through the piping Y^2 to the chamber Y and so through the piping Y^1 to the outer ends of the cylinders W where it will act on the pistons and draw the tube L inwards. At the same time the chamber X is placed in communication through the piping X^2 with an exhaust or relief chamber.

The flow of pressure fluid to effect these movements can be controlled in some convenient manner.

The invention is particularly suitable for use where it is desirable to supply additional fuel into the tail pipe or jet pipe E near the nozzle F. In that case one arrangement shown for example in Figures 7 and 8 may comprise a series of fuel delivery nozzles Z disposed radially and spaced apart circumferentially, the nozzles for example being carried by the fixed sleeve G^3 and passing through the spacing pads G^2 between this sleeve and the nozzle tube F within which the fuel will be delivered from these nozzles into the stream of propellant gases. Each fuel nozzle Z is supplied through a separate branch Z^1 from a common annular supply or manifold Z^2 disposed around the end of the nacelle H. Air for the combustion of this fuel can flow through the annular space K^1, J^1 around the nozzle F, or may be surplus air from the main jet. These figures show a single telescopically sliding member L mounted and movable on the fixed sleeve G^3.

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

1. Turbo-compressor propulsive apparatus of the type comprising a compressor, means for admitting air to said compressor and means for passing air around said compressor, at least one combustion chamber into which air is delivered by the compressor and wherein fuel is burnt, a turbine driven by hot gases from the combustion chamber, the turbine being co-axial with and rotatably connected to the compressor to drive it, and a nozzle from which the gases which have passed through the turbine issue with propulsive effect, in combination with an adjustable sleeve surrounding and spaced from the nozzle to permit passage therebetween of said air passed around said compressor, and means for extending the sleeve in the direction of its axis relatively to the nozzle so as to project beyond the mouth of the nozzle, the end of the projected sleeve thereby forming the effective mouth of the nozzle, whose cross-sectional exit area is correspondingly increased with consequent reduction in the velocity of the propulsive jet.

2. Turbo-compressor propulsive apparatus of the character set forth in claim 1 wherein the sleeve surrounding the propulsion nozzle has an outwardly flaring mouth.

3. Turbo-compressor propulsive apparatus of the character set forth in claim 1 wherein the sleeve surrounding the nozzle is constituted by at least two concentric tubular parts relatively movable telescopically.

4. Turbo-compressor propulsive apparatus of the type comprising a compressor, at least one combustion chamber into which air is delivered by the compressor and wherein fuel is burnt, a turbine driven by the gases from the combustion chamber, the turbine being coaxial with the said compressor to which it is connected and whereby the compressor is driven, and a nozzle from which the gases which have passed through the turbine issue with propulsive effect, in combination with an adjustable sleeve surrounding and spaced from the nozzle and constituted by at least two concentric tubular parts relatively movable telescopically, and means for sliding the parts of the sleeve relatively and causing a part of the sleeve to project beyond the nozzle and thereby increase the cross-sectional exit area of the mouth of the nozzle.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
719,849	Oberwalder	Feb. 3, 1903
1,140,259	Elliott et al.	May 18, 1915
2,102,559	Kadenacy	Dec. 14, 1937
2,402,363	Bradbury	June 18, 1946
2,408,099	Sherman	Sept. 24, 1946
2,418,488	Thompson	Apr. 8, 1947
2,487,588	Price	Nov. 8, 1949
2,501,633	Price	Mar. 21, 1950
2,503,006	Stalker	Apr. 4, 1950

FOREIGN PATENTS

Number	Country	Date
82,468	France	Dec. 7, 1868
577,949	Great Britain	June 6, 1946