PATENT SPECIFICATION

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471,368

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PROVISIONAL SPECIFICATION

Improvements relating to the Propulsion of Aircraft

I, Frank Whittle, of Blackamoors, Harston Road, Trumpington, Cambridgeshire, British Subject, do hereby declare the nature of this invention to be as follows:—

This invention refers to apparatus, the function of which is to provide a supply of working fluid at a pressure above that of the atmosphere for the purpose of doing useful work in its subsequent expansion, as for example in a turbine, or through the propelling jet of an aircraft propelled by fluid reaction, or through the reaction jets of an airscrew acting as a reaction turbine in the manner of a " Barker's Mill ".

A known form of such an apparatus is one in which a centrifugal compressor compresses air into a combustion chamber wherein it is heated at a constant pressure by the burning of a suitable fuel, the heated products of combustion then expanding through the nozzles of a turbine, the function of which is to drive the compressor and necessary auxiliaries.

The fluid leaving the turbine, being capable of further expansion, forms a supply of working fluid for the production of power in various ways, such as those cited above.

The purpose of this invention is to provide improved apparatus for the same purposes. The primary object is to provide a great mass flow of the working fluid as possible in proportion to the size of the mechanisms employed, in order that certain losses, such as fluid friction loss, shall be kept as low as possible in all components.

The high mass flow is particularly desirable in the case of the propulsion of aircraft by fluid reaction, in order that the jet velocity shall be as low as possible for a given thrust.

According to the invention, a double thermal cycle is employed, the whole of the working fluid passing through a " lower cycle ", and a portion of the working fluid passing through a " higher cycle ".

The lower cycle consists of a compression to an " intermediate pressure " and an expansion back to atmospheric pressure after expansion at the intermediate pressure as a result of a portion of the fluid having passed through the higher cycle.

The higher cycle consists of a compression from the intermediate pressure, a heating by the combustion of a suitable fuel and an expansion back to the intermediate pressure.

The work of expansion in the higher cycle provides the power for the whole of the compression and for the drive of necessary auxiliaries. The work of expansion of the lower cycle represents the energy content available for any suitable purpose.

The mechanism by which the various operations are performed may be of any suitable type and may incorporate known features to improve the efficiency or power, such as heat interchangers, or additional fuel combustion at the intermediate pressure, and/or at suitable points in the expansion of the higher cycle.

Describing the invention in one form deemed suitable for the propulsion of aircraft either by direct fluid reaction, or by gas turbines driving airscrews, or by airscrews driven by reactive jets at their tips; air slightly precompressed by virtue of the forward speed of the aircraft is compressed to the intermediate pressure by a suitable mechanical compressor. From this compressor the air passes into an intermediate pressure chamber. From the intermediate pressure chamber a portion of the air is compressed in a second compressor; the air leaving the second compressor passes through a heat interchanger and into a combustion chamber where it is heated by the constant combustion of a suitable fuel. From the combustion chamber the heated products of combustion expand through one or more turbine wheels coupled directly or geared to the compressors. The exhaust from the turbine or turbines passes through the heat interchanger to give up some of its heat to the compressed air leaving the second compressor, and thence back into the intermediate pressure chamber to mix with the remainder of the

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working fluid, the whole then forming a supply of working fluid capable of further expansion.

In more particularly describing the invention in a form suitable for aircraft propulsion by fluid reaction, air is taken into the aircraft through a diverging passage wherein the kinetic energy which the air possesses relative to the aircraft by virtue of the forward speed is partially or wholly converted into pressure. This slightly compressed air is then further compressed to an intermediate pressure by a centrifugal compressor of moderate speed whence it passes to the intermediate pressure chamber. A portion of the air from the intermediate pressure chamber is then compressed in a second high speed centrifugal compressor and passed through a heat interchanger into a combustion chamber where it is heated by the constant combustion of oil fuel. It then expands through two impulse turbines, each driving a compressor. The exhaust from the turbines then passes through the heat interchanger, and into the intermediate pressure chamber, where it mixes with the remainder of the working fluid. The whole of the working fluid then expands through a nozzle discharging rearwardly, to provide thrust by fluid reaction.

In order that the mass flow is as great as possible inproportion to the size of the components, it is deemed particularly desirable that both compressors should be of the type with bilateral intakes.

The high speed compressor has an impellor with a large number of straight radial blades formed on a suitably shaped central disc which has tapering extensions forming strengthening ribs at the back of each radial blade. The impellor also has a large number of rotating guide blades to impart the initial change of angular momentum to the inspired fluid, the said guide blades being of a number and shape the most suitable for this purpose.

The compressor has a bladeless discharge ring of substantial radial dimensions, and a second diffuser stage formed by a diverging passage or groups of diverging channels.

The moderate speed compressor may be similarly constructed, but considerable latitude is possible owing to the less severe conditions under which it operates.

The above describes one form of the invention, but there are many possible variations. For example, the compression of the lower cycle may be formed in two or more compressors, working in parallel, either driven by separate turbines or by a single turbine, or multi stage compressors may be used instead of the single stage compressors described, or again the compression of the lower cycle may be wholly or partly performed by screw type axial flow compressors. Again all compressors may be driven by a single turbine, or where more than one turbine is employed, the expansion may take place through them either in parallel or in series.

An example of one such modification suitable for the propulsion of aircraft by fluid reaction is one in which two compressors working in parallel perform the compression of the lower cycle, and a single high speed compressor performs the compression of the higher cycle, each compressor being driven by separate turbines in parallel. In this arrangement the two lower cycle compressors with their drivers are housed in nacelles carried on the wing structure, while the high speed compressor and its driver is housed in the hull or fuselage; each turbine being fed from a separate combustion chamber. The propelling nozzles would then be at the rear of each nacelle.

Another form of the invention is one in which the higher cycle is wholly performed in any well known type of internal combustion engine.

Describing a particular example of such a form, a compression ignition engine drives an air compressor which delivers air under a moderate pressure to a chamber from which the engine inspires and into which it exhausts; only a portion of the air at the intermediate pressure passing through the engine. The engine may have a normal supercharger in addition to the main compressor. The fluid from the intermediate pressure chamber may then be used for any desired purpose, such as the working fluid supply for one or more turbines. It can be shown that the thermal efficiency of such a combination may be as much as 30% greater than for the engine working alone, and for that reason such a power plant would be very suitable for the propulsion of long range aircraft at moderately high altitudes.

In all applications of this invention the shape and arrangement of the intermediate pressure chamber is such that the flow of the fluid will not permit the products of combustion to enter the intake of the higher cycle compressor. For normal purposes it would be sufficient to arrange that the higher cycle compressor inspires from the intake end of the intermediate pressure chamber while the products of combustion enter near the discharge end, but for starting, when there may not be a natural flow preventing the products of combustion from entering the compressor intake, it may be necessary to arrange an adjustable butterfly valve in the intermediate pressure chamber, whereby the intermediate pressure chamber may be temporarily divided into two parts.

The supply of working fluid which results from any of the described arrangements of the invention may be further heated before final expansion of the combustion of additional fuel. Such a modification may provide a useful means of dealing with a temporary overload.

The invention may include any other devices necessary for its efficient operation, such as electric starter motors or hand starting means, fuel ignition devices, fuel pumps, pumps for lubrication, water jackets for the turbine wheelcases and other parts, fuel heaters, radiators, throttles or other suitable governing means, and any other necessary or desirable auxiliaries.

March 3rd, 1936.

F. WHITTLE.

COMPLETE SPECIFICATION

Improvements relating to the Propulsion of Aircraft

I, FRANK WHITTLE, a British Subject, of "Blackamoors", Harston Road, Trumpington, Cambridgeshire, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention refers to apparatus, the function of which is to provide a supply of working fluid at a pressure above that of the atmosphere for the purpose of propelling an aircraft by fluid reaction, such propulsion being commonly known as "jet propulsion".

A known form of such an apparatus is one in which a centrifugal compressor compresses air into a combustion chamber wherein it is intended to be heated at constant pressure by the burning of a suitable fuel, the heated products of combustion then expanding through the nozzles of a turbine, the function of which is to drive the compressor and any desired auxiliaries. The fluid leaving the turbine, being capable of further expansion, form a supply of working fluid for the production of power in various ways, such as that cited above.

In a reaction propulsion system for boats or aircraft, a prior proposal is the provision of a compressor followed by a burner and delivering through propulsion nozzle means, the compressor being fed by fluid taken in at a pressure created by movement of the whole vehicle in the fluid medium, and it is mentioned that the internal combustion engine which drives the compressor may be fed by part of its output.

The term "internal combustion engine" in the following statements includes any engine which compresses air, effects combustion in it, and is operated by the expansion of the combustion products, and thus includes a reciprocating internal combustion engine or a compressor-burner-turbine combination in which the turbine drives the compressor.

The purpose of this invention is to provide an improved system, apparatus, or power unit, for the same purpose. The primary object is to provide as great a mass flow of the working fluid as possible in proportion to the size of the mechanisms employed, in order that certain losses, such as fluid friction loss, shall be kept as low as possible in all components.

High mass flow is particularly desirable in the case of propulsion of aircraft by fluid reaction, in order that the jet velocity shall be as low as possible for a given thrust, and it is to this purpose that the invention is primarily applicable.

According to the invention, there is combined in a fluid-reaction propulsion system for aircraft an air compressor which in effect divides the output from the compressor into a first stream which is passed out through a propulsion nozzle and a second stream, an internal combustion engine supplied by the second stream, and a gas turbine supplied wholly or partly by the effluent gas from said engine and driving the said air compressor. In this system the combustion products of the engine preferably contribute to the thrust by fluid reaction, for example joining the main flow from which they were originally diverted before combustion. The engine referred to may be a compressor-burner-gas turbine combination. The system is embodied, in accordance with the invention, in a unit for aircraft propulsion, and this in two examples takes the form diagrammatically illustrated in the drawings. Where a gas turbine is employed it may be adapted to operate with a plurality of stages of compression of the kind in which the compressor means is in the form of a bilateral intake centrifugal compressor and may generally follow the form described in relation to my British Patent Specification No. 456,980. It may be convenient to provide the whole device in the form of a unit comprising hollow nacelle with an entry opening to face the direction of travel (whereby incidentally a certain head of pressure termed "Pilot pressure" may be derived) and in such nacelle all those components apt to lose heat may be completely housed to conserve energy. The invention is further to be understood by reference to the following description. Where the description or claims seem to refer to the whole or a determined part, of a flow, it is to be understood that a portion thereof may be separated and utilised for such purposes as driving auxiliaries, cabin heating, etc.

The accompanying drawings diagrammatically illustrate applications of the invention:

Figure 1 is a partial section in plan of a twin aircraft propulsion system, employing a type of combustion unit more fully explained in my British Patent Specification No. 456,980;

Figure 2 is a partial elevation section of a further alternative example.

Referring to Figure 1 there is illustrated what may be termed a twin apparatus, that is, it is symmetrical about a central line. For aircraft use it may be important to select the directions of rotation of rotatable parts, having regard to their gyrostatic reactions. Considering this apparatus as comprising virtually a port and a starboard intake and accompanying reaction jets, only one side will be described, the other, apart from any question of rotational direction, being substantially identical. The initial compressors are of the axial flow single-stage type, whilst the internal combustion engine includes a constant pressure gas turbine of the type described below. The arrangement involves a first stage axial flow compressor 50 supplied by an annular intake orifice 51, and discharging into a nacelle 52 within which, behind the compressor 50 is driving gear 53 powered by a shaft 54 connected to a driving turbine 55 within a casing 56A. The main flow created in the first place by the compressor 50 and subject to any Pitot pressure at 51 of which advantage can be taken, passes rearwardly through the nacelle 52 to emerge from the nozzle 52A. The flow from the compressor 50 is divided; part of it is diverted, (and any suitable guiding means such as baffles may help to divert it) into a lateral trunk 56 which is common to both starboard and port nacelles. Within the trunk 56 is housed a two-stage bilateral intake compressor, a fuller description of which can be found in my British Patent Specification No. 456,976. In short, this comprises twin first stage compressors 57 outputting to the second stage compressor 58. From the secondary diffuser of the compressor 58 the second stage output is led as indicated by the arrow 59 to the delivery chamber 60 of a turbine, the mechanical output of which drives the compressor shaft 61 common to both 57 and 58. In the passage indicated by the arrow 59 is a combustion chamber with any suitable fuel-burning means, arranged for example somewhat in the manner of that described in relation to the above numbered Specification. This unit comprising compressor means, combustion means, and turbines, is an internal combustion engine. It is here noted that as between port and starboard sides of the whole apparatus the working directions must of course be appropriate for both port and starboard turbines to drive the shaft 61 mutually. The combustion effluent expands through the vanes of the gas turbine rotor 62 and by a passage 63, 64, 65 is delivered to the nozzle scroll of the turbines 55 through which these gases 8 expand further rejoining the main flow in the nacelle 52 through the exhaust 66.

In the alternative illustrated diagrammatically in Figure 2, the propelling unit comprises a nacelle or duct 30 with a forwardly facing entry 30A and a rearwardly facing exit or propulsion nozzle 30B. This nacelle encloses within its entry 30A an axial flow compressor with rotor 31 driven by a shaft 32 from an axial flow turbine rotor 33. In practice there will be step-down gearing between the turbine 33 and rotor 31. Also within the nacelle 30 is a compression ignition engine represented at 34; this engine drives through its gear box 34A a centrifugal bilateral intake compressor 35 with its intakes (indicated by arrows) collecting from the interior of the nacelle 30. The output of the compressor 35 is led by a duct indicated at 36 which leads such output in the direction of the arrows 36A to the nozzle scroll 37 of the turbine 33, the effluent therefrom escaping through the duct 38 and a rearwardly facing propulsion nozzle 39 with such energy as remains after passage through the turbine 33. This unit therefore consists in a first compression with divided output, a second and centrifugal compressor intaking the diverted flow of air, driven by and supplying part of its air output to the compression ignition engine 34, the exhaust from which rejoins the rest of the air supply for the said second compressor to form the working fluid in the turbine 33. To this end the engine 34 has its air intake 34B in the duct 36A and its exhaust 34C returning to that duct. The engine 34 may also have its own supercharger, and of course its own auxiliary apparatus. The whole output of the first compressor is finally employed for reaction propulsion.

It may be found possible to enhance the propulsive efficiency by deriving some or all of the air flow from the boundary layer at or over any desired part of the structure; and it may also be possible to make use of the discharged gases to modify or improve aerodynamic effects.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. In a fluid reaction propulsion system for aircraft, the combination of an air compressor, an arrangement which in effect divides the output from the compressor into a first stream which is passed out through a propulsion nozzle and a second stream, an internal combustion engine supplied by the second stream, and a gas turbine supplied wholly or partly by the effluent gas from said engine and driving the said air compressor.

2. A system as set forth in Claim 1, in which the combustion products of the engine also contribute to the thrust by fluid reaction.

3. A system as set forth in Claim 2, further characterised in that the combustion products rejoin the remainder of the compressor output before final expansion.

4. A system according to Claims 1, 2, or 3, having a plurality of compressors each with its own related driving turbine, mutually combined with a single internal combustion engine.

5. A system according to any previous claim, in which the engine itself includes a gas turbine other than that which drives a compressor.

6. A propulsion system for aircraft as claimed in any previous claim 1—4 constructed as a unit, comprising an air duct with an entry opening to face the direction of travel, an axial flow compressor therein, and an internal combustion engine together with its cooling appurtenances wholly within said duct being said compressor, the duct having an outlet orifice facing oppositely to the entry.

7. A unit according to Claim 6, substantially as described and illustrated in Figure 1.

8. A unit according to Claim 5, in which the gas turbine is a constant pressure gas turbine employing centrifugal compressor means for its compression, continuous combustion, and expansion through turbine means which provide power for the compression.

9. A unit according to Claim 8 in which the compressor means is a multi-stage centrifugal compressor.

10. A unit according to Claim 8, in which there are two mechanically independent turbine systems, one of which drives the compressor means of the gas turbine, and the other of which supplies the remainder of the power required for the energising of the whole air throughput.

11. A system according to Claim 5 in which the gas turbine comprises a centrifugal compressor driven by, and supplying part of its air output to a compression ignition engine the exhaust from which rejoins the rest of the air supply from the said compressor to form the working fluid in a turbine.

12. An aircraft provided with and adapted to be propelled by one or a plurality of the devices substantially as described.

Dated this 17th day of February, 1937.
For the Applicant,
F. J. CLEVELAND & COMPANY,
Chartered Patent Agents,
29, Southampton Buildings,
Chancery Lane, London, W.C.2.

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FIG. 1.

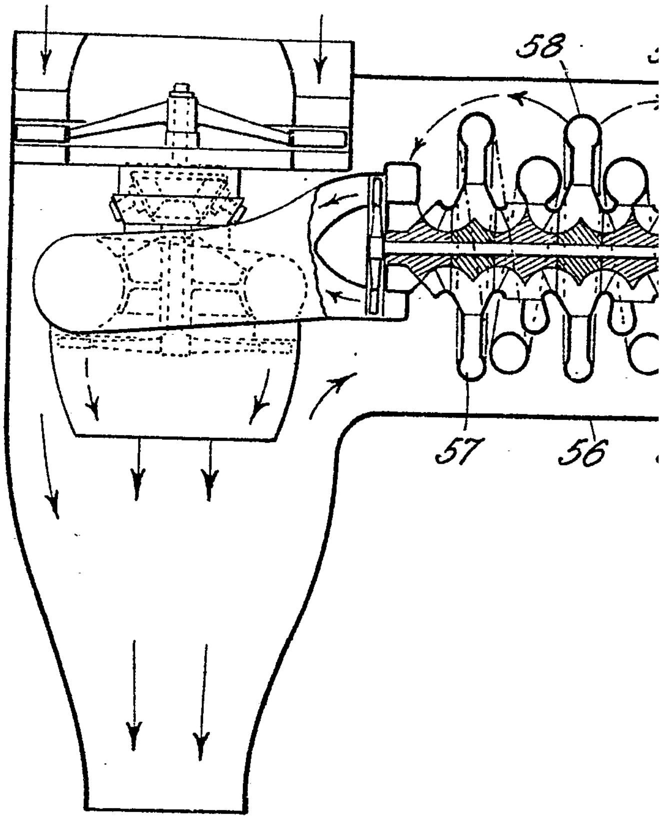


FIG. 2.

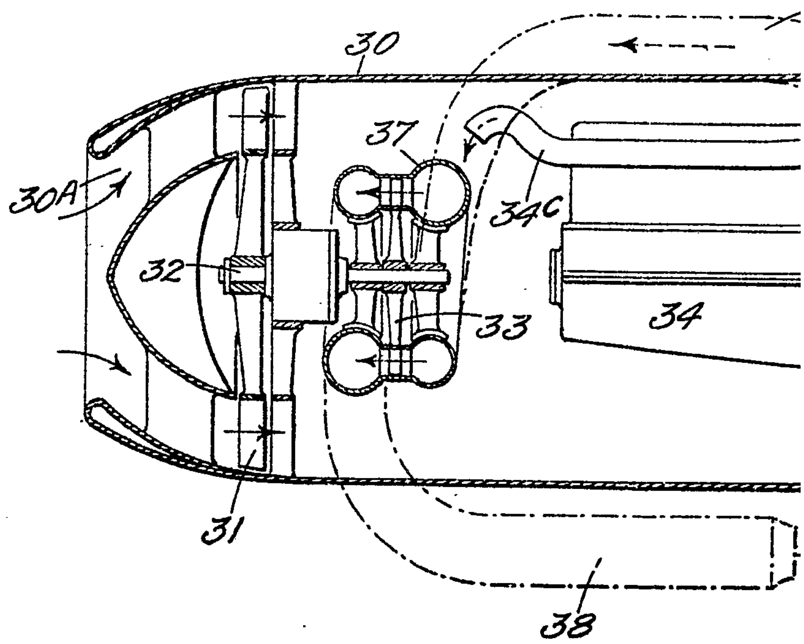
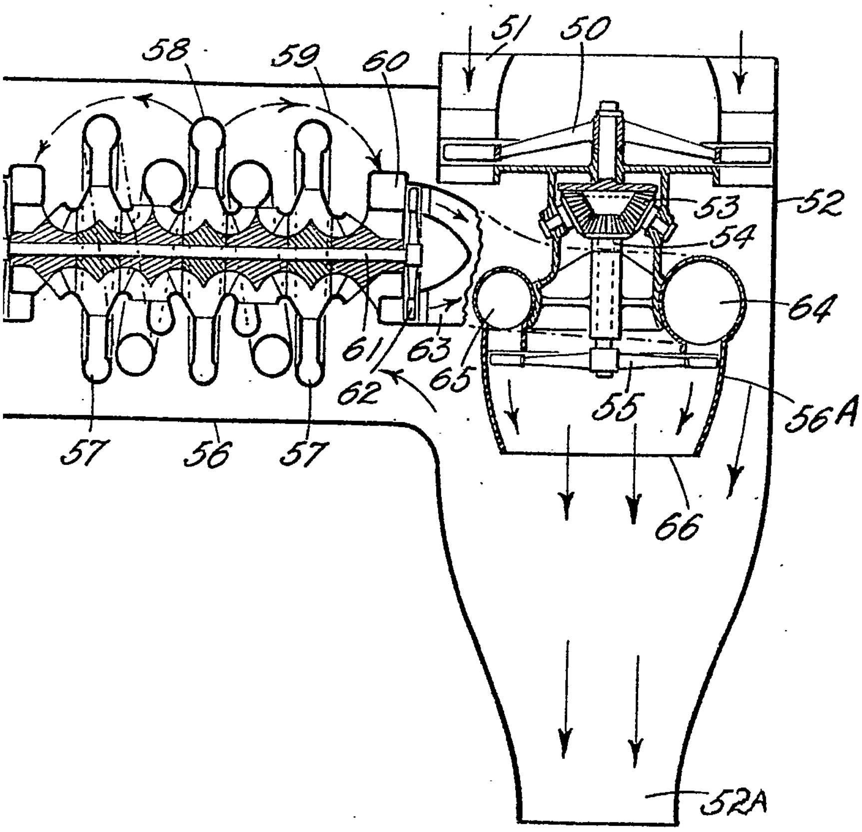


FIG.1.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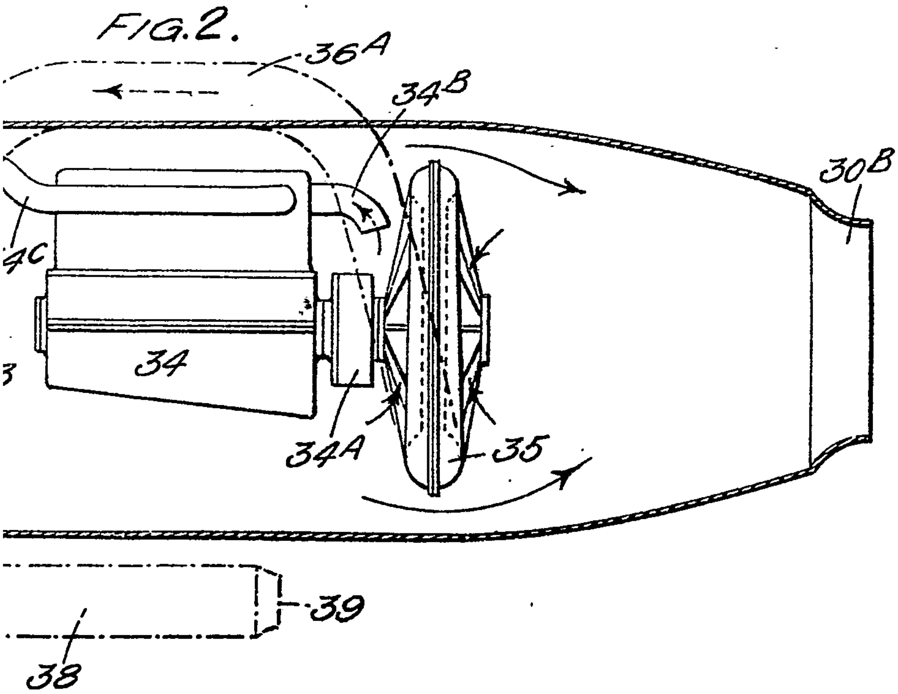
52A

FIG.2.


36A
34B
30B
4C
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34A
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FIG. 1.

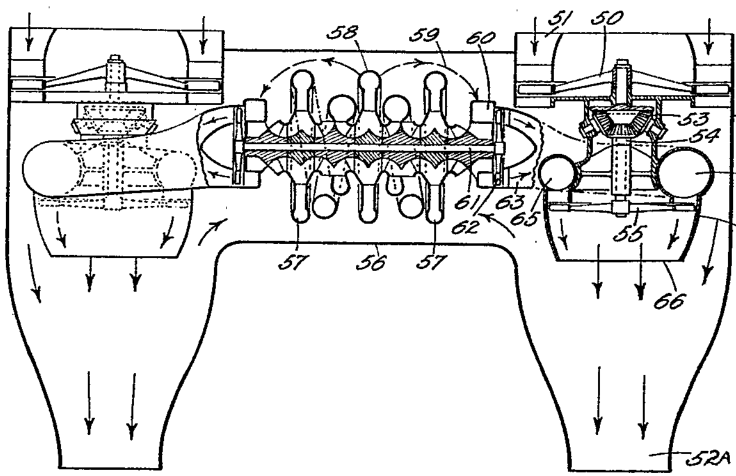
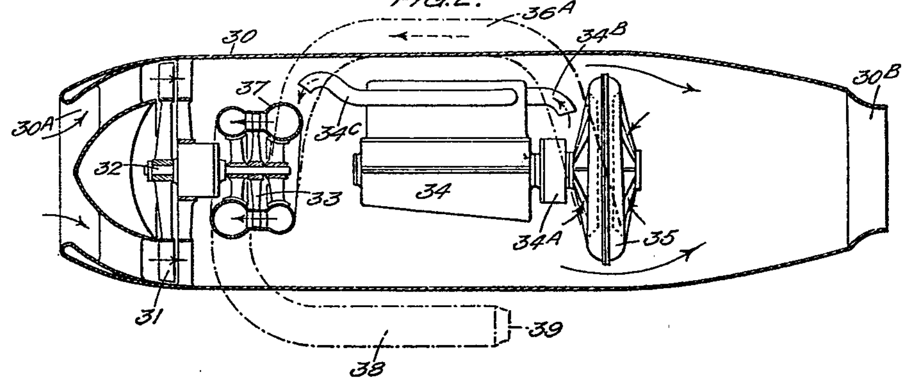


FIG. 2.



[This Drawing is a reproduction of the Original on a reduced scale.]