THROTTLE CONTROL FOR USE IN A JET ENGINE HAVING AN AFTERBURNER

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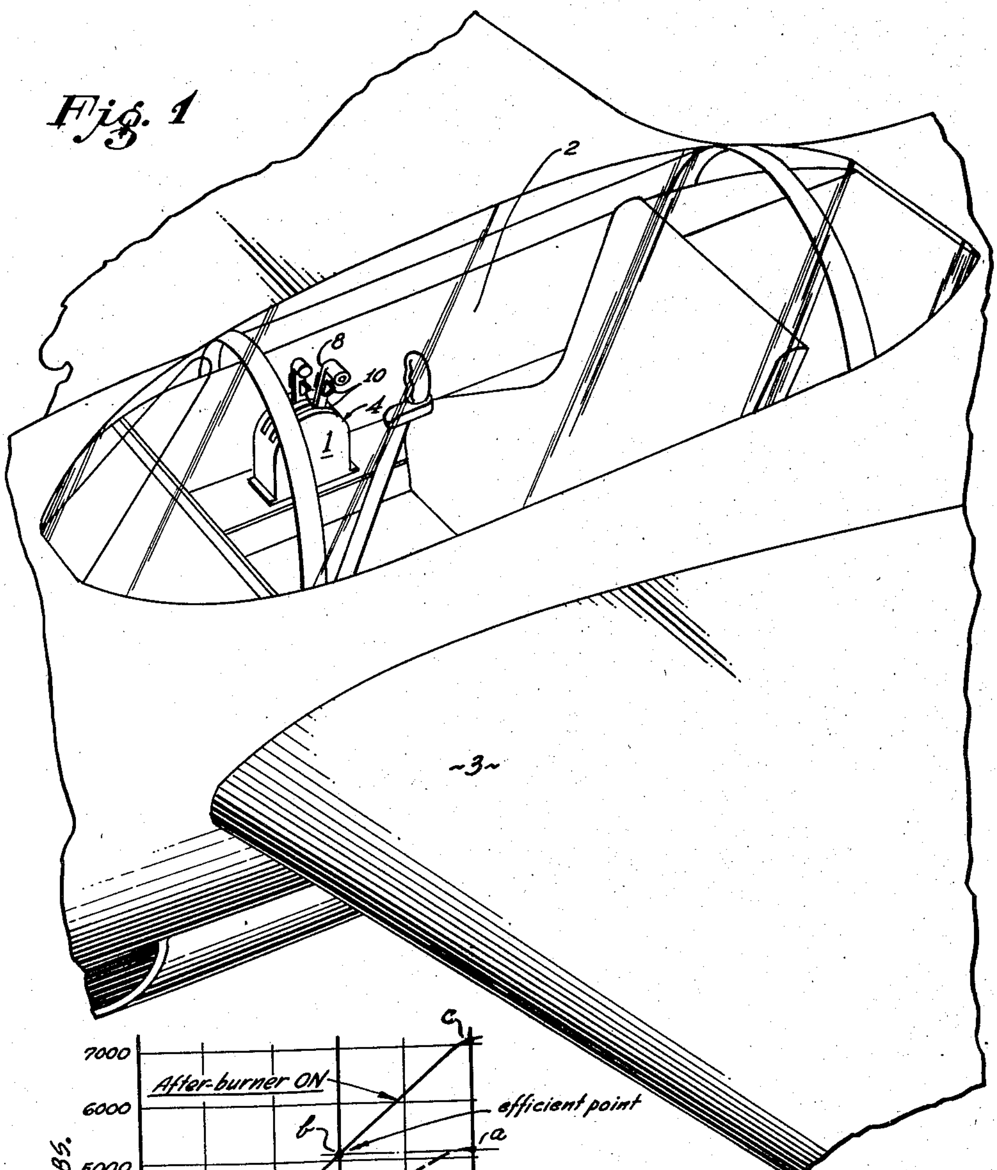
Fig. 1



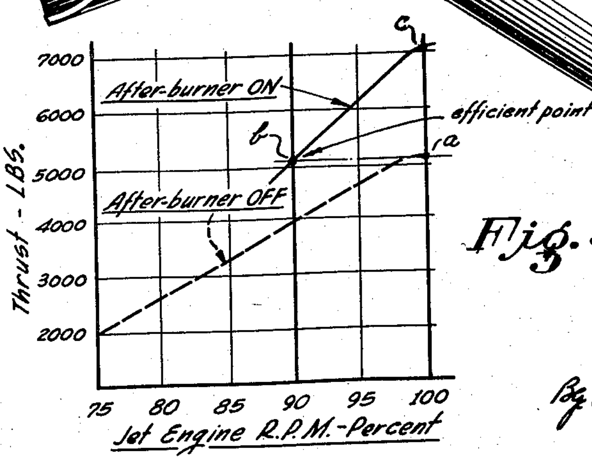


Fig. 5

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Fig. 2

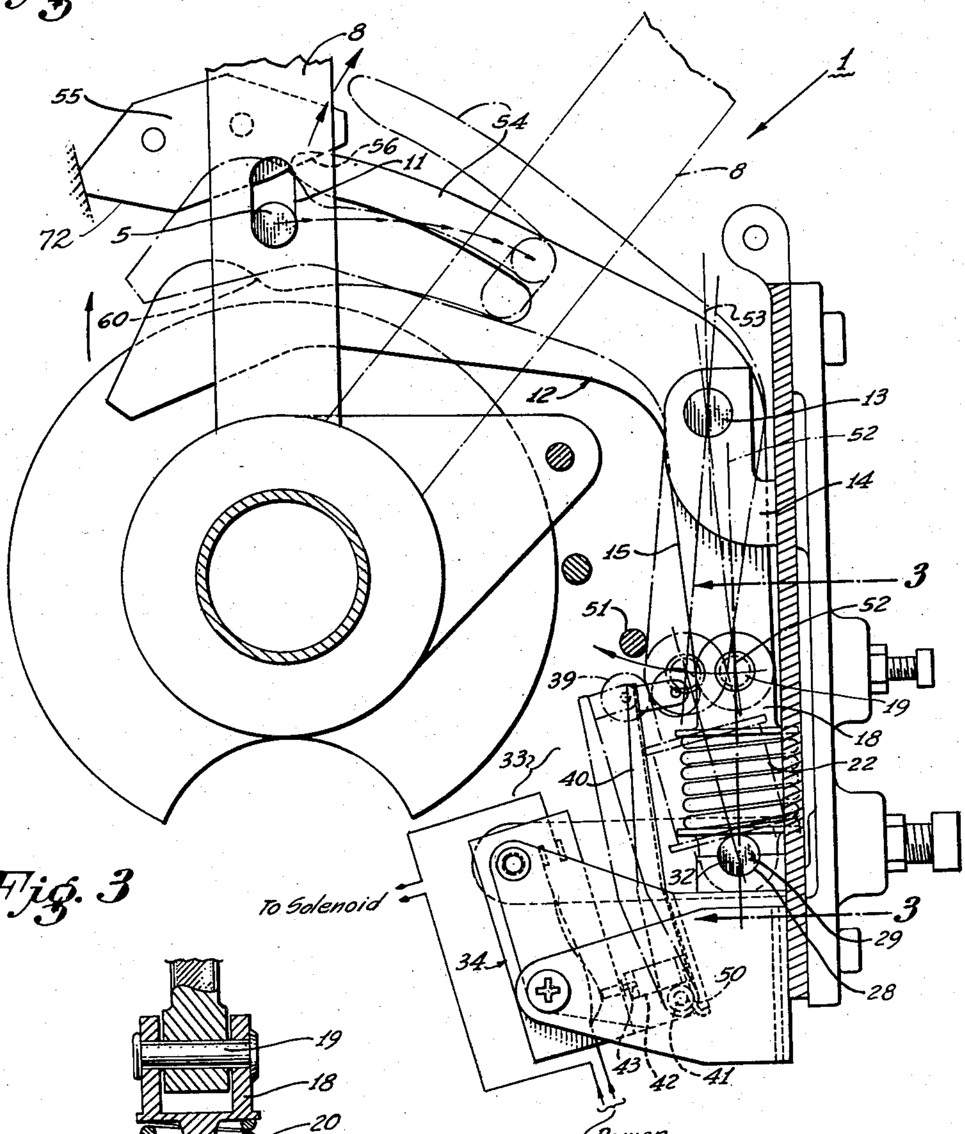
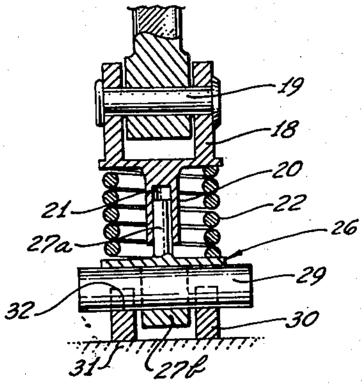


Fig. 3



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THROTTLE CONTROL FOR USE IN A JET ENGINE HAVING AN AFTERBURNER

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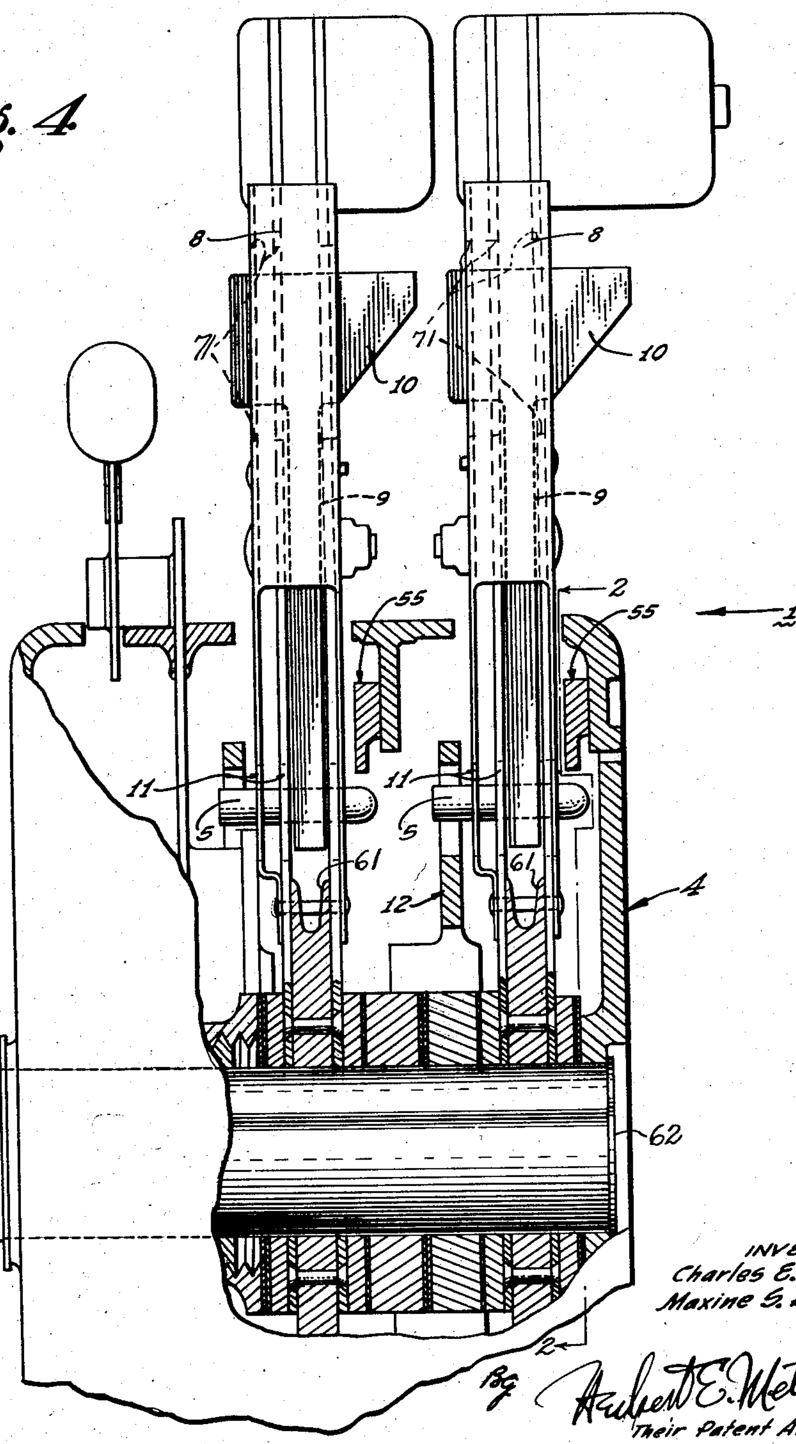
Fig. 4



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Feb. 3, 1959 C. E. OATES ET AL 2,871,657

THROTTLE CONTROL FOR USE IN A JET ENGINE HAVING AN AFTERBURNER

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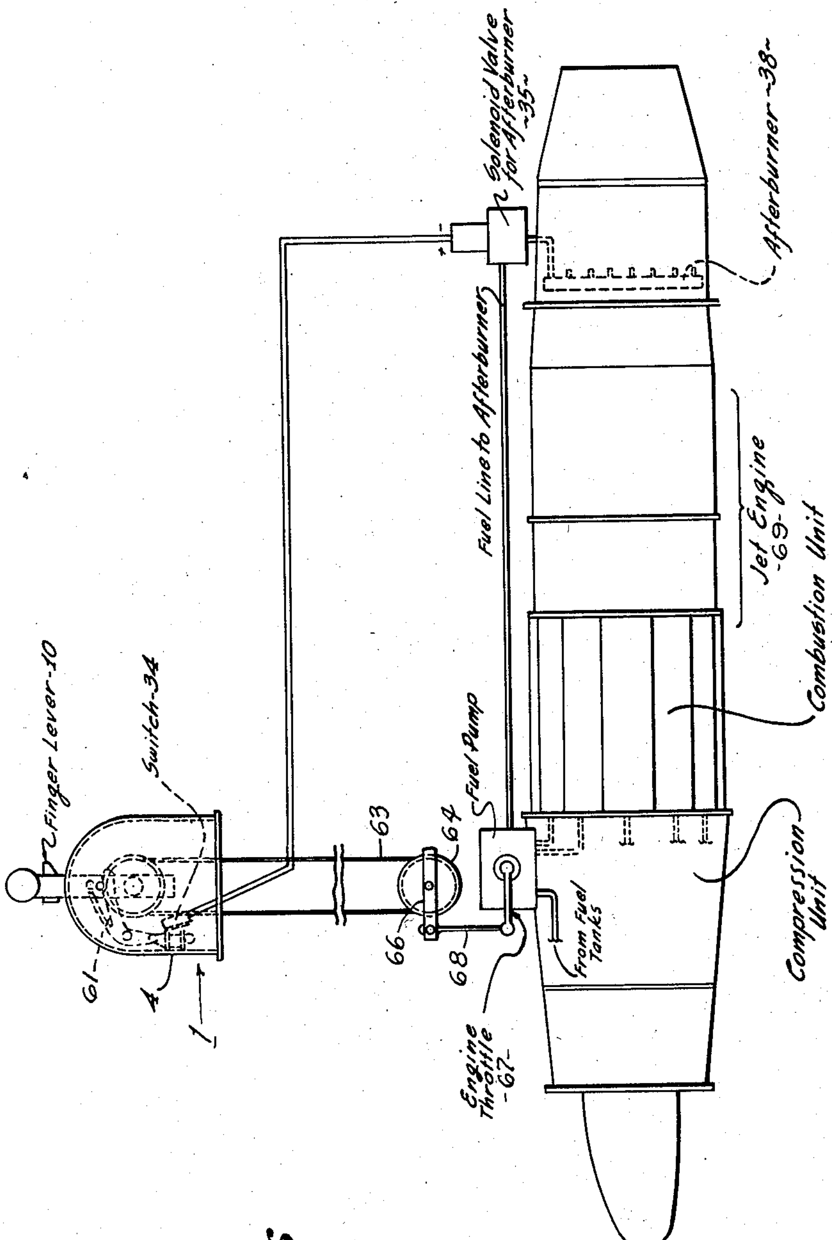

Fig. 6

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THROTTLE CONTROL FOR USE IN A JET ENGINE HAVING AN AFTERBURNER

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Fig. 7

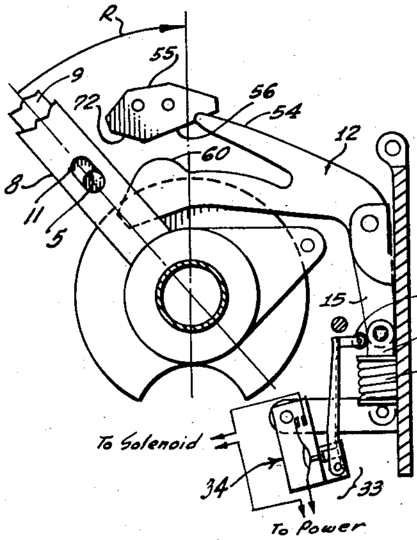
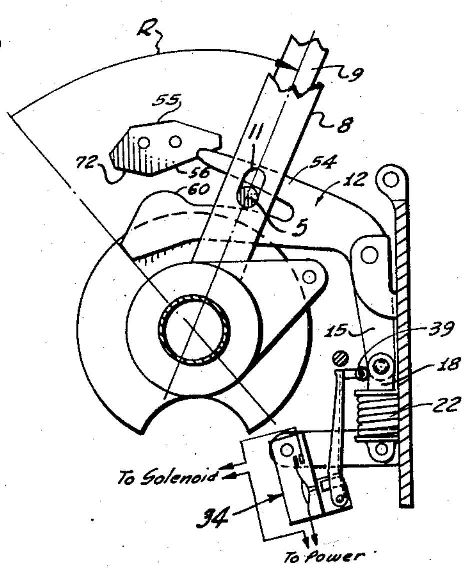


Fig. 8



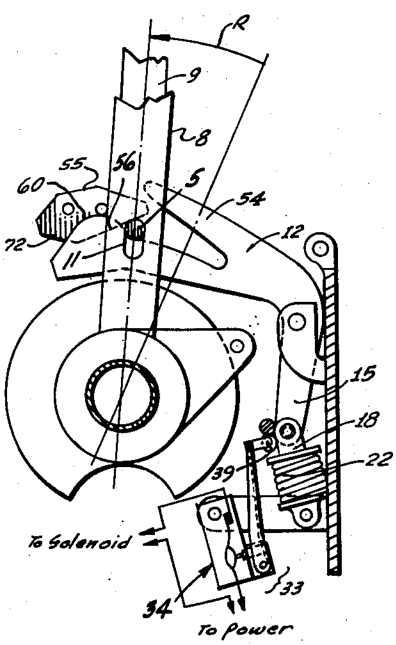


Fig. 9

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THROTTLE CONTROL FOR USE IN A JET ENGINE HAVING AN AFTERBURNER

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Application February 1, 1954, Serial No. 407,232

4 Claims. (Cl. 60—35.6)

My invention relates to the field of engine throttle controls and more particularly to novel throttle means for controlling the flow of fuel to the main and afterburner nozzles of a jet engine thereby making possible variable output thrusts over a range not presently available with conventional throttles.

In military aviation it has been found desirable to augment the total power at full R. P. M. of a turbo-jet aircraft engine, as for example, by use of an afterburner. Jet engine afterburners inject fuel into the jet engine tailpipe rearwardly of the engine turbine section, this fuel being converted into a combustible mixture by mixing with air bypassed around the combustors of the engine. A substantial increase in thrust of the engine is thus obtained. As the rate at which the fuel is injected is substantially constant, the thrust increment produced by the afterburner is also substantially constant.

Due to the high jet temperatures, sometimes resulting in damage to the engine tailpipe, the tail assembly, or the fuselage of the airplane, and the large quantities of fuel consumed by afterburning, it has heretofore been the custom that afterburners only be used for relatively short time intervals, such as during take-offs and for emergency combat situations. A natural outgrowth of this procedure has been the placing of the afterburner actuator at the high speed end of the throttle quadrant so that the pilot must first command full turbo-jet power before seeking augmented power. Similarly, as the pilot moves his throttle control to reduce power, the afterburner is cut off first before the engine R. P. M. can be reduced. With such a throttle control no substantial variation of power is possible while afterburner power was being utilized.

It was found, however, that there were many times, during afterburner use, when it would be highly desirable to vary power with the afterburner on, such as for example, in combat formation flying.

Formation flying while using the afterburners of the jet engines has recently been made possible by increasing the amount of fuel which can be carried by fighter planes, as by the use of large tip tanks; underwing tanks, permanent or releasable, and the like. Tail pipes have been made more heat resistant and the aircraft skin adjacent the jet has been covered with high melting point metals. Thus afterburners, at least in some of the latest fighters such as for example the U. S. A. F. twin jet F–89 "Scorpion" all weather fighter can be used for extended periods during combat. During these periods thrust control is highly desirable.

Turbo-jet engines deliver most of their usable thrust over a relatively short R. P. M. range. For example, the more common types of jet engines require approximately 60% of engine R. P. M. for idling, and at 90% of engine R. P. M. the thrust is roughly only 50% of the maximum power obtained at 100% R. P. M.

In practicing the present invention, I have found it possible to turn the engine afterburner on at some point less than 100% R. P. M. as I have found that sufficient oxygen exists in the tailpipe to properly burn the afterburner fuel when the engine is rotating at somewhat less than maximum speed. As the afterburner supplies a thrust increment only slightly increasing as engine R. P. M. increases, and as the engine can be accelerated up to maximum R. P. M. after the afterburner has been turned on, a power range is thereby made available to the pilot during afterburner use. This range of power can be used by the pilot for speed control of his airplane. As quantity of fuel used by the afterburner is quite large, about 2½ times that used by the jet engine alone, the most efficient point, i. e. the percentage of engine R. P. M. at which afterburner may properly be turned on, is that percentage R. P. M. at which the thrust delivered with afterburner on will substantially equal or slightly exceed the thrust delivered at 100% R. P. M. of the engine with the afterburner off. Since this precise point of necessity must be predicated on the particular type of engine used, this point on the R. P. M. curve will vary somewhat in engines of different makes and powers, the average point being at about 90% engine R. P. M. My invention also provides a means for controlling the engine and the afterburner so that the afterburner can be cut in or out at will at any engine speed over about 90% R. P. M.

Hence it is a general object of my invention to provide in an airplane a means and method of engine throttle control which will give the pilot a range of thrust with an augmented source of power turned on and working in conjunction with the engine of the aircraft.

A more specific object of my invention is to provide a throttle control effective to operate a jet engine at less than full R. P. M. with the afterburner of the jet engine in operation.

A further object of my invention is to provide a throttle control which will automatically turn off the afterburner of a jet engine below a predetermined percentage engine R. P. M.

Another object of my invention is to provide a throttle control for a jet engine which may be operated by a pilot's demand device which is effective to control the thrust of the engine below 100% engine R. P. M. with an augmented source of power turned on.

Other objects, uses and advantages will manifest themselves in view of the subsequent disclosure.

For a more complete description of my invention reference is had to the drawings in which:

Figure 1 is a fragmentary perspective view of an aircraft showing the location of the engine throttle control actuator.

Figure 2 is a cross sectional view of the throttle control actuator taken on the line 2—2 of Figure 4.

Figure 3 is a cross sectional view taken along line 3—3 of Figure 2.

Figure 4 is a front elevational view of the throttle control actuator having certain parts thereof broken away to better show the interior construction of the actuator.

Figure 5 is a comparative chart showing the range of throttle control with the afterburner on and the added thrust which is supplied to the aircraft.

Figure 6 is a schematic view showing the throttle control system and the means for turning the afterburner on prior to full engine R. P. M.

Figures 7, 8, and 9 are views of the actuator showing the component parts thereof in various operational positions.

Referring now to the drawings for a description of a preferred embodiment of my invention, the throttle control mechanism 1 as shown is located in the cockpit 2 of a jet-type aircraft 3. The throttle control mechanism comprises a housing 4 in which a pair of throttle arms

8 are mounted in side by side relationship in a conventional manner. Each throttle arm is attached to a respective cable quadrant 61 whereby the latter is caused to pivot through a predetermined angle on the shaft 62 in response to angular movement of a respective throttle arm. The throttle control mechanism of the instant invention functions to control the flow of fuel to respective ones of a pair of jet engines each mounted on the aircraft 3. Accordingly two throttle arms 8 are shown, however, inasmuch as the function and construction of each arm is identical the description of one will also apply to the other.

Referring to Figure 6 a cable 63 transmits angular movements of the arm 8 and quadrant 61 to a quadrant 64. The quadrant 64 is keyed to an arm 66 which in turn is connected to the engine throttle 67 through a connecting link 68. Accordingly as the throttle arm 8 is moved throughout its respective range the throttle 67 is actuated thereby regulating the flow of fuel to the main nozzles (not shown) located in the main combustion chambers of the jet engine 69.

The throttle arms 8 are U-shaped in cross section and carry an elongated member 9 in the channel defined by the sides and bottom portions of the arm. An actuating pin 5 is fixedly secured to the member 9 adjacent one end thereof and extends through elongated slots 11 provided in the side walls of the arm 8. The other end of the member 9 terminates in lateral projections 10 extending through elongated slots 71 also provided in the side walls of the arm 8 substantially as shown in Figure 4. The projections 10 provide means whereby the members 9 may be moved longitudinally, in the channel defined by the arm 8, a predetermined distance depending upon the length of the slots 11 and 71.

A bifurcated cam member 12 is pivotally secured by a pin 13 to a support member 14 which constitutes a portion of the housing 4, the cam arm 15 thereof being pinned near its unitary end to a retaining member or clevis 18 by means of a pin 19. The clevis 18 is formed with a central protruding member 20 having a cavity 21 formed therein. Disposed over said protruding member 20 is a compression spring 22 one end of which is seated on a support 26 having an upper central vertical extension 27*a* disposed within said cavity 21 of the clevis 18 and a lower central extension 27*b* is provided with a bore 28 in which a pin member 29 is fixedly secured to extend on each side of the extension 27*b*. The pin member 29 is seated in a secondary support 30 attached to the housing 4 said support 30 being formed with a cradle 32 in which the pin member 29 is seated. A switch actuating mechanism 33 is adapted to actuate a switch 34 which in turn energizes a solenoid comprising a part of the solenoid valve 35 (Figure 6). The aforementioned solenoid when energized actuates the valve 35 causing the latter to admit fuel to an afterburner 38. The mechanism 33 includes a roller 39 pinned to an arm 40 which in turn is pivotally secured to the housing 4 as indicated at 41, said arm 40 having a lateral extension 42 thereon effective to depress a switch button 43 of the switch 34 and a spring member 50 to return the arm 40 to its original position. Where a hydraulic valve is used to control the flow of fuel to the afterburner a direct mechanical linkage may be used. A stopper member 51 is positioned adjacent the cam arm 15 to limit movement of the arm 15 in a clockwise direction as viewed in Figure 2. Pivotal movement of the cam arm 15 in a counter clockwise direction is limited by a vertical wall portion of the housing 4. The vertical axis 52 of the clevis 18, passing through the axis of the pin 29, and the vertical axis 53 of the cam 12, passing through the axis of the pin 13 are deliberately in slight horizontal misalignment thereby providing the cam with two over-center positions. Thus the forked portion of the cam 12 will be held in either an "up" or "down" position by the force exerted by the spring 22. Secured to the housing 4 is a cut-off cam 55 having downwardly sloping surfaces 56 and 72. The cam 55 is further positioned so that, if the member 9 is raised thereby positioning the pin 5 in the upper end of the slot 11, the pin 5 will contact the surfaces 71 and 56 as the arm 8 is advanced and retarded, respectively, for a purpose which will be presently apparent. A lobe 60 is provided on the lower portion of the bifurcated cam 12 to coact with the sloping surfaces 56 and 72 of the cut-off cam 55 through the pin 5. Thus the pin member 5 will be depressed downwardly when the throttle 8 is advanced or retarded causing the pin 5 to pass the low portion of the cam 55. This action of the pin 5 forces the cam 12 downwardly to the position as shown in Figure 8, hereinafter referred to as the first over-center position of the cam 12. This action of the cam 12 allows the contact points of the switch 34 to separate, the valve 35 is closed, and fuel flow to the afterburner 38 is arrested. When the cam 12 assumes the position as shown in Figure 9, hereinafter referred to as the second over-center position of the cam 12, results in the closing of the contact points of the switch 34. Also the position of the member 9 as shown in Figure 8, in which the pin 5 is seated in the lower ends of the slots 11, is hereinafter referred to as the lowered position thereof and the position as shown in Figure 9, in which the pin 5 is seated in the upper ends of the slots 11, as the raised position of the member 9.

Further it will be seen that as the arm 8 is advanced a predetermined distance from its intermediate position, that is in which the pin 5 is directly below the juncture of the surfaces 56 and 72, it is not possible to move the pin 5 to its full raised position due to obstruction provided by the camming surface 56. Accordingly it will be apparent that the valve 35 can not be actuated at this time and accordingly fuel will only reach the afterburner during the final portion of the advance range of the arm 8. At all other positions of the arm 8 upward movement of the pin 5 will be arrested by the camming surface 56 or the pin will not contact the upper portion of the bifurcated arm of the cam 12. Therefore it is seen that it is only possible to admit fuel to the afterburner 38 at such times as a predetermined quantity of fuel is flowing to the main nozzles of the jet engine 69.

A description of the operation of the throttle control mechanism follows in view of the aforementioned structural relations.

As viewed in Figure 7 the throttle arm 8 is shown at an intermediate position but before the range is reached in which the afterburner 38 becomes effective. If the throttle arm is advanced further, in the direction indicated by the arrow, it will be apparent that the pin 5 will enter between the bifurcated portions 54 of the cam 12. If for any reason the member 9 should be in a raised position, at such time as the arm 8 is advanced from its position as shown in Figure 7, the pin 5 will contact the camming surface 72 and will automatically be lowered so that it will effectively enter below the bifurcated portion 54 of the cam 12. As long as the arm 8 is in a position locating the pin 5 below the surface 56 the member 9 can not be raised sufficiently to actuate the cam 12 into its up position.

At such time as the arm 8 assumes any position, in which the pin 5 if moved upwardly in the slot 11 will clear the forward end of the cam 55 and the fully advanced position of the throttle arm, the cam 12 may be actuated between its up and down positions. A typical position of the lever arm as described above is shown in Figure 8. During the time the throttle arm is located in the range just described it is possible for the pilot to control the flow of fuel to the afterburner in accordance with varying conditions. At this time, with the member 9 in a lowered position, the cam 12, clevis 18, and arm 40 will assume the positions as shown in Figure 8. Accordingly the switch 34 will be open, the solenoid of the valve 35 will be de-energized, and fuel flow to the afterburner **38** will be arrested. If, however, the member **9** is raised to its up position the cam **12** will be pivotally moved in a clockwise direction causing the cam **12** and associated parts to assume the positions as shown in Figure 9. This action causes the switch **34** to close, the solenoid of the valve **35** to become energized, and fuel to be admitted to the afterburner. Thus it is seen that the cam **12**, coacting with associated parts, permits the use or discontinuance of the afterburner as desired during the final phase of the advanced portion of the range of the throttle arm. The range of the throttle arm as just described represents engine speeds ranging between ninety (90) and one hundred (100) percent of maximum engine speed.

Should the throttle arm **8** be retarded from a position as shown in Figure 8, without the pilot first lowering the member **9** and thus arrested the flow of fluid to the afterburner **38**, the flow of fluid to the afterburner will be automatically arrested due to the pin contacting the camming surface **56**. Referring to Figure 9, if it is assumed the arm **8** is moving in a retarding direction as indicated by the arrow R, the pin **5** will contact and subsequently ride along the camming surface **56**. During this movement of the pin it will contact the lobe **60** causing the cam **12**, clevis **18**, and arm **40** to return to the positions as shown in Figure 8. Thus the electrical circuit to the solenoid of the valve **35** will be interrupted, the solenoid will be de-energized, and fuel flow to the afterburner will be arrested.

The cut-off cam **55** precludes premature action of the cam **12** and accordingly action of the afterburner **38**. The cam **55** is preferably located with respect to the pin **5** so that the afterburner can not become effective unless the total engine thrust with the afterburner on will result in no more or slightly more engine thrust than will be available with the engine running at maximum speed with the afterburner off.

Referring now to Figure 5, a comparative chart of a typical engine performance respecting thrust output with afterburner on and afterburner off is shown. Prior to my new throttle control mechanism the pilot had to take the engine to point "*a*" before putting the afterburner on, thus increasing the thrust approximately 28% all at once, as for example from "*a*" to "*c*." Now the pilot has control of the engine over approximately 10% of the R. P. M. range with the afterburner turned on at the efficient point "*b*." This allows R. P. M. control with afterburner on from points "*b*" to "*c*" thus rendering the accomplishment of the objectives laid out earlier in the specification.

Though the preferred throttle mechanism shown, described and claimed herein is particularly adapted for the control of jet engines equipped with afterburners, it is equally suitable for use with piston type engines where the source of augmented power is the injection of water and/or alcohol into the engine cylinders.

While in order to comply with the statute, the invention has been described in language more or less specific as to structural features, it is to be understood that the invention is not limited to the specific features shown, but that the means and construction herein disclosed comprises a preferred form of putting the invention into effect, and the invention is therefore claimed in any of its forms or modifications within the legitimate and valid scope of the appended claims.

What is claimed is:

1. In an aircraft powered by a combustion engine having main and auxiliary fuel jets, a throttle assembly comprising: a throttle housing mounted in said aircraft; a throttle arm having a pair of opposed surfaces and being mounted on said housing for pivotal movement through a predetermined arcuate path between retarded and advanced positions in which said arm is disposed at respective opposite ends of said arcuate path; said arm having an intermediate position in which said arm is disposed at a predetermined angular position between said retarded and advanced positions; first means operatively connected to said arm and being adapted to regulate fuel flow to said main jets as said arm is pivoted between said retarded and advanced positions; and second means including cam means pivotally mounted in said housing in the arcuate path of said arm; manually operable means mounted on said arm for movement through a limited range; a valve adapted to allow and arrest fuel flow to said auxiliary jets when actuated between open and closed positions, respectively; said manual means being in contact with said cam means at such time as said arm is in said intermediate, advanced and all positions therebetween; said manual means acting to pivot said cam means in one direction to open said valve when moved to one end of its range and acting to pivot said cam in the opposite direction to close said valve when moved to the other end of its range.

2. Apparatus as set forth in claim 1: further characterized by including a block mounted in said housing and having a camming surface cooperable with said manual and camming means whereby the latter is automatically pivoted in a direction closing said valve at such times as said arm is moved from said intermediate position to positions adjacent thereto which are located in the direction of said retarded position.

3. Apparatus as set forth in claim 1: further characterized in that said cam means constitutes an elongated member one end of which is bifurcated; said manual means including a pin extending outwardly from each of said opposed surfaces; one end of said pin being located between the branches of said bifurcated end at such times as said arm is located in said intermediate, advanced, and all positions therebetween.

4. Apparatus as set forth in claim 3: further characterized by including a block mounted in said housing and having a camming surface; one branch of said bifurcated end having a lobe portion protruding toward the other branch of said bifurcated end; said lobe, camming surface, and pin being located substantially the same distance from the pivotal axis of said arm so that one end of said pin contacts said lobe and camming surface, at such times as said cam means is in a position opening said valve and said arm is moved from said intermediate position to positions adjacent thereto which are located in the direction of said retarded position, to automatically pivot said cam means in a direction closing said valve.

References Cited in the file of this patent

UNITED STATES PATENTS

2,217,364	Halford et al.	Oct. 8, 1940
2,288,204	Ostlund et al.	June 30, 1942
2,388,079	Rhodes	Oct. 30, 1945
2,508,420	Redding	May 23, 1950
2,520,434	Robson	Aug. 29, 1950
2,544,853	Oates	Mar. 13, 1951
2,559,814	Whittle	July 10, 1951
2,565,854	Johnstone et al.	Aug. 28, 1951
2,570,591	Price	Oct. 9, 1951
2,664,762	Morris	Jan. 5, 1954