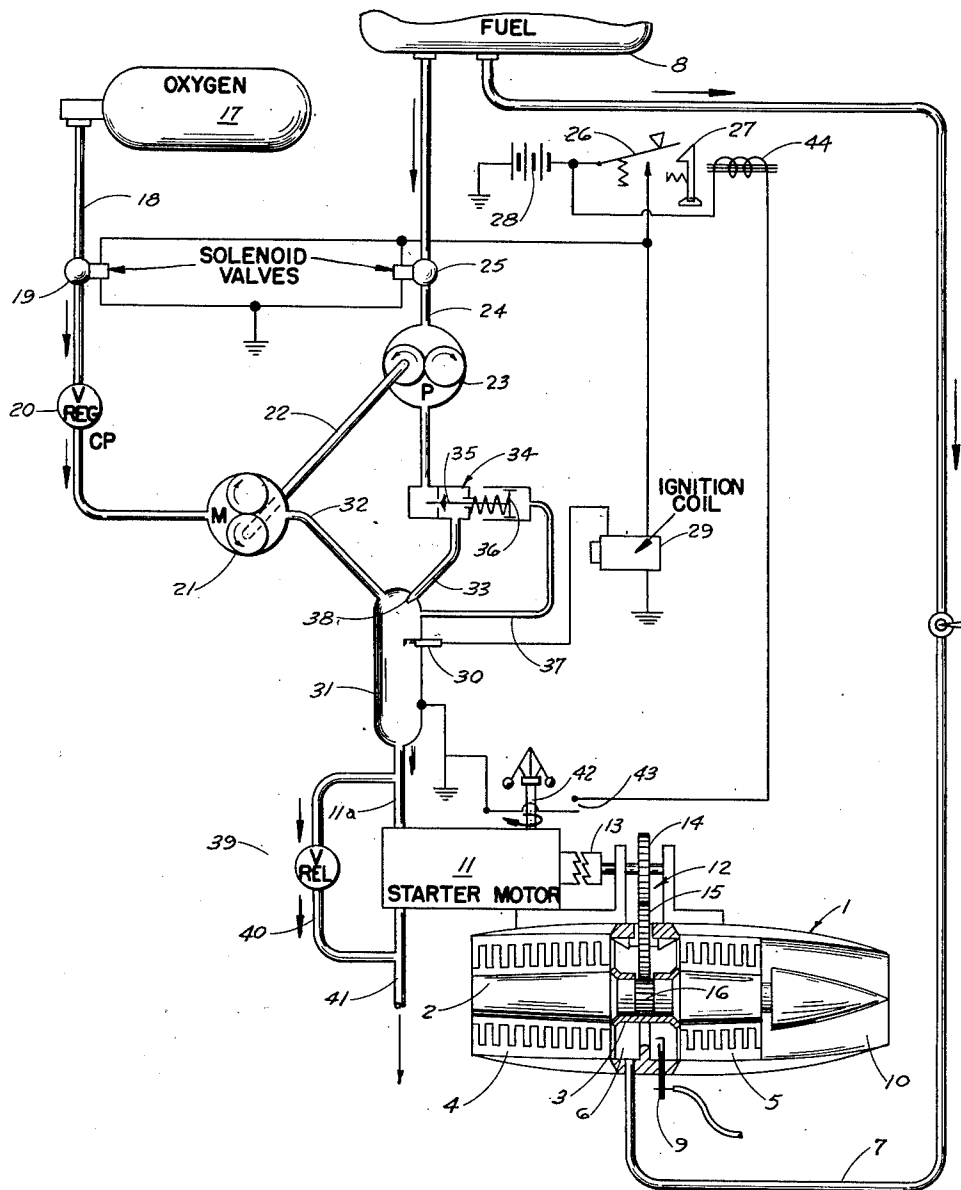


June 30, 1953

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2,643,511

ENGINE STARTER HAVING COMBUSTION CHAMBER SUPPLIED
WITH FUEL AND COMBUSTION SUPPORTING MEDIUM
FOR CONSTANT RATIO BY WEIGHT
Filed Oct. 7, 1949



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2,643,511

ENGINE STARTER HAVING COMBUSTION
CHAMBER SUPPLIED WITH FUEL AND
COMBUSTION SUPPORTING MEDIUM
FOR CONSTANT RATIO BY WEIGHTArthur T. Briggs, South Williamsport, Pa., as-
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Application October 7, 1949, Serial No. 120,101

4 Claims. (Cl. 60—39.14)

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This invention relates to prime movers and particularly to engine starter mechanisms which are capable of producing a high starting torque under a wide variety of ambient atmospheric conditions. The present invention is particularly useful in starting aircraft propulsion units, such as turbo-jet engines, and for this reason the preferred embodiment herein disclosed is described with reference to such an aircraft engine.

An object of the present invention is the provision of an engine starter device which is substantially instantaneously available when required to start an associated engine. This is obviously a highly desirable feature, particularly when an aircraft engine must be started under flight conditions.

Inasmuch as aircraft propulsion units are required to operate under a wide variety of altitude conditions, it is an object of the present invention to provide an engine starter device that is capable of producing a high starting torque at high altitudes as well as at sea level and that is capable of starting an engine regardless of the variations of atmospheric temperature and pressure to which the starter is subjected.

Another object of the present invention is the provision of an engine starter which is compact and very light in weight but nevertheless capable of producing a high starting torque with safety and reliability. A further object of the invention is the provision of an engine starter which is practically independent of heavy batteries and consumes very little electrical energy in its operation, contrary to the requirements of certain electrical type engine starters that are in common use today.

The present invention embraces a starter mechanism, the starting cycle of which is electrically initiated by the pilot or attendant of the engine to be started. The mechanism comprises a combustion chamber to which is supplied oxygen and liquid fuel in a predetermined ratio, the fluids being mixed and ignited within the combustion chamber thus producing highly heated and compressed gaseous combustion products for energizing a starter motor associated with the engine.

A desirable feature of a prime mover mechanism is inherently stable operation and also automatic regulation. It is therefore an important object of the present invention to provide a mechanism that is inherently stable and automatically regulated in its production of power gases of a substantially constant temperature and pressure for energizing a starter motor to accelerate an engine to be started.

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A still further object of the present invention is the provision in an engine starter mechanism of a simple, cheap and effective mechanical device which is constructed and arranged to deliver fuel and a combustion supporting medium to a combustion chamber in a fixed ratio, regardless of the rate of consumption of the mixture and demand to which the combustion chamber is subjected by the associated starter motor.

The starter motor incorporated in the present invention is supplied with highly heated and compressed fluid from the combustion chamber at all times during the starting cycle. Depending upon the type of starter motor used, the rate of flow of power gas to the motor may vary with the speed of the starter motor correspondingly as the associated engine, driven thereby, is accelerated and increases in speed. It is desirable to have the pressure of the gas, supplied to the starter motor, regulated to a constant value at all times regardless of the rate of consumption of the fluid and for this reason a particular advantage and object of the present invention is that the preferred embodiment is constructed and arranged to provide automatic pressure regulation of the power gas under all operating conditions, such regulation being accomplished by means controlling the flow of fluids to the combustion chamber, thus eliminating the need for regulating the pressure of the extremely hot and highly compressed gas itself.

A still further object of the present invention is the provision of an engine starter mechanism incorporating a speed sensitive element which automatically shuts off the mechanism after the associated engine has been started. Another object of the present invention is to provide an aircraft engine starter which operates with increasing efficiency as the ambient atmospheric pressure decreases with increases of altitude.

Another object of the herein disclosed invention is its inherent efficiency of operation and relative simplicity. An advantage of this invention is that a wide variety of fuels may be used by the starter mechanism for starting an associated engine, thus making it possible to use the same fuel supply that the engine itself uses.

The novel features that are considered characteristic of the invention are set forth in the appended claims; the invention itself, however, both as to its organization and method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in conjunction with the accompanying drawing which shows diagrammatically

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the construction and arrangement of the engine starter mechanism in operative relation to a turbo-jet aircraft engine.

With reference to the drawing, the preferred embodiment of my engine starter is shown in conjunction with a turbo-jet aircraft engine generally designated 1, comprising a rotor 2 rotatively secured in bearings 3, the forward end of the rotor constituting a part of a compressor section 4 and the rear portion of the rotor constituting a part of a turbine section 5. Disposed intermediate the compressor and turbine sections is a fuel burner 6 to which liquid fuel is conveyed by a fuel pipe 7 from a fuel tank 8, which may be one of the main fuel tanks of the aircraft. Ignition plug 9 is provided in the fuel burner 6 to ignite the mixture of fuel and the compressed air supplied thereto by the compressor section. The highly heated resulting products of combustion undergo a partial expansion in the turbine section and complete their expansion in nozzle section 10, provided in the after part of the turbo-jet engine, the power developed by the turbine driving the compressor, thus making operation of the engine continuous.

Turbo-jet engines of the type herein disclosed cannot be started by merely supplying fuel to the combustion chamber, while energizing the ignition plug, because initially there is no pressure head available to force air through the fuel burner to support combustion and provide compressed gases for expansion through the turbine. For this reason, supplementary means must be provided for initially accelerating the rotor to a predetermined rotational speed in order to render the compressor section operative and assure a continuous supply of compressed air to the fuel burner. When such a supply of compressed air is provided, continuous combustion is established in the burner by the ignition plug, and the energy subsequently developed by the expansion of the hot gases in the turbine section supplies the energy necessary for continuing the rotation of the rotor and compression of air in the compressor section.

The supplementary starting means which constitutes a preferred embodiment of the present invention comprises a starter motor 11 which is arranged to drive rotor 2 through associated gearing, generally designated 12. A clutch 13 interconnects the gearing and the starter motor and transmits the energy of the motor to a drive gear 14 which delivers power through intermittent idler gear 15 to a driven gear 16 which is joined to and rotates with engine rotor 2.

During the starting cycle power gas is supplied to the starter motor which is thereby rotated and delivers energy through clutch 13 and the associated gearing to the engine proper. The application of energy in this manner is continued until the rotor has attained a self-sustaining operating speed at which time the clutch is disengaged and the starter system is rendered inoperative.

It is contemplated that various types of conventional clutches, well known in the art, may be used; and it is recognized that disengagement of the clutch may be made dependent upon the speed attained by the engine relative to that of the starter motor, such as effected by a conventional over-running clutch when the speed of the normally driven member exceeds that of the driving member.

Many designs of starter motors may be used in a practical application of this invention, either

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a turbine type or direct displacement type of motor being suitable for the purpose. The present invention has particular utility and advantage when used in conjunction with a direct displacement type motor, such as a conventional piston and cylinder type motor, in which the flow of power gas actuating the motor varies more or less linearly with its rotational speed; and for this reason, the invention will be described with reference to such a starter motor. As will be recognized by a person skilled in the art, it is important to the proper operation and durability of a direct displacement motor that the temperature of the power gas supplied thereto be regulated so as not to exceed and preferably to be held constant at a given value lest the oil film on the running surfaces of the motor be destroyed and general deterioration instigated.

A unique system is provided by the present invention to supply highly compressed and heated power gas to the starter motor at a substantially constant temperature and pressure. This system comprises a high pressure source of oxygen gas 17 such as a commercially available flask of oxygen, connected to a conduit 18 in which is operatively disposed a normally closed solenoid valve 19 which, when energized and opened, admits a flow of the highly compressed oxygen to a pressure reducing valve 20. After being reduced to a predetermined pressure, the oxygen is directed to a rotary oxygen motor 21, which is directly coupled by a shaft 22 to a gear pump 23. The gear pump increases the pressure of and meters liquid fuel, supplied thereto by a conduit 24, which communicates with the main engine fuel tank 8. Disposed in conduit 24 is a normally closed solenoid valve 25 which is energized and opened to permit a flow of fuel simultaneously with the opening of solenoid valve 19.

It is desirable, although not necessary, to maintain the oxygen gas at constant temperature, variations of temperature causing the mixture ratio to depart slightly from a constant value. However, for practical purposes, the mixture ratio is maintained substantially constant by the herein disclosed device. Any temperature variation is of minor importance, particularly during any starting cycle, which is usually less than a minute in duration.

It will be obvious from the description and the associated drawing that of necessity a pressure drop must occur across the motor 21 in order to develop energy therein for the rotation of shaft 22. Preferably the rotary motor 21 should have a very small clearance volume to make the metering characteristic of the motor per revolution relatively independent of the down stream pressure of the oxygen. The rotary oxygen motor 21 may in practice be merely a gear pump of conventional design used as a motor, the gears of the gear pump being driven by the passage of oxygen, thus rotating the associated shaft 22.

When the engine starting cycle is initiated, the normally closed solenoid valves are opened, permitting the flow of oxygen and liquid fuel to rotary motor 21 and gear pump 23, respectively. The flow of oxygen through the motor drives shaft 22 and gear pump 23. Inasmuch as the motor is supplied with oxygen at a substantially constant density because of its essentially constant pressure and temperature, each rotation of the motor represents the passage therethrough of a definite weight of oxygen. Similarly each rotation of gear pump 23 compresses and passes a fixed quantity of liquid fuel. In order to estab-

lish the proportion in which the oxygen and liquid fuel are to be metered, it is merely necessary to choose a motor 21 and a gear pump 23 having the desired volumetric displacements per revolution. Another very simple way of changing the mixture ratio established by the oxygen motor and fuel pump is by varying the pressure setting of oxygen pressure regulator 20. A variation of the pressure regulator whereby it establishes a higher down stream pressure increases the density of the oxygen at the inlet of rotary motor 21. In a similar manner a decrease of pressure setting of the oxygen pressure regulator decreases the pressure of the oxygen at the inlet of the rotary motor and correspondingly decreases the density. It will be apparent that inasmuch as the displacement of liquid fuel per revolution of shaft 22 is constant at all times a change in the weight of oxygen passed per revolution of the rotary motor directly changes the resulting mixture ratio.

From experiments that have been completed with devices similar to the preferred embodiment herein disclosed it is apparent that a fuel to oxygen ratio of 2 to 1 by weight is satisfactory for producing power gas to start associated engines. It will be apparent from a later part of this description that the actual mixture ratio used may be varied over a wide range, the ratio of 2 to 1 being merely illustrative of what has been actually used satisfactorily in practice.

In order to initiate the starting cycle, an electrical switch 26 is closed by the pilot or attendant and is held in its closed position by an associated spring-urged latch member 27. The closing of switch 26 completes an electrical circuit through battery 28 and ignition coil 29, as well as through solenoid valves 19 and 25, which are energized and admit fluid flow to the rotary motor and gear pump. Energization of the ignition coil 29 supplies a high potential current to a spark plug 30 which is provided in a side wall of a combustion chamber 31.

The oxygen flowing through and being metered by motor 21 is conveyed by conduit 32 to the combustion chamber where it joins and is intimately mixed with metered fuel conveyed to the combustion chamber by a conduit 33 in which a flow regulator, generally designated 34, is provided. This flow regulator may be any conventional type and may include a needle valve 35, which is normally forced open by an associated spring and which is arranged for closing movements in response to fluid pressure acting on a piston member 36, the compressed fluid being conveyed to the piston member from the combustion chamber by a conduit 37. The regulated fuel is atomized in the combustion chamber by a fuel nozzle 38.

The intimate mixture of fuel and oxygen within the combustion chamber is ignited by spark plug 30, the ensuing combustion rapidly producing a high temperature within the chamber. The highly heated and compressed products of combustion flow from the chamber to starter motor 11 through conduit 11a and provide the energy for driving the starter motor which, through clutch 13 and the associated gearing, drives the engine to be started.

The starter mechanism disclosed can be made very light and compact. It is noteworthy that a combustion chamber approximately one inch in diameter and less than a foot long may be used to supply power gas for starting a full size, commercial turbo-jet engine.

As the engine being started is accelerated and

increases in rotational speed, the direct displacement starter motor increases in speed and requires an increased rate of flow of power gas, placing an increased demand on the combustion chamber and causing a decrease of pressure therein. The pressure reduction is communicated to piston 36 of the fuel flow regulator permitting needle valve 35 to open and admit an increased fuel flow to the combustion chamber.

The increased fuel flow permitted by needle valve 35 allows a greater rotational speed of shaft 22 resulting in a simultaneous increase of oxygen flow until the flow of fuel and oxygen have increased sufficiently to reestablish the original pressure. It will be apparent that inasmuch as a constant amount of oxygen and fuel is passed to the combustion chamber per revolution of shaft 22, the mixture ratio of the fuel and oxygen remains substantially constant whereby temperatures within the combustion chamber will remain within predetermined limits.

If for any reason the pressure tends to rise within the combustion chamber, the pressure increase is transmitted to piston 36 which moves needle valve 35 towards the closed position, thus restricting the flow of fuel to the combustion chamber. The restriction of the fuel flow reduces the rotational speed of shaft 22 and correspondingly the flow of oxygen through motor 21. In this manner the rate of flow of oxygen and fuel to the combustion chamber is decreased until the original pressure is reestablished.

If a slight variation in the combustion chamber pressure is allowable, the fuel flow regulator 34 may be omitted entirely. The pressure within the combustion chamber will then be determined by that pressure which is established by the oxygen pressure regulator less the loss of pressure resulting from the flow of oxygen through the oxygen motor. In the event that the fuel flow regulator is omitted, the pressure drop in the oxygen, as it flows through the motor, will be greater at high flows than at low flows in order to compensate for the increased resistance of the fuel lines and fuel nozzle 38 at the higher flows. For example, it has been calculated that with a fuel to oxygen ratio of 2 to 1 by weight the chamber pressure will vary from approximately 200 p. s. i. a. at 100% flow to 211 p. s. i. a. at no flow.

For safety, a pressure relief valve 39 has been provided in a conduit 40 to relieve any excess pressures, generated within the combustion chamber during the establishment of combustion therein, to exhaust pipe 41 through which the spent gases are vented from the starter motor to the atmosphere.

A fly ball governor 42 of conventional design is directly driven by the starter motor and is constructed and arranged to close an electrical switch 43 when the starter motor has attained a rotary speed in excess of that required for the continuous operation of the turbo-jet engine. Closing of electrical switch 43 completes an electrical circuit through battery 28 and a solenoid 44, the solenoid being cooperatively disposed to latch member 27 for disengaging it from switch 26 upon its energization. Release of switch 26 renders the starter system inoperative by permitting the closing of solenoid valves 19 and 25 and deenergizing spark plug 30. As described hereinbefore, at this point clutch member 13 will be disengaged thereby disconnecting the starter motor from the engine while the engine continues its operation.

It will be obvious to those skilled in the art that a combustion supporting medium different from oxygen can be used in conjunction with the herein disclosed device and that, furthermore, by simply varying the volumetric displacements of motor 21 and pump 23 the proportions of fuel and oxygen combined in the combustion chamber may be varied to limit the final temperature of the mixture of combustion products to a value acceptable for use in the starter motor. The temperature may be limited by the provision of either an excess of fuel or oxygen in the combustion chamber, the deviation of the mixture from the chemically correct mixture in each case tending to decrease the temperature of the final products of combustion.

In analyzing the operation of my system it should be remembered that the combustion of hydro-carbon fuels in either air or oxygen in chemically correct mixtures results in temperatures much too high to be utilized in a conventional starter motor even if the motor be of the turbine type. It is to be noted that, as a result of the addition of fuel in excess of that required for combustion, the volume of power gas is augmented not only by the vaporization of the excess fuel but also by the formation of intermediate combustion products rather than the final products of combustion which would be formed were sufficient oxygen available for complete combustion of the fuel.

From the nature of my invention it will be apparent that the successful operation of my mechanism is relatively independent of the type of fuel used. The fuel may be the same as that used by the engine being started, thereby eliminating the need for any special starting fuel or tanks. Inasmuch as an ample supply of fuel is available in most aircraft installations, it may be considered desirable to operate the combustion chamber of my mechanism with a very rich mixture, thus conserving the oxygen and limiting the temperature of the combustion products. Since my mechanism provides a high torque by virtue of the high power gas temperature and pressure produced, the starting cycle is of relatively short duration and the actual consumption of fuel is negligible.

From a consideration of the disclosed device it will be evident that the operation of starter mechanism is instantaneous for practical purposes. The thermal mass of the combustion chamber and motor is relatively small, enabling the system to rapidly attain thermal equilibrium and stable operating conditions.

In the event that a direct displacement motor is used, the efficiency of the motor will increase with an increase of altitude, since the accompanying decrease in ambient pressure will increase the available pressure differential which the motor can utilize in developing its power, the oxygen pressure at the inlet of rotary motor being completely independent of ambient conditions.

The herein disclosed device has been described with reference to an electrical ignition means. It is recognized, however, that any means capable of initiating combustion of the mixture within the combustion chamber is suitable for the purposes of my invention. In fact, if a self-igniting mixture of fuel and combustion supporting medium be used, no ignition means is necessary.

The principles herein disclosed are described and claimed in their broader aspects in my application, Serial No. 82,223, filed March 18, 1949, now Patent No. 2,611,239.

Having described a preferred embodiment of my invention, I claim:

1. In an engine starter system; a source of oxygen under pressure; a source of liquid fuel; normally closed electrically actuated valves to permit a flow of oxygen and fuel upon simultaneous energization; a pressure reducing valve supplied with oxygen under pressure upon energization of said valves; a constant displacement rotary oxygen actuated motor supplied with oxygen at constant pressure by said reducing valve; a constant displacement gear pump driven by said rotary oxygen actuated motor for compressing fuel supplied thereto upon the energization of said valves; a connection between said motor and said gear pump to insure corresponding rotational speeds thereof; a combustion chamber, said combustion chamber being connected with said rotary motor and gear pump whereby it is supplied with fuel and oxygen in a ratio determined by the volumetric capacity of said motor and pump; flow regulating means responsive to the pressure within said combustion chamber for regulating the flow of fuel supplied thereto; ignition means for initiating combustion within said combustion chamber; a starter motor driven by combustion products from said combustion chamber; and means for energizing said electrically actuated valves.

2. In an engine starter system; a source of oxygen under pressure; a source of liquid fuel; normally closed electrically actuated valves to permit a flow of oxygen and fuel upon simultaneous energization; a pressure reducing valve supplied with oxygen under pressure upon energization of said valves; a constant displacement rotary oxygen actuated motor supplied with oxygen at constant pressure by said reducing valve; a constant displacement gear pump driven by said rotary oxygen actuated motor for compressing fuel supplied thereto upon the energization of said valves; a connection between said motor and said gear pump to insure corresponding rotational speeds thereof; a combustion chamber, said combustion chamber being connected with said rotary motor and gear pump whereby it is supplied with fuel and oxygen in a ratio determined by the volumetric capacity of said motor and pump; flow regulating means responsive to the pressure within said combustion chamber for regulating the flow of fuel supplied thereto; ignition means for initiating combustion within said combustion chamber; a starter motor driven by combustion products from said combustion chamber; means for energizing said electrically actuated valves; and governor means responsive to the speed of the engine being started; whereby said valves are deenergized when a predetermined speed has been attained.

3. In an engine starter system; a source of combustion supporting medium under pressure; a source of fuel; normally closed valves to permit a flow of combustion supporting medium and fuel when opened; a pressure reducing valve supplied with combustion supporting medium under pressure upon opening of said valves; a constant displacement rotary fluid actuated motor supplied with combustion supporting medium at constant pressure by said reducing valve; a constant displacement pump driven by said rotary fluid actuated motor for compressing fuel supplied thereto upon the opening of said valves; a connection between said motor and said pump to insure corresponding rotational speeds thereof; a combustion chamber, said combustion chamber being

connected with said rotary motor and pump whereby it is supplied with fuel and combustion supporting medium in a ratio determined by the volumetric capacity of said motor and pump; flow regulating means responsive to the pressure within said combustion chamber for regulating the flow of fuel supplied thereto; ignition means for initiating combustion within said combustion chamber; a starter motor driven by combustion products from said combustion chamber; and means for opening and closing said valves.

4. Apparatus as defined in claim 3 and, in addition, governor means responsive to the speed of the engine being started, said governor means being connected with said valve opening and closing means whereby said valves are closed when a predetermined speed has been attained by the engine.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,040,350	Keys	Oct. 8, 1912
1,052,588	Janicki	Feb. 11, 1913

Number
1,528,902
1,815,097
2,154,572
2,197,904
2,347,843
2,351,750
2,390,959
2,397,659
2,406,926
2,450,950
2,503,289
2,505,798
2,550,678

20

Name	Date
Williams	Mar. 10, 1925
Davidson	July 21, 1931
Lansing	Apr. 18, 1939
Terry	Apr. 23, 1940
Rayfield	May 2, 1944
Fawkes	June 20, 1944
Pfenninger	Dec. 11, 1945
Goddard	Apr. 2, 1946
Summerfield	Sept. 3, 1946
Goddard	Oct. 12, 1948
Nettel	Apr. 11, 1950
Skinner	May 2, 1950
Deacon	May 1, 1951

FOREIGN PATENTS

Number	Country	Date
606,613	France	Mar. 12, 1926
616,695	Great Britain	Jan. 26, 1949

OTHER REFERENCES

"Starter-Generator Control System for a Multijet Airplane," paper 48-239, presented at the AIEE Middle Eastern District meeting, Washington, D. C., October 5-7, 1948.

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