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ADJUSTABLE JET PROPULSION NOZZLE FOR GAS TURBINES

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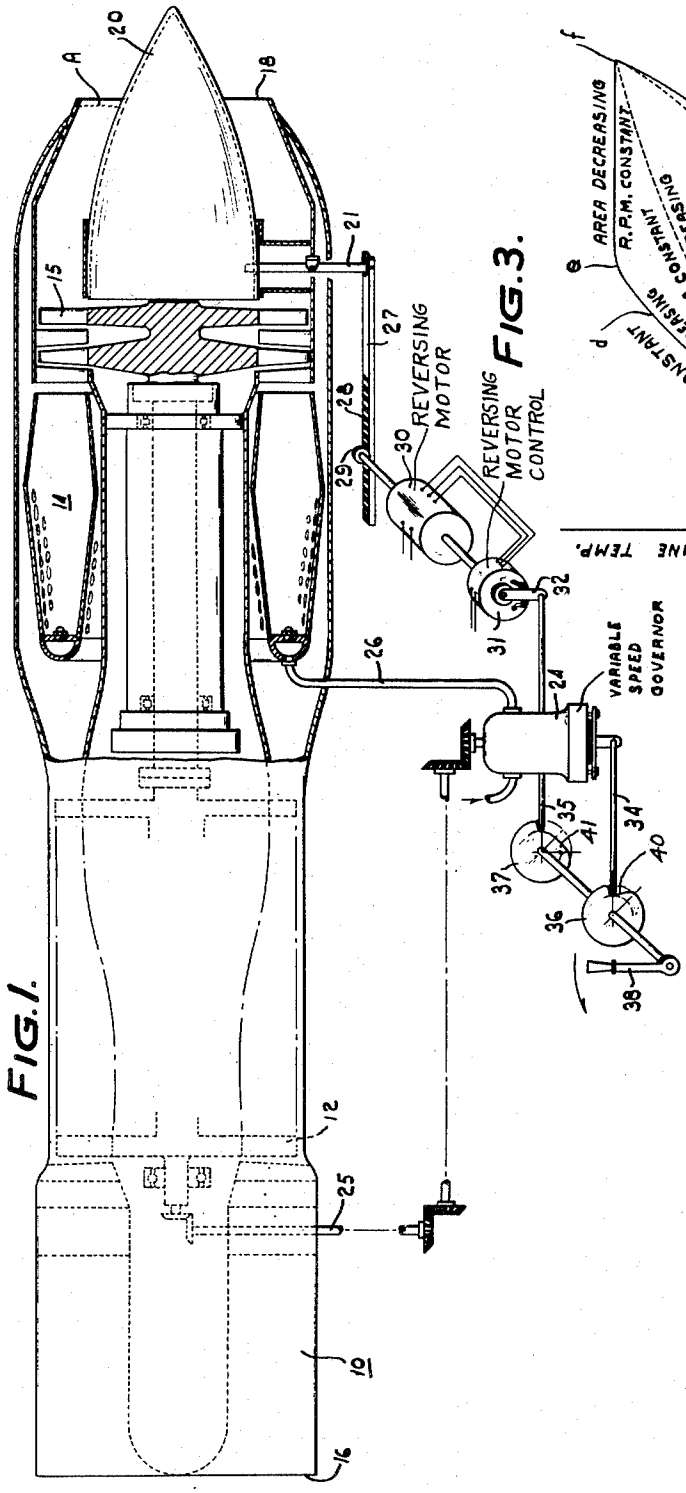


FIG. 1.

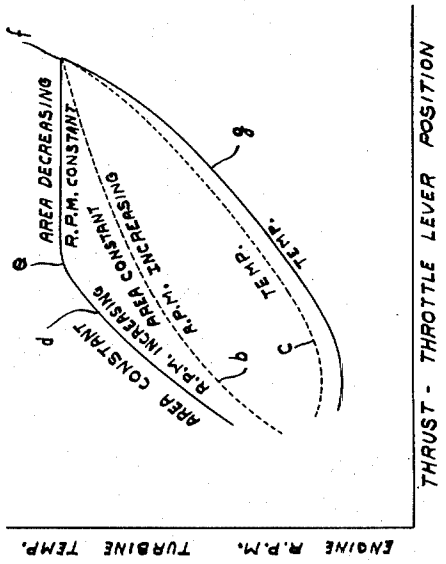


FIG. 3.

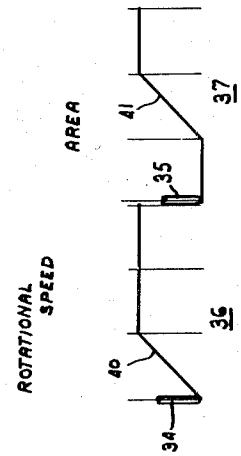


FIG. 2.

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ADJUSTABLE JET PROPULSION NOZZLE FOR GAS TURBINES

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1 Claim. (Cl. 60—35.6)

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The invention relates to jet propulsion apparatus wherein motive fluid exhausting from a turbine through a propulsion nozzle is supplied to the turbine from a combustor furnished with fuel and supplied with air by a compressor driven by the turbine and it has for an object to provide improved means for controlling the turbine speed and the thrust of the propulsion jet to simplify control from the standpoint of the operator, to provide for rapid acceleration of the aircraft, and to assure of a lower turbine inlet temperature at cruising or normal speeds, whereby the life of the apparatus is prolonged.

The ordinary turbo-jet engine having a fixed nozzle exit area may have the throttle lever provided with cams arranged so that the lever setting has proportional relation to jet thrust.

The present invention involves a nozzle having a movable component to vary the exit area and interconnection of the operating means therefor so that, with the component positioned to provide an area somewhat larger than that giving full thrust at full engine speed, the engine or turbine is brought up to full speed and then, with the turbine or engine continuing to operate at full speed the nozzle component is moved to reduce the exit area to increase the jet thrust.

Accordingly, a more particular object of the invention is to provide jet propulsion apparatus wherein the throttle lever has cams or the like arranged to operate speed control means for the turbine and exit area varying means for the nozzle in sequence so that, with the nozzle exit area somewhat larger than that for full thrust at full turbine speed, the turbine is first brought up to full speed and then, while continuing to operate at full speed, further movement of the throttle lever is used to bring about adjustment of the nozzle to reduce the exit area to increase the jet thrust.

The foregoing and other objects are effected by the invention as will be apparent from the following description and claim taken in connection with the accompanying drawing, forming a part of this application, in which:

Figure 1 is a diagrammatic view showing a jet propulsion plant with the improved control mechanism for the turbine and the propulsion jet nozzle;

Figure 2 is a diagrammatic development showing the relationship of cam surfaces operated by the throttle lever and the follower elements which cooperate with the cam surfaces; and

Figure 3 is a diagram contrasting operation of

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the improved arrangement with that heretofore employed.

In the drawing, there is shown a turbo-jet plant, at 10, including an axial-flow compressor 12, a combustor arrangement 14, a turbine 15, arranged in sequence between the forward air inlet 16 and the jet nozzle, at 18.

Motive fluid exhausting from the turbine 15 passes through the nozzle, at 18, to form the propelling jet, and motive fluid is supplied to the turbine from the combustor or combustors 14 furnished with fuel and supplied with air by means of the compressor 12 driven by the turbine.

The turbine speed is controlled or regulated by varying the rate at which fuel is supplied to the combustors.

The thrust of the exhaust nozzle, at 18, is varied by axial adjustment of the movable component 20 thereof; for example, such movable component is shown as being constituted by an axially movable tail cone 20, which is moved to and fro to vary the exit area A by means of a lever 21.

To facilitate an understanding of the present unified control of engine speed and propulsion jet nozzle exit area, reference is made to the conventional turbo-jet plant now in use and which has a fixed exit nozzle area. A throttle lever is usually provided; and, by the selection of suitable cams the setting of such lever may be made proportional to thrust; operation of the lever to increase the thrust involving increasing the rate of fuel, or speed, as indicated by the dotted line *b* in Figure 3, while, at the same, the temperature is increased as indicated by the dotted line *c*. The present invention involves variation in exit area with the turbine operating approximately at full speed so that the thrust may be increased from about one-half of full thrust to full thrust merely by decreasing the nozzle exit area. Accordingly, therefore, the present invention involves interrelating turbine speed and nozzle exit area so that, with the exit area somewhat larger than that for full thrust at full turbine speed, the turbine speed is increased as indicated by the full line *d* in Figure 3, full speed being reached at *e*; and, with the turbine operating at full speed the nozzle exit area is reduced, as indicated by the full line between *e* and *f*. The line *g* shows that, with the improved control arrangement, the turbine inlet temperature is lower throughout the thrust range, this feature contributing to longer life of the apparatus,

particularly when operating at cruising or normal speeds.

The turbine speed is regulated over a suitable range by mechanism including a governor 24 operated by mechanism including the take-off shaft 25 driven by the turbine, the governor controlling the input of fuel to the line 26 to the combustor or combustors 14.

Any suitable means may be employed to move the lever 21 or the like for shifting the tail cone 20. By way of example, the lever 21 is shown as being connected to a link 27 having rack teeth 28 meshing with a pinion 29 driven by a reversible electric motor 30, the motor having a controller 31 equipped with a lever 32, the controller being constructed and arranged so that movement of the lever causes the motor to operate in one direction or the other, and it is so arranged that its travel follows that of the controlling lever to maintain the proportionality as between the position of control lever 32 and the position of the tail cone 20.

As it is required that the turbine be brought up to full speed before the nozzle exit area is reduced, the controlling lever 32 of the motor controller and the speed adjusting means of the governor are operated, respectively, by rods 34 and 35, which cooperate with cams 36 and 37 connected to the throttle lever 38 so that the cams adjust the governor and the motor controller in sequence. The arrangement is such that until the throttle lever 38 is brought to full speed position, the tail cone 20 occupies a position such that the nozzle exit area A is somewhat larger than that for full thrust at full turbine speed. The throttle lever is moved over a range to move the cam 36 to adjust the governor to increase the fuel supply to increase the turbine speed to full speed, this operation being indicated by the line *d* in Figure 3; and, with the turbine operating at full speed, further movement of the throttle lever 38 moves the cam 37 to control the motor 30 to move the tail cone 20 so as to restrict the nozzle exit area, the area adjustment operation being indicated by the line *e*—*f* in Figure 3.

Any suitable arrangement of cams or mechanism associated with the throttle lever may be used to accomplish the purpose just indicated so long as the proper sequential operation is secured, the sequence being clearer from a consideration of diagrammatic Figure 2, in which it will be seen that, with the follower 34 at the lower end of the lift portion 40 of the cam 36, the follower 35 of the motor control lever will be in advance of the lower end of the left portion 41 of the cam 37 of the motor controller a distance corresponding to the distance required to move the follower for the turbine speed range, that is, when the follower 34 reaches the maximum lift end of the cam surface 40, the follower 35 for the motor controller will be at the lower end of the lift surface 41 of the cam 37; and, continued motion of the cams in the same direction is effective to hold the follower 34 in the turbine full speed position while the follower 35 is moved to bring about movement of the tail cone to reduce the nozzle exit area, such area being reduced to the minimum value when the follower 35 reaches the maximum lift end of the cam surface 41.

From the foregoing, it will be apparent that we have improved control of apparatus of the above character, made operation thereof in propelling aircraft safer and more reliable, and have provided for operation at lower turbine inlet temperatures particularly at normal or cruising speeds, thereby giving to the apparatus longer life. The sequential operations of increasing the turbine speed and of reducing the nozzle exit area may be effected by movement of a simple throttle lever in a single direction. Safer and more reliable propulsion of aircraft is secured because change in thrust from one-half of full thrust to full thrust is effected merely by adjusting the nozzle exit area, the speed being held substantially constant. Therefore, the thrust may be reduced for landing without reducing the engine speed and it may be increased by a decreasing of the exit area without having to accelerate the engine speed, whereby acceleration of aircraft in the event of wave-off when coming in for landing may be quickly effected.

With the tail cone at normal or cruising position and the turbine operating at full speed, as indicated by the temperature line *g*, it will be noted that the turbine inlet temperature is substantially lower than that corresponding to the line *c* for a turbo-jet plant having a nozzle or fixed exit area. The latter feature contributes to lower fuel consumption and cruising operation of the turbine with lower outlet temperatures, thereby resulting in longer life of the apparatus.

While the invention has been shown in but one form, it will be obvious to those skilled in the art that it is not so limited, but is susceptible of various changes and modifications without departing from the spirit thereof.

What is claimed is:

In jet propulsion apparatus, a turbine, means providing motive fluid for the turbine and including a combustor furnished with fuel and supplied with air by a compressor driven by the turbine, a nozzle acting on the exhaust of the turbine to provide a propulsion jet, said nozzle including a component which is movable to vary the nozzle exit area to vary the jet thrust, a speed governor operated by the turbine for controlling the supply of fuel to the combustor and including speed-setting means, and mechanism for adjusting the speed-setting means of the governor and the movable component of the nozzle and including a member movable to adjust the governor speed-setting means to increase the fuel input to increase the turbine speed to maximum and then, while maintaining the turbine speed at maximum, movable to operate the movable component of the nozzle to reduce the nozzle exit area to increase the jet thrust.

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