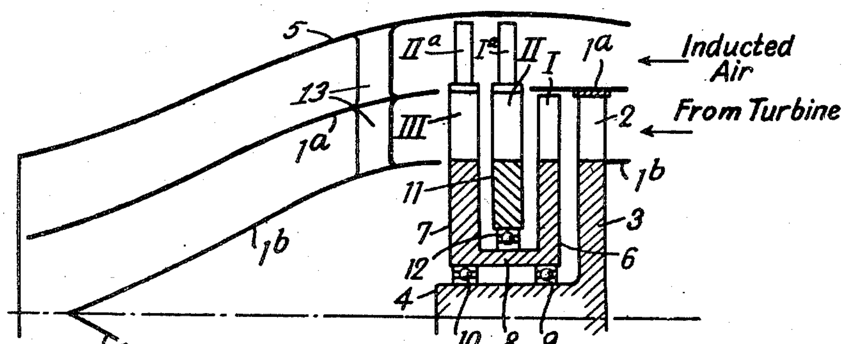

FIG. 1.

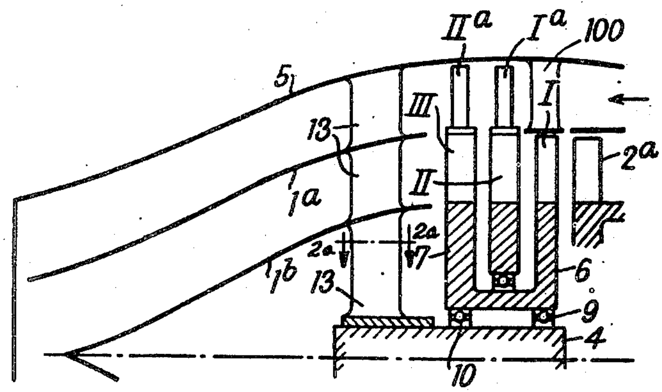

FIG. 2.

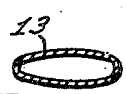

FIG. 2a.

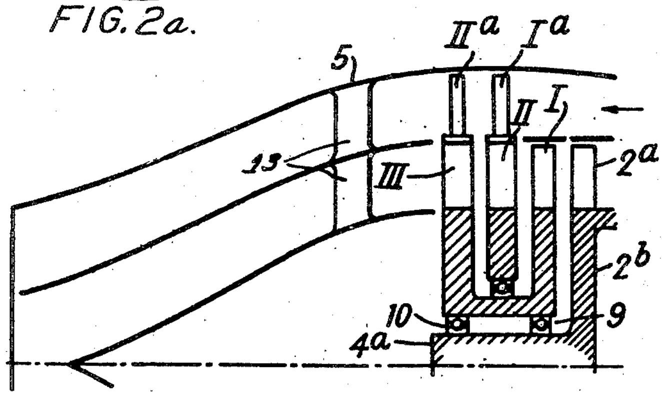

FIG. 3.

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AUGMENTOR FOR JET PROPULSION HAVING MORE ROWS OF TURBINE DRIVING BLADING THAN DRIVEN AIR BLADING

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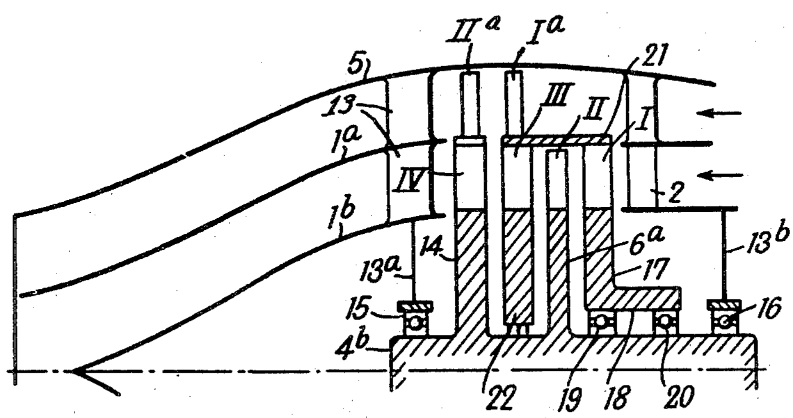

FIG. 4.

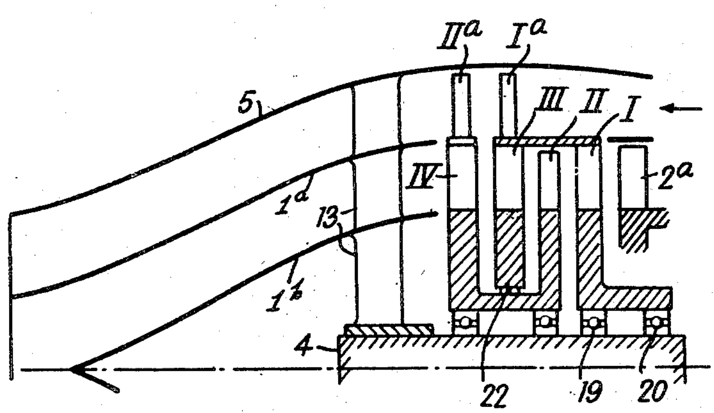

FIG. 5.

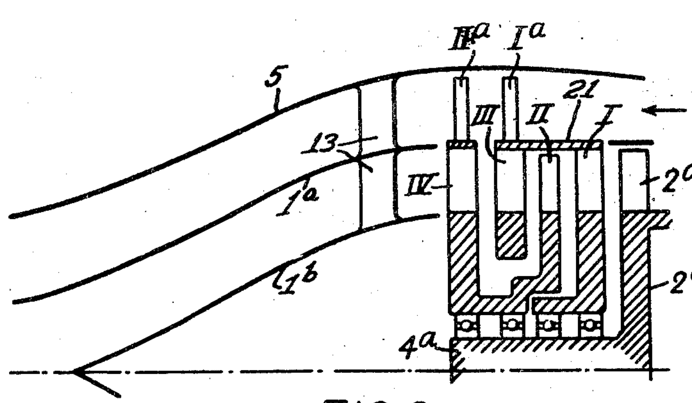

FIG. 6.

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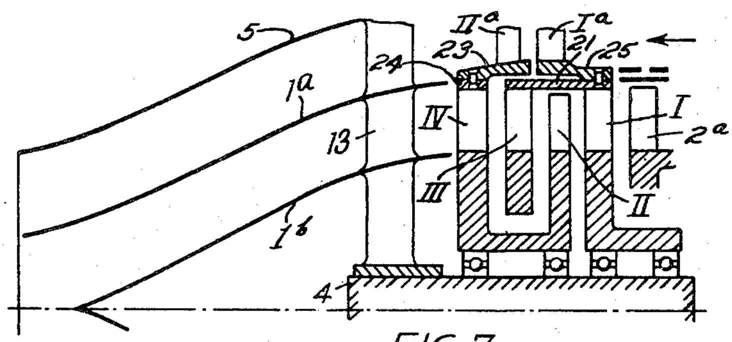

FIG. 7.

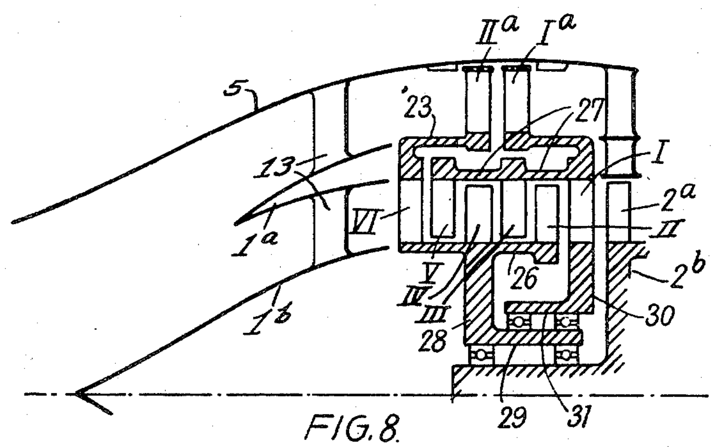

FIG. 8.

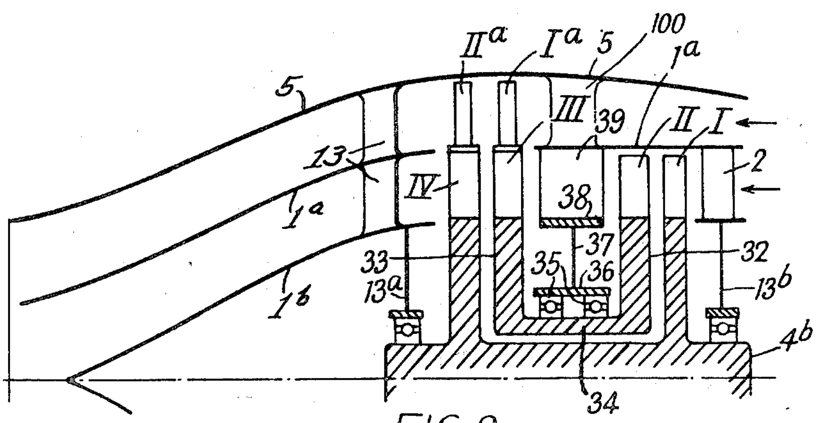

FIG. 9.

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AUGMENTOR FOR JET PROPULSION HAVING MORE ROWS OF TURBINE DRIVING BLADING THAN DRIVEN AIR BLADING

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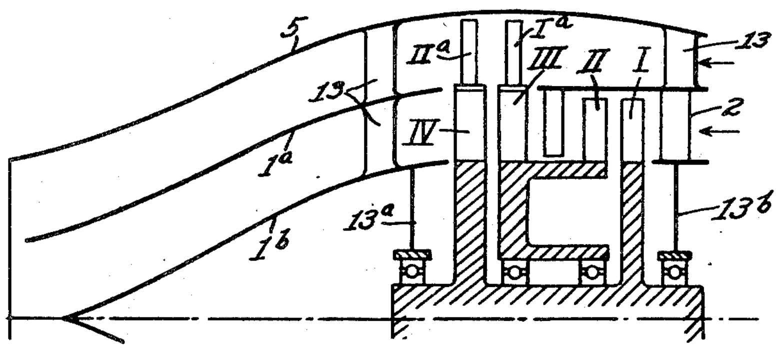

FIG. 10.

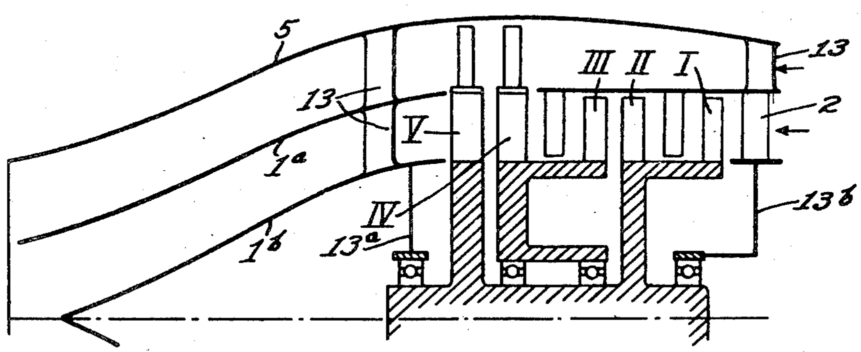

FIG. 11.

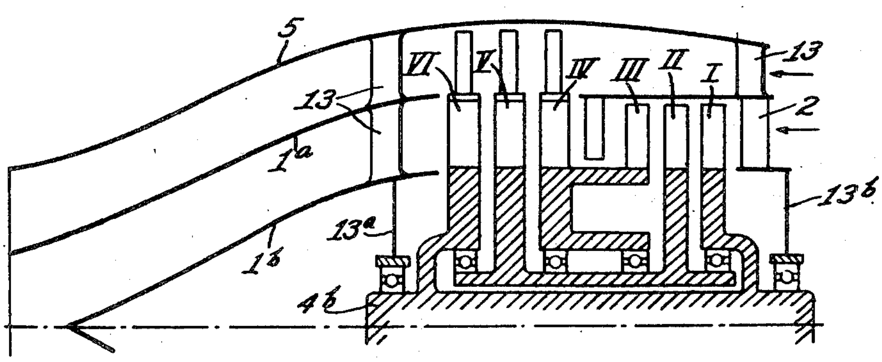

FIG. 12.

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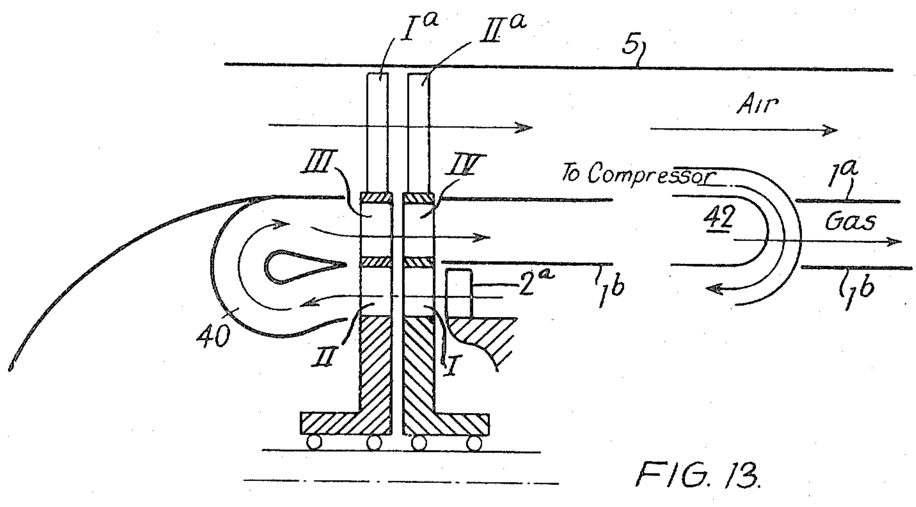

FIG. 13.

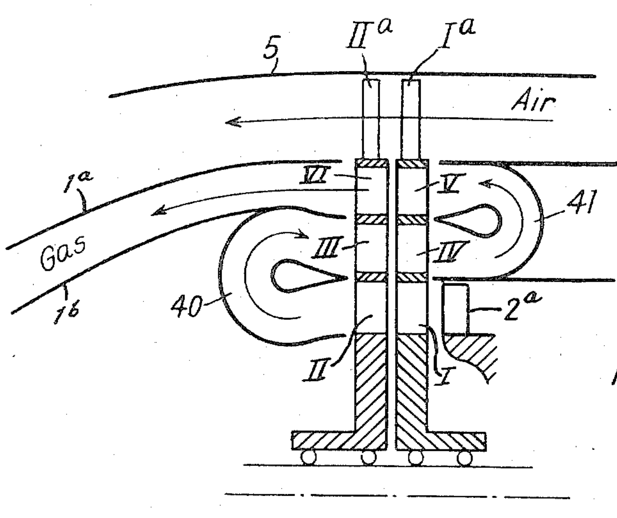

FIG. 14.

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AUGMENTOR FOR JET PROPULSION HAVING MORE ROWS OF TURBINE DRIVING BLADING THAN DRIVEN AIR BLADING

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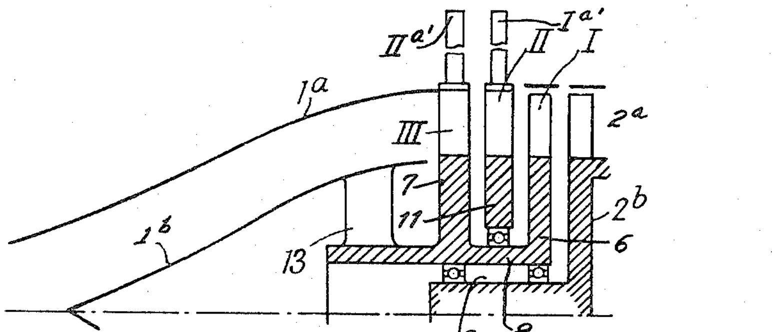

FIG. 15.

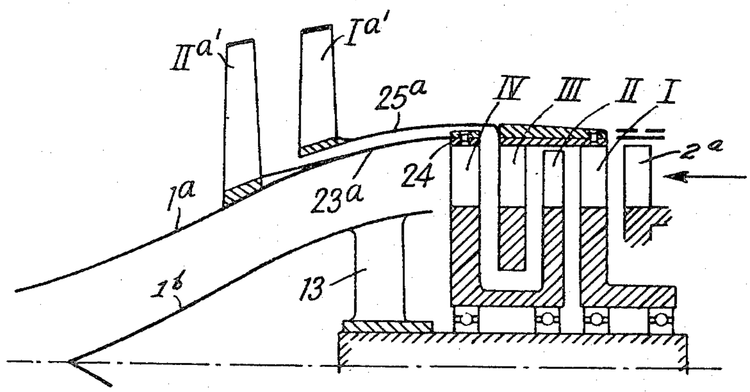

FIG. 16

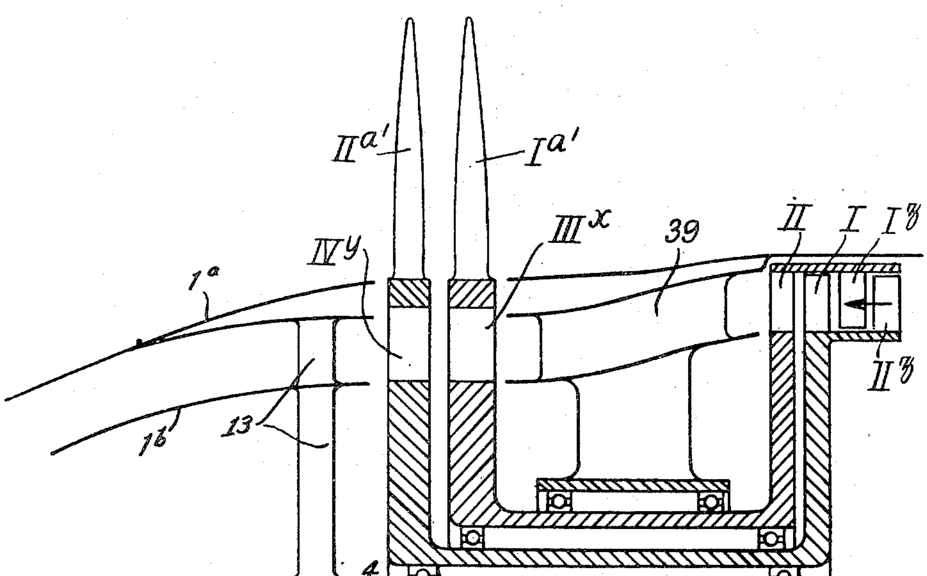

FIG. 17.

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AUGMENTOR FOR JET PROPULSION HAVING MORE ROWS OF TURBINE DRIVING BLADING THAN DRIVEN AIR BLADING

Filed Jan. 13, 1944 8 Sheets-Sheet 7

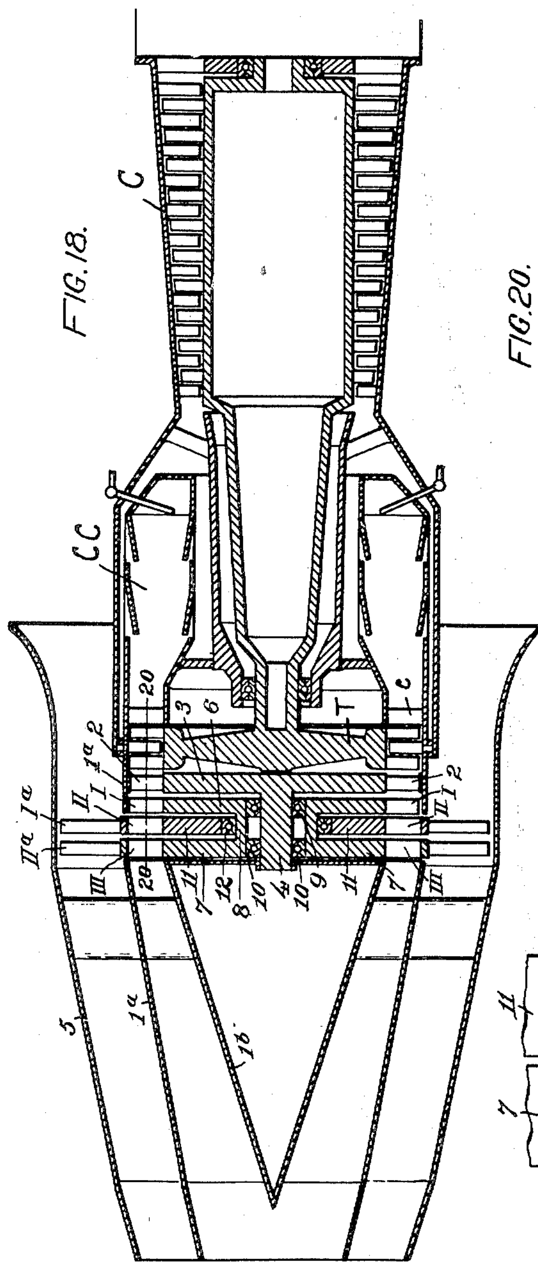

FIG. 18.

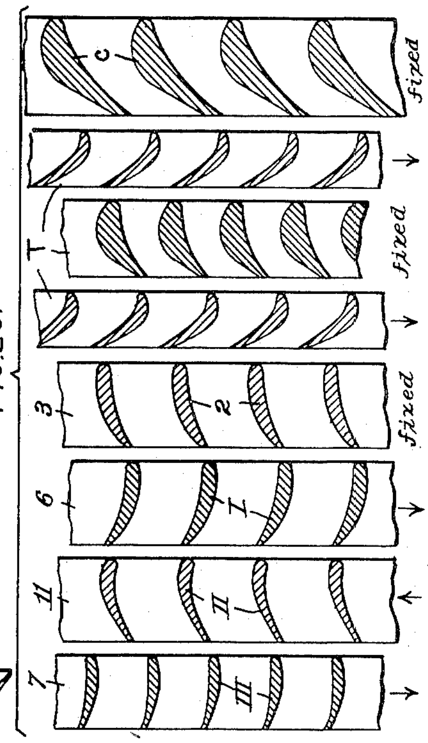

FIG. 20.

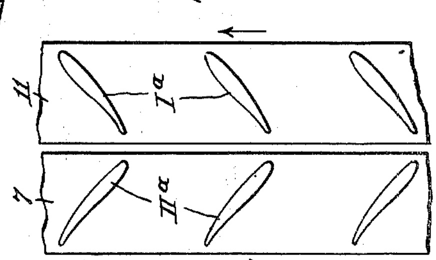

FIG. 19.

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Karl Baumann

BY

[signature]

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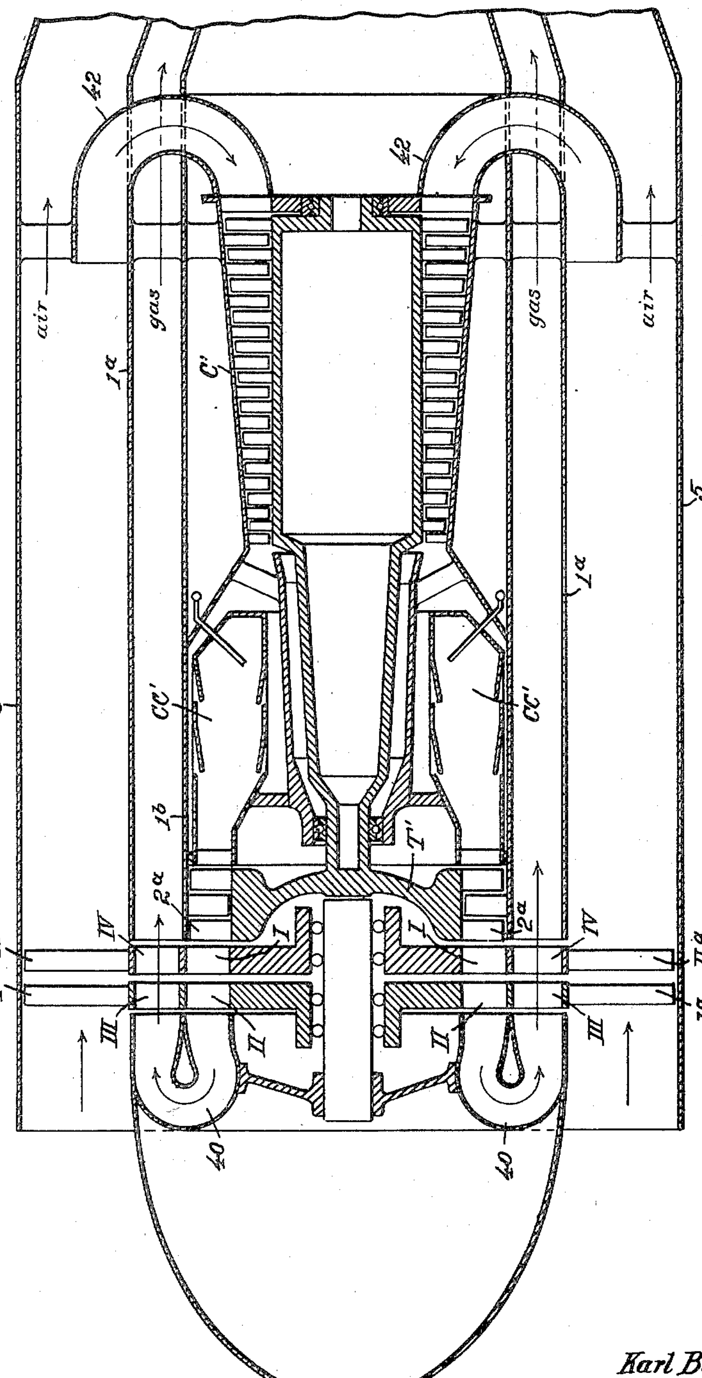

FIG. 21.

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Patented Apr. 25, 1950

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UNITED STATES PATENT OFFICE

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AUGMENTOR FOR JET PROPULSION HAVING MORE ROWS OF TURBINE DRIVING BLADING THAN DRIVEN AIR BLADING

Karl Baumann, Knutsford, England, assignor to Metropolitan-Vickers Electrical Company Limited, London, England, a company of Great Britain

Application January 13, 1944, Serial No. 518,165
In Great Britain October 14, 1941

Section 1, Public Law 690, August 8, 1946
Patent expires October 14, 1961

6 Claims. (Cl. 60—35.6)

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This invention relates to internal combustion power plant for propulsion in air of the kind wherein the energy in the rearwardly exhausting products of combustion is utilised at least to assist in the propulsion by so-called jet action, such plant being notably but not exclusively employed for the propulsion of aircraft.

The invention furthermore specifically concerns an internal combustion power turbine component operated by the exhausting products of combustion and arranged to drive or work upon air additional to that used for the internal combustion, whereby essentially to increase the propulsion effect in at least one way.

The present invention provides a thrust "augmentor" comprising in combination at least two coaxial contra-rotationally bladed turbine rotors all adapted to be driven by a flow of high velocity combusted gas, and each driving air screw or ducted fan blading which is at a greater mean diameter than that of the turbine blading, whilst at least one of said rotors has more turbine blading stages than air screw or fan blading stages.

The contra-rotational augmentor arrangement just above set forth according to the invention enables the weight of this part of the plant to be reduced because of the essentially relatively smaller number of air augmenting stages, there being more than two turbine stages, whereby to use efficiently at relatively low peripheral speeds the heat drop available in these turbine stages. This is an important aspect, since the peripheral speed of the air screws or fan stages is limited by reason of "compressibility effect," which causes a serious loss of efficiency when the relative veelocity of the air past the blades approaches the velocity of sound.

It will be appreciated furthermore, that by reason of the contra rotation of the stages the gyrostatic effect thereof is minimised, this being important when aircraft is required to change direction quickly. The fact will be appreciated that were the number of air screws or fan stages made equal to the number of stages of turbine driving them, the heat drop available per stage in the gas entering the contra-rotational turbine would be many times the heat rise per stage of the air screws or of the fan, while on the other hand the peripheral speed of the contra-rota-

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tional inner turbine stages is essentially lower than that of the air screws or fan blades. Whilst normally two rows of air screws or fan stages are sufficient for the acceleration or the compression (respectively) of the air required, more than two rows of turbine stages are essentially required to utilise efficiently the available energy in the gases such as the gases leaving the compressor turbine before further expansion in the jet nozzle.

While convenient arrangements of parts of the plant lead naturally to the adoption of a direction of flow of the products of combustion through the compressor turbine first and the power turbine subsequently, this order is in no way essential, and arrangements in which the flow is through the power turbine first and the compressor turbine subsequently, which latter then exhausts to the propelling nozzle, are within the scope of the invention, although not illustrated.

Several preferred embodiments of the invention will now be respectively described by way of example with reference to the accompanying drawings, which are purely diagrammatic views in conventional form illustrating different forms of "augmentor." For the sake of simplicity, such constructional details as glands, bearing seals, joints or flanges required for assembly, and so on, are omitted.

Fig. 1 is a radial section of the thrust augmentor and adjacent cooperative elements of an internal combustion turbine power plant according to one embodiment of the present invention, in which a row of fixed blading is interposed between the compressor and the power turbines.

Fig. 2 is a view similar to Fig. 1, but showing the last stage of the compressor turbine immediately adjacent to the intake of the power turbine, and illustrating modified means for supporting the bearings for the power turbine rotors.

Fig. 2*a* is a detail section on the line 2*a*—2*a* in Fig. 2.

Fig. 3 is a view similar to Figs. 1 and 2, but showing means carried by the last stage of the compressor for supporting the bearings for the rotors of the power turbine.

Fig. 4 is a radial section of the augmentor, showing another means for supporting the rotors of the power turbine.

Fig. 5 is a radial section of an augmentor which embodies the turbine stage arrangement of Fig. 2

combined with that shown in Fig. 4 to provide a four stage arrangement.

Fig. 6 is a radial section of another form of four stage arrangement for the power turbine.

Fig. 7 is a view similar to Fig. 6, but showing a modified arrangement of the fan blading relatively to the rotors of the power turbine.

Fig. 8 is a radial section of a six stage power turbine blading.

Fig. 9 is a view of a four stage arrangement similar to that shown in Fig. 4, but showing modified means for supporting the bearings for the second and third stages.

Fig. 10 is a radial section of a modified arrangement of a four stage power turbine rotors employing stationary guide blading.

Fig. 11 is a view similar to Fig. 10, but employing five stages and a modified arrangement of the stationary guide blading.

Fig. 12 is a view similar to Figs. 10 and 11, but showing a six stage power turbine.

Fig. 13 is a radial section of a portion of a multiple tier blading for the turbine of the augmentor, and showing a cross-over air duct leading to the combustion air compressor.

Fig. 14 is a view of a multiple tier blading similar to that shown in Fig. 13, but showing modified duct arrangement for gases exhausted from the power turbine.

Fig. 15 is a radial section of an augmentor similar to that shown in Fig. 3, but showing unshrouded air screws, and in which the nozzle walls are rotatable with a stage of the power turbine.

Fig. 16 is a radial section of another form of augmentor, in which one of the nozzle walls is rotatable with a stage of the power turbine, and showing a modified mounting of the air screws on the rotors of the power turbine.

Fig. 17 is a radial section of a form of augmentor similar to that shown in Fig. 9, but showing a modified arrangement of the rotors of the power turbine for driving air screws, and employing additional turbine blading.

Fig. 18 is a diagrammatic longitudinal section of an internal combustion power turbine plant for jet propulsion, embodying the thrust augmentor of Fig. 1.

Fig. 19 is an enlarged detail view of a portion of the fan blading of the augmentor shown in Figs. 1 and 18.

Fig. 20 is an enlarged section of a portion of the turbine blading, taken on the line 20—20 in Fig. 18.

Fig. 21 is a longitudinal section of an internal combustion turbine plant embodying the structure shown in Fig. 13.

Similar parts are designated by the same reference characters in the different figures.

Referring to Figs. 1, 18, 19 and 20 of the drawings, at *1a* and *1b* are shown annular walls which constitute the entry to the final expansion jet for propulsion by the exhaust gases from the internal combustion turbine T for driving the compressor C, the compressor turbine being located immediately to the right in Fig. 1 (and all the other figures) so that the exhaust from the compressor turbine is connected with the right-hand end of the annular wall members *1a* and *1b* although as shown in Figure 1, there may be interposed between the compressor turbine and the power turbine of the present invention a row **2** of fixed blading which can be carried by a diaphragm **3** having integal with it or fixed to it a non-rotating stub axle **4**. The compressor turbine T is arranged to receive combusted gases from the combustion chamber CC through an annular row of fixed blading *c* in the discharge duct of the combustion chamber.

The augmentor shown in Figs. 1, 18, 19 and 20 has three contra-rotational stages of power turbine blading (in this case low pressure) and two stages of fan blading, the latter being located in the annular duct between the annular wall member *1a* and an outermost wall **5** into the right-hand end of which duct the air to be power driven may enter as shown by the upper of the two arrows in Fig. 1. As hereinbefore mentioned, when the stages indicated at I*a* and II*a* are air screws the outermost wall **5** will be omitted. The air screws may assume various shapes as desired: they may be in the form of propellers.

In Figures 1 to 12, and 15 to 20, the stages of the "augmentor" of both power turbine and fan or air screw are counted from right to left namely in the direction of air or gas flow, and are all indicated by Roman numerals.

In Figures 1, 18, 19 and 20 the first and last augmentor turbine stages I and III are carried by discs **6** and **7** respectively, rigid with a sleeve shaft **8** having ball bearings **9** and **10** the inner races of which are carried by the stub axle **4**. The middle row of turbine blading II is carried by a disc **11** having a ball bearing **12**, the inner member of which is carried on the outer periphery of the sleeve shaft **8**.

The contra-rotational ducted fan stages (or it may be alternatively air screws) are shown at I*a* and II*a*, these constituting with the stages II and III of turbine blading "double tier" stages.

In the arrangement illustrated by Figure 1, and in Figures 18, 19 and 20 it will be seen that according to one aspect of the invention the second stage II*a* of fan blading is rotated by the two stages I and III of turbine blading, whilst the first stage I*a* of the fan blading is rotated by the middle stage II of the power turbine.

The arrangement shown in Figure 2 differs from that shown in Figure 1 in that there is no fixed guide blading **2**; at **2***a* is indicated the last rotating stage of the compressor turbine, whilst the axle **4** instead of extending from the fixed diaphragm **3** is carried through radial webs, which are preferably streamlined with respect to the gas and air flow, by the wall members *1b*, *1a* and **5**, one of these webs being indicated at **13** and streamlined as shown in Fig. 2*a*. These or equivalent webs may be assumed to be used in all of the illustrated arrangements, as and where necessary.

By reason, as preferred, of the immediate juxtaposition of the final blading row **2***a* of the compressor turbine and the first row I of the power turbine rotating in the opposite direction, it becomes convenient to utilise a greater heat drop in the blades **2***a* and to discharge the gas from those blades with a velocity relatively to the non-rotating structure which has a tangential component in the direction of movement of the adjacent power turbine blading I while arranging the cross sectional contours and speeds of this and the succeeding blade rows II and III in such manner that the gas shall leave the blades III in substantially an axial direction. Associated with this acceptance by the power turbine of swirl in the incoming gas, corresponding provision can be made in the ducted fan for a change of tangential component of air velocity during passage through the two fan stages, for instance by the introduction of guide blades **100** at the inlet, or by constituting the webs **13** in the form of guide blades, or by both means. It will be appreciated that the relative tangential component of air velocity involved will be much less than that of the gas made use of in the power turbine on account of the greater rate of flow by weight of air than of gas.

The arrangement shown in Figure 3 only differs from the arrangements shown in Figures 1 and 2 in that the ball bearings 9 and 10 for the power turbine stages III and I have their inner races associated with a shaft extension 4a carried by or integral with the disc 2b carrying the blading 2a, being the last stage of the compressor turbine.

It will be appreciated that in the arrangements shown in Figures 2 and 3 the power turbine stages I and III rotate in the opposite direction to that of rotation of the final stage 2a of the compressor turbine. It will also be noticed that the fan blading stages IIa and Ia are associated with the lowest pressure power turbine stages II and III: whilst this is preferred it is not essential as will hereinafter appear.

Referring to Figure 4, it will be seen that the second stage IIa of the fan blading is driven by the fourth stage IV of the power turbine blading carried by a double tiered disc (or equivalent) 14 fixed on a central shaft 4b which is carried at each end from the fixed wall member 1b and the housing of a row of stationary guide blading 2 by radial members or discs 13a, 13b through ball bearings 15, 16 respectively. The blading of the second turbine stage II is carried on a disc or equivalent 6a also secured to the shaft 4b. The first stage I of turbine blading is carried by a disc 17 integral with or connected to a sleeve shaft 18 which is carried through ball bearings 19 and 20 by the shaft 4b.

The first fan blading stage Ia and the third power turbine blading stage III are both carried at one end of a sleeve 21 the other end of which is carried by the outer periphery of the power turbine blading stage I. The inner periphery of the turbine blading stage III is secured to or integral with a diaphragm 22 or an inner foundation ring. The row of stationary guide blading 2 shown is similar to the guide blading shown in Fig. 1.

Figure 5 shows a four turbine stage augmentor combining features of the three turbine stage arrangement of Figure 2 and the four turbine stage arrangement of Figure 4, as will be readily apparent from an inspection of Figure 5, a specific description of which is therefore considered unnecessary.

The arrangement of Figure 6 shows another four stage power turbine embodying features of earlier figures, as will be readily apparent from an inspection of Figure 6 so that again a specific description thereof is considered unnecessary.

Figure 7 shows an arrangement which differs from the arrangement shown in Figure 6 in the feature that the fan blading stages Ia and IIa are, so to speak, shifted to be in the centre of the length of the axial turbine stages, namely by carrying the blading stage IIa at the right-hand end of a foundation ring or cylinder 23, the left-hand end of which is riveted or otherwise fixed to the outer ring 24 of the turbine blading stage IV. The fan blading of stage Ia is similarly fixed to the left-hand end of a ring 25 which at its right-hand end is fixed to the sleeve 21 (see Figures 5 and 6). The fan blades need not however be located as shown; they may for instance both be located upstream or downstream relatively to the power turbine stages, and in the latter case the blade root diameter may be smaller than the tip diameter of the turbine blades.

The arrangement shown in Fig. 8 differs from earlier arrangements in the main in that there are six stages of power turbine blading, alternate stages being carried by inner and outer rotor cylinder members 26 and 27 respectively. The rotor cylinder 26 is shown as being carried centrally along its length by a disc 28 fixed to a sleeve shaft 29. The rotor cylinder 27 is shown as carried from its end through the blading stage I by a disc 30 fixed to a sleeve shaft 31 coaxially surrounding the sleeve shaft 29, the two rotors having bearings as shown.

It will be understood that the disc members 28 and 30, in fact any of the disc members shown in any of the figures, may if desired be replaced by annularly dished discs giving in relation to their weight, considerable stiffness in the axial direction but permitting some flexibility in the radial direction relatively to the non-rotating structure.

Figure 9 shows an arrangement having four stages of turbine blading, the first and fourth of which are carried, (generally after the manner shown in Figure 4) from a central shaft 4b. The second and third turbine stages are shown as carried by discs 32 and 33 which at their inner peripheries are connected to a sleeve shaft 34. This shaft is carried in bearings 35 the outer races of which are carried by a sleeve 36, in turn carried by a disc or the equivalent 37 the outer periphery of which is carried by a sleeve or foundation ring 38 for a row of fixed guide blading 39. The outer periphery of this guide blading 39 is carried by the annular duct wall 1a and preferably connected by webs 100 with the outer wall 5.

Figures 10, 11 and 12 show further arrangements the features of which will be readily apparent upon inspection, after perusal of the majority of the description of the arrangements of the earlier figures; therefore no specific description is considered necessary of Figures 10, 11 and 12.

Referring to Figures 13 and 14, these show "augmentor" arrangements embodying inter alia multiple tier turbine blading involving, as will be readily apparent from inspection of these figures, the reversal of flow of the gases from the compressor turbine T′, the final stage of which is indicated at 2a, the reversal of flow taking place in annular duct 40 in Fig. 13 and in ducts 40 and 41 in Fig. 14. At 42 in Figs. 13 and 21 there is indicated a curved, cross-over air duct leading to the combustion air compressor C′ which duct may tap off air in the annular duct 1a, 5 and augmented by the contra-rotational fan blading stages Ia and IIa. The compressor C′ delivers compressed air to a combustion chamber CC′ which discharges products of combustion therefrom to the compressor turbine T′, the latter discharging the products of combustion to the stages I and II and then through the duct 40 to the stages III and IV of the power turbine.

Such multiple-tier arrangements can clearly be applied in combination with arrangements illustrated in the preceding figures.

Referring next to Figure 15, it will be apparent that so far as the power turbine is concerned, the arrangement is generally the same as that shown in Figure 3 but differing merely pictorially in that the ducted fan blades Ia and IIa of Figure 3 are here unshrouded air screw blades Ia′

and IIa', the outer nozzle member 5 being omitted: also, as an example, the nozzle wall 1a (of Figures 1 to 12) is shown as rigidly attached to the outer shrouding of the power turbine stage III as by welding, as shown so as to rotate solidly with the latter.

In the arrangement illustrated by Figure 16, the unducted but not necessarily individually unshrouded air screws Ia' and IIa' are driven by the arrangement substantially as illustrated by Figure 7 but, apart possibly from the omission of the outer nozzle wall 5, and outer part or parts of the radial webs 13 the ring or cylinder 23 (of Figure 7) is modified to extend left-wardly as at 23a, whilst the ring 25 of Figure 7 is made longer as shown at 25a in Figure 16, to bring the air screw stage Ia close to the stage IIa: furthermore the nozzle wall 1a may be solidly connected at its right-hand end to the shrouding 24 as by riveting it thereto as shown.

Referring lastly to Figure 17, it will be seen that the arrangement here illustrated is in principle the same as certain of the arrangements previously herein illustrated, and the augmenting air blading is in the form of propellers Ia' and IIa', these latter being associated with the power turbine stage IIIx and IVy as double tier members, the turbine stages IIIx and IVy receiving the gases from the stages I and II through fixed guide blading 39. It may be that in practice the blading stages IIIx and IVy might pass the gases without much work being done on this blading, or IIIx and IVy may represent simple orifices: in either case it will of course be necessary to provide additional turbine blading stages which are indicated at Iz and IIz mounted as shown.

In Figures 15 and 16 the walls 1a and 1b of the nozzle are shown as fixed to the final rotor stage so as to rotate therewith, and in Fig. 15 the wall 1b is shown as fixed to the sleeve 8 of the final rotor by the web 13, and it will be appreciated that if found convenient the innermost wall member 1b in Fig. 16 may also be rigidly fixed to a final rotor, as by the web 13 as shown in Fig. 15, or fixed similarly to any rotor having a sleeve which extends beyond the final rotor stage.

I claim:

1. A propulsion system for aircraft comprising an air compressor, a combustion chamber connected to said chamber to receive air therefrom, a first turbine arranged to receive combusted gases from said chamber and connected to said compressor for driving the latter, a reaction jet thrust nozzle, an inner annular duct for conducting combusted gases exhausted from said turbine to said nozzle, an outer annular duct leading to said nozzle, and a second turbine disposed between said first turbine and said nozzle for augmenting the thrust due to the flow of combusted gases through said nozzle and for reducing the velocity of such flow, said second turbine comprising two contrarotational rotors

carrying an inner tier of driving blading rows arranged in said inner annular duct to be operated on by said combusted gases and an outer tier of driven blading rows arranged in said outer annular duct, at least one of said rotors having a plurality of driving blading rows driving a smaller number of driven blading rows.

2. A propulsion system as defined in claim 1, wherein said air compressor, combustion chamber and first and second turbines are aligned axially with said jet nozzle, and including ducts for straight through flow of air from the compressor to the combustion chamber and of combusted gas from the combustion chamber to the jet nozzle.

3. A propulsion system as defined in claim 1, wherein the driving blading rows on the respective rotors of said second turbine are spaced axially and the rows of driving blading rows of said rotors are in adjacent relation, and including a row of relatively fixed guide blading mounted between the axially spaced rows of driving blading rows on said rotors.

4. A propulsion system as defined in claim 1, wherein the driving blading rows of said second turbine are arranged in successive tiers, and including means for reversing the direction of flow of gas through successive tiers.

5. A propulsion system as defined in claim 1, wherein the driving blading rows of said second turbine are arranged in successive tiers, and including means for reversing the direction of flow of gas through successive tiers, and ducts leading from said outer annular duct to said compressor for supplying air to the latter.

6. A propulsion system as defined in claim 1, wherein the driving blading rows of said second turbine are spaced axially from the blading of said first turbine, and including a fixed row of guide blading mounted in the space thus provided.

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