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METHOD FOR INCREASING THE THRUST OF JET ENGINES BY
THE USE OF RAPIDLY DECOMPOSABLE NITROGEN COMPOUNDS

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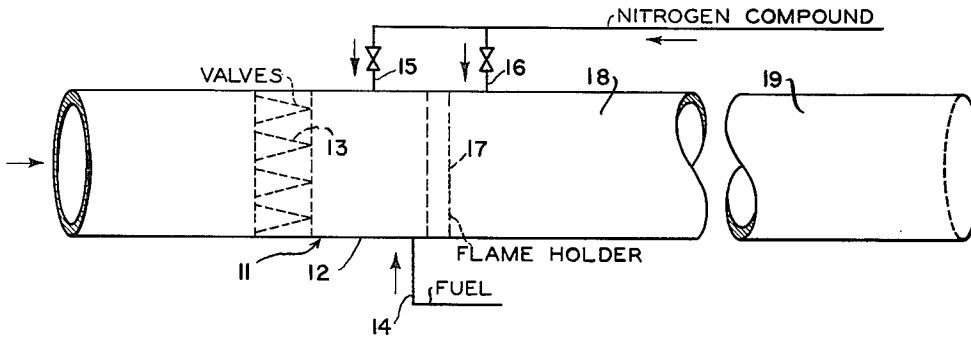


FIG. 1

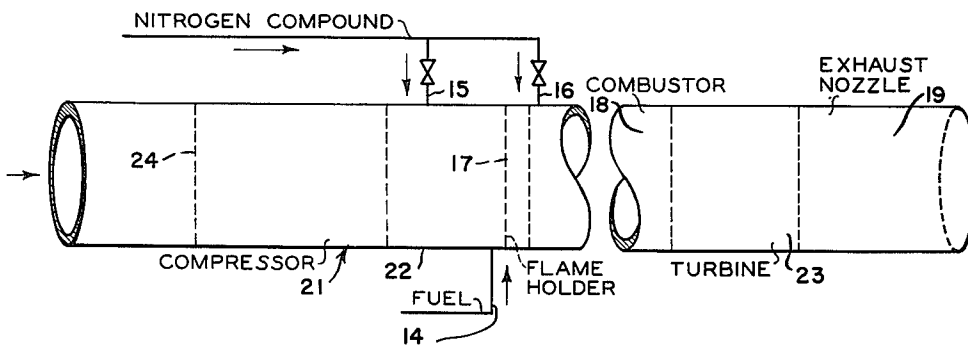


FIG. 2

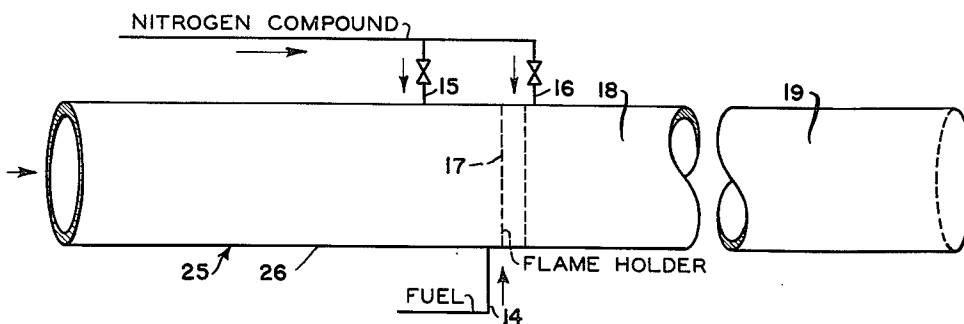


FIG. 3

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METHOD FOR INCREASING THE THRUST OF
JET ENGINES BY THE USE OF RAPIDLY
DECOMPOSABLE NITROGEN COMPOUNDSGeorge N. Cade, Bartlesville, Okla., assignor to
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This invention relates to jet engines. In one of its more specific aspects it relates to the operation of jet engines. In another of its more specific aspects it relates to a method for intermittently and continuously operating jet engines.

Jet engines, which may be generally classified as aerodynamic power plants, fall specifically into three distinct categories, i. e., ram jets, turbo jets and pulse jets. The working cycle of the ram jet and the turbo jet is essentially the same. One distinct difference in operation, however, is apparent in the compression step. Air is jammed into the combustion zone of the turbo jet by a gas turbine. Compression in a ram jet engine is provided by the ramming effect of the oncoming air. Compression in the pulse jet engine is obtained by oncoming air and by the intermittent closure of valves upstream of the combustion zone to prevent the escape of gases through the upstream end of the engine.

Fuel which is injected into the combustion zone of the above designated jet engine may originally be ignited therein by a spark producing device, such as a conventional spark plug mounted in the wall of the combustion chamber. Additional fuel is thereafter ignited by the flame of burning fuel or by the heat from hot combustion gases remaining in the combustion zone or by heat from the hot combustion chamber wall. The air and exhaust gases within the combustion zone are heated by the heat of combustion and are exhausted from the combustion zone through a rearwardly extending exhaust conduit at an exit velocity higher than the flying speed of the engine. The thrust produced thereby equals the gas mass flowing through the exhaust duct times its increase in speed, according to the law of momentum.

Attempts are now being made to develop jet powered air craft that will operate at very high altitudes and at sonic or supersonic speeds. Such jet engines require the use of fuels which will produce a maximum of power per unit liquid fuel volume. Generally speaking, those hydrocarbon fuels which will produce the greatest temperature rise through the jet engine have proved to be highly desirable for producing the greatest amount of thrust.

Other factors which must be considered in connection with the selection of a fuel for ram jet, turbo jet, and pulse jet engines are the ignition and combustion speed of the fuel. These fuel qualities are particularly important in connection with the operation of the ram jet and turbo jet engines. In the latter two engines a peculiar operational problem is encountered

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which is not generally found in the operation of a pulse jet engine. As air flow through the ram and turbo jet engine increases, the flame front is carried further and further to the rear of the combustion chamber. In some cases the flame front has a tendency to move downstream from the fuel injection nozzles in the engine, and then to return to a point adjacent the nozzle tips and to periodically follow the same combustion pattern. That type of combustion pattern is known as cycling. A characteristic noise is produced when the fuel burns in this manner and the flame is often near the point of "blow out." Blow out is the point at which the flame is completely extinguished as it moves further and further away from the fuel injection nozzle tips.

Figure 1 diagrammatically sets forth a pulse jet engine. Figure 2 diagrammatically shows a turbo-jet engine. Figure 3 diagrammatically shows a ram-jet engine.

An object of this invention is to provide an improved method for operating jet engines. Another object of this invention is to provide an improved method for increasing the thrust of jet engines. Another object of this invention is to provide improved means for increasing the thrust of jet engines even with ordinary hydrocarbon fuels. Another object of this invention is to provide a method for extending the operational limits of jet engines. Another object of the invention is to reduce cycling in a continuous combustion jet engine. Other and further objects and advantages of the invention will be apparent upon study of the accompanying disclosure.

Generally speaking, the invention resides in the injection into the combustion zone of a jet engine of a normally nongaseous nitrogen compound which decomposes rapidly upon heating to give large volumes of gas. The nitrogen compound may be injected into the combustion chamber in the form of a comminuted solid. It may also be suspended in a gas, such as nitrogen, and injected into the combustion zone as a suspension. One preferred method of injecting the nitrogen compound into the combustion zone is to form a solution of the nitrogen compound in alcohol and to inject the solution into the combustion zone as a spray. Other solvents, such as water, may also be used, although a water solvent has a relatively high freezing point and in many types of operation would not be a desirable means for injecting a nitrogen compound into the jet engine combustion zone. Normally solid nitrogen compounds decompose rapidly upon heating and give a large volume of gas. Among the preferred nitrogen compounds which may be utilized in this

invention are ammonium nitrate, ammonium nitrite, hydroxylamine nitrate, urea, and urea nitrate.

Better understanding of this invention will be obtained upon study of the drawing in which Figure 1 is a diagrammatic representation of a pulse jet engine. This pulse jet engine 11 comprises an elongated shell 12 open at its upstream and downstream ends so as to permit the passage of air therethrough. Immediately downstream of the upstream end of engine 11 is a plurality of flapper valves 13 which open in response to normal flow of air through engine 11 but which close upon the pressure downstream of the valves becoming greater than the pressure of the incoming air. Fuel inlet conduit 14 is provided immediately downstream of valves 13, and nitrogen compound inlet conduits 15 and 16 having valves therein are provided downstream of valves 13, inlet 15 preferably being upstream of fuel inlet conduit 14 and conduit 16 being downstream of the fuel inlet conduit. Flame holder 17, which may be of any conventional type of flame holder, is provided downstream of the fuel inlet conduit and preferably upstream of inlet conduit 16. A combustion zone 18 is formed downstream of flame holder 17 wherein fuel, generally a hydrocarbon fuel, is burned in the presence of air, and a nitrogen compound introduced through at least one of the inlet conduits 15 and 16 is decomposed therein. Gases resulting from the burned hydrocarbon and decomposed nitrogen compound are exhausted through an exhaust zone 19 in the downstream end of engine 11.

Figure 2 is a diagrammatic representation of a turbojet engine. Parts like those described in connection with Figure 1 of the drawing are indicated by like numerals. Turbojet engine 21 comprises an elongated shell 22, open at its upstream and downstream ends so as to permit high velocity gases to flow therethrough. Turbine 23 is provided downstream of combustion zone 18 and the gases resulting from the burning and decomposition of hydrocarbon fuel and nitrogen compound within the combustion zone are expanded through turbine 23 to the atmosphere through the exhaust zone 19. Turbine 23 is operatively connected to compressor 24 which is positioned upstream of the fuel and nitrogen compound inlet conduits. Compressor 24 aids in compressing the high velocity air stream supplied to the combustion zone.

A ram jet engine is diagrammatically shown in Figure 3 of the drawing. Ram jet engine 25 comprises an elongated shell 26, open at its upstream and downstream ends so as to permit the flow of high velocity gas therethrough. The fuel inlet 14 and nitrogen compound inlets 15 and 16 together with flame holder 17 are positioned similarly to that shown in connection with Figures 1 and 2. Combustion zone 18 and exhaust zone 19 are also similar to those shown in connection with Figures 1 and 2 of the drawing.

As pointed out above, the thrust produced by a jet engine equals the mass flow through the exhaust duct times its increase in speed. By producing larger volumes of gas in the combustion zone by means of this invention, a substantially greater gas mass is caused to flow through the exhaust duct, thus increasing the factor by which the increase in speed is multiplied. It will thus be seen that the thrust which is produced by a jet engine utilizing this invention is greatly increased.

Care must be taken, however, to maintain the

jet engine at operational efficiency. When too much of the nitrogen compound is injected into the combustion zone of the jet engine, a back pressure is produced which tends to cut down on the operational efficiency of the engine. The jet engines should be operated so that the gas liberated by the decomposition of the nitrogen compound is less than the volume of other gases in the combustion chamber. Generally speaking, the ratio of gas produced by the decomposition of nitrogen compound to other gases in a jet engine combustion chamber should be maintained within the limits of from 1:1.25 to 1:10. It is preferred, however, to maintain the ratio within the limits of from 1:2 to 1:5.

The point at which the normally solid nitrogen compound is injected into the combustion zone of a jet engine should be carefully selected so as to insure proper heating of the nitrogen compound. Although the nitrogen compound is decomposed if it is injected at a point upstream of the fuel injection point, best operation is obtained when the material is injected into the combustion zone at a point downstream of the fuel injection point. In ram jet and turbo jet engines the combustion zone may comprise nearly the entire structure downstream from the fuel injection.

The above designated jet engine types may generally be operated by injecting a hydrocarbon fuel and air into the combustion zone of the jet engine at a fuel-air ratio between .005 and .10 and igniting the fuel so as to heat the air and combustion gases, thus increasing the volume of gas mass which is exhausted through the exhaust zone of the jet engine. Turbo jet engines are preferably operated on a fuel-air ratio between .01 and .03. Ram jet and pulse jet engines are preferably operated at fuel-air ratios of from .03 to .07. In the operation of this invention fuel and air are injected into the combustion zone of the engine at a fuel-air ratio between .005 and .10. At least one normally solid nitrogen compound is injected into said combustion zone at such a rate that upon decomposition of the nitrogen compound the ratio of the gas produced thereby to the other gases in the combustion chamber is within the range of from 1:1.25 to 1:10. The fuel is burned in the combustion zone so as to heat the air and combustion gases and at the same time decompose the nitrogen compound. The gas mass is then exhausted from the combustion zone through a rearwardly extending exhaust zone, thereby increasing the speed of the engine by the increased thrust of the exhaust gases in the exhaust zone.

This invention not only results in an increase in the thrust of a jet engine, but also tends to obviate cycling and also extends the operational limits of jet engines by increasing the speed of the engine before blow out point is reached. It is believed that the result in reducing cycling and the tendency to extend the operational limits of the jet engine is due to the increased compression which is made possible by the increased volume of gas present in the combustion zone. By utilizing this invention a hydrocarbon fuel having poorer combustion characteristics than are ordinarily desired may be utilized and will produce better results than had been obtained with them heretofore.

As an example of how this invention operates, it should be noted that 80 grams (47 cc.) of ammonium nitrate decomposes to give 67 liters of gas at standard temperature and pressure.

If, however, the temperature is raised to about 1650° C. at atmospheric pressure, which is within the temperature range of a ram jet exhaust gas, the volume of resulting gases is about 470 liters. The gas mass which is thus made available for exhaust is substantially increased thereby.

Other modifications will be apparent to those skilled in the art upon study of the accompanying disclosure. The principle of this invention may be utilized to increase the power output of non-aerial gas turbine power plants. This modification together with other obvious modifications is believed to be within the spirit and scope of the disclosure.

I claim:

1. In a method for operating a jet engine in the propulsion of an aircraft, wherein high velocity gas passes successively through a compression zone, a combustion zone, and an exhaust zone at operating conditions of varying severity such as result in unstable burning of fuel in said combustion zone and wherein hydrocarbon fuel and air are injected into said combustion zone of said jet engine at a fuel-air ratio between .005 and .10; the improvement which comprises injecting into said combustion zone a normally solid nitrogen compound selected from the group consisting of ammonium nitrate, ammonium nitrite, hydroxylamine nitrate, urea, and urea nitrate, at such a rate that the ratio of gas produced from said nitrogen compound to other gases in said combustion zone ranges from 1:2 to 1:5; burning said fuel with said air in said combustion zone so as to heat any excess air and combustion gases and decompose said nitrogen compound to form a gas in such quantity as to stabilize the burning of said fuel; and exhausting said gases from said combustion zone through an exhaust zone.

2. A method of claim 1, wherein said nitrogen compound is urea; and the ratio of gas produced from said injected nitrogen compound to other gases in said combustion zone ranges from 1:2 to 1:5.

3. A method of claim 1, wherein said nitrogen compound is urea nitrate; and the ratio of gas produced from said injected nitrogen compound to other gases in said combustion zone ranges from 1:2 to 1:5.

4. The method of claim 1, wherein said nitrogen compound is ammonium nitrate; and the ratio of gas produced from said injected nitrogen compound to other gases in said combustion zone ranges from 1:2 to 1:5.

5. The method of claim 1, wherein said nitrogen compound is ammonium nitrite; and the ratio of gas produced from said injected nitrogen compound to other gases in said combustion zone ranges from 1:2 to 1:5.

6. The method of claim 1, wherein said nitrogen compound is hydroxylamine nitrate; and the ratio of gas produced from said injected nitrogen compound to other gases in said combustion zone ranges from 1:2 to 1:5.

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