Feb. 24, 1953 R. M. AMMANN 2,629,225

PULSE FLOW FUEL INJECTION SYSTEM FOR TURBOJET ENGINES

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Fig 1

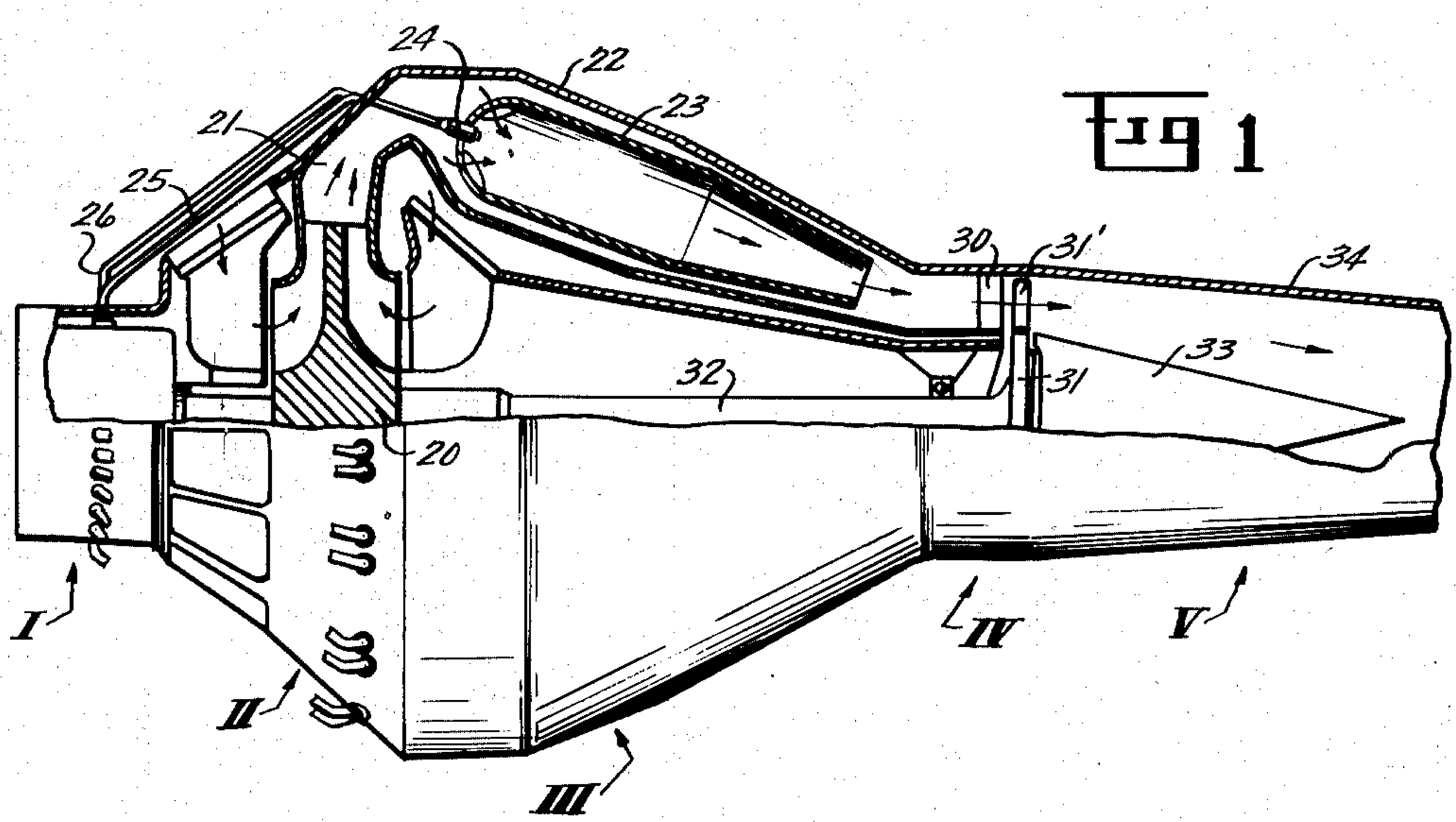
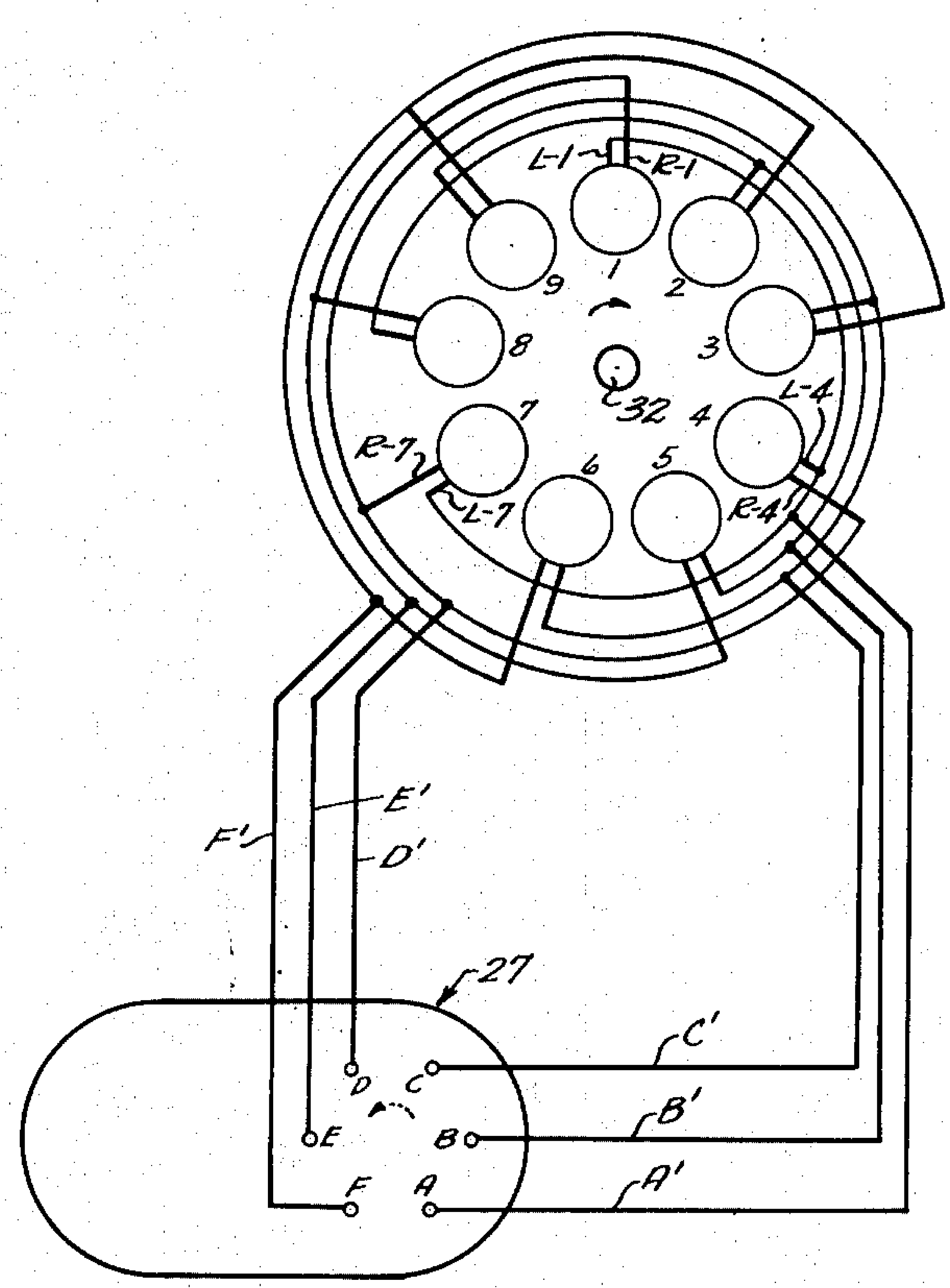


Fig 2



INVENTOR.
ROLF M. AMMANN
BY Wade Koontz
ATTORNEY and
Charles L. Burgoyne
AGENT

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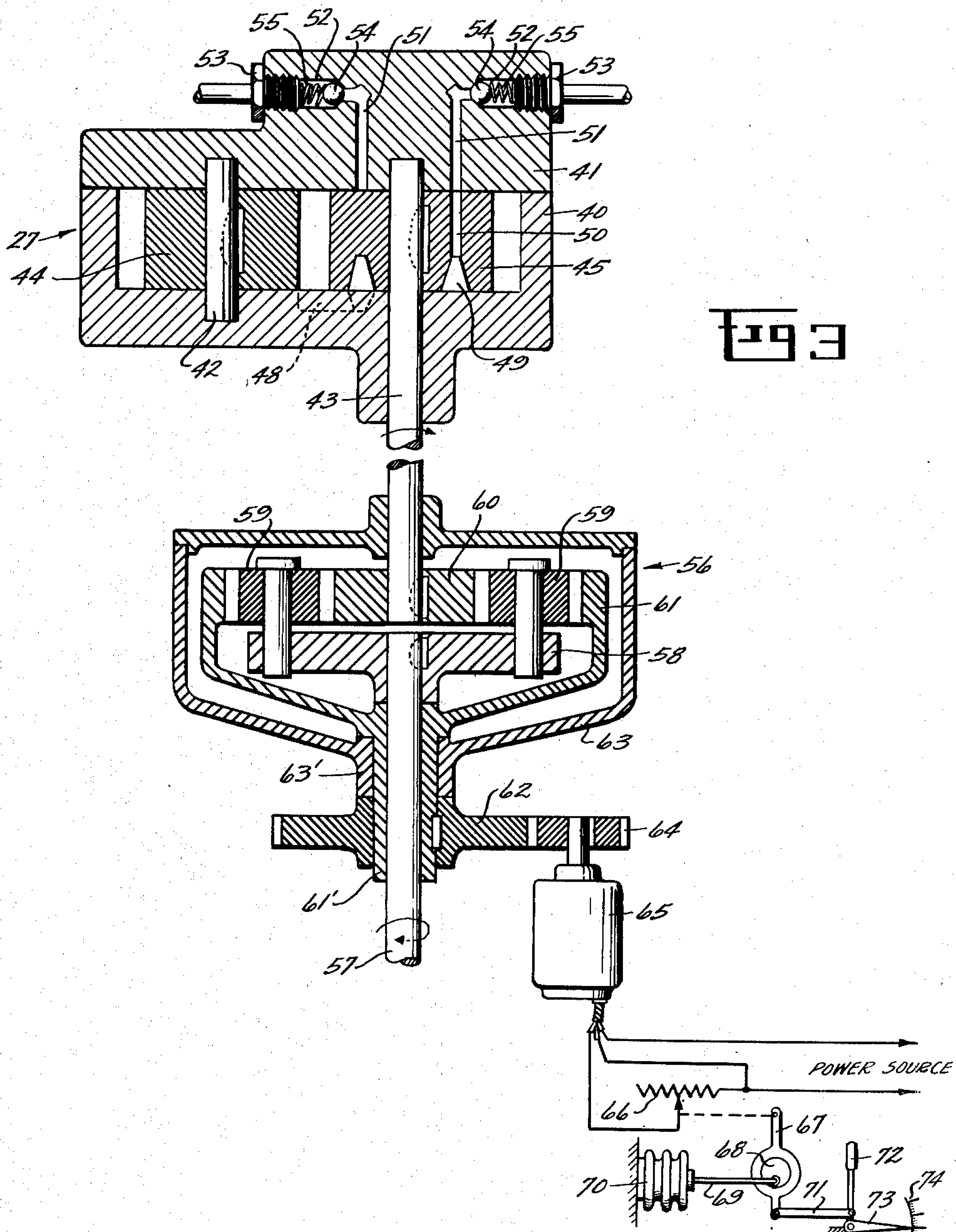

Fig 3

INVENTOR.
ROLF M. AMMANN
BY Wade Koontz
ATTORNEY and
Charles L. Burgoyne
AGENT

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FIG 6

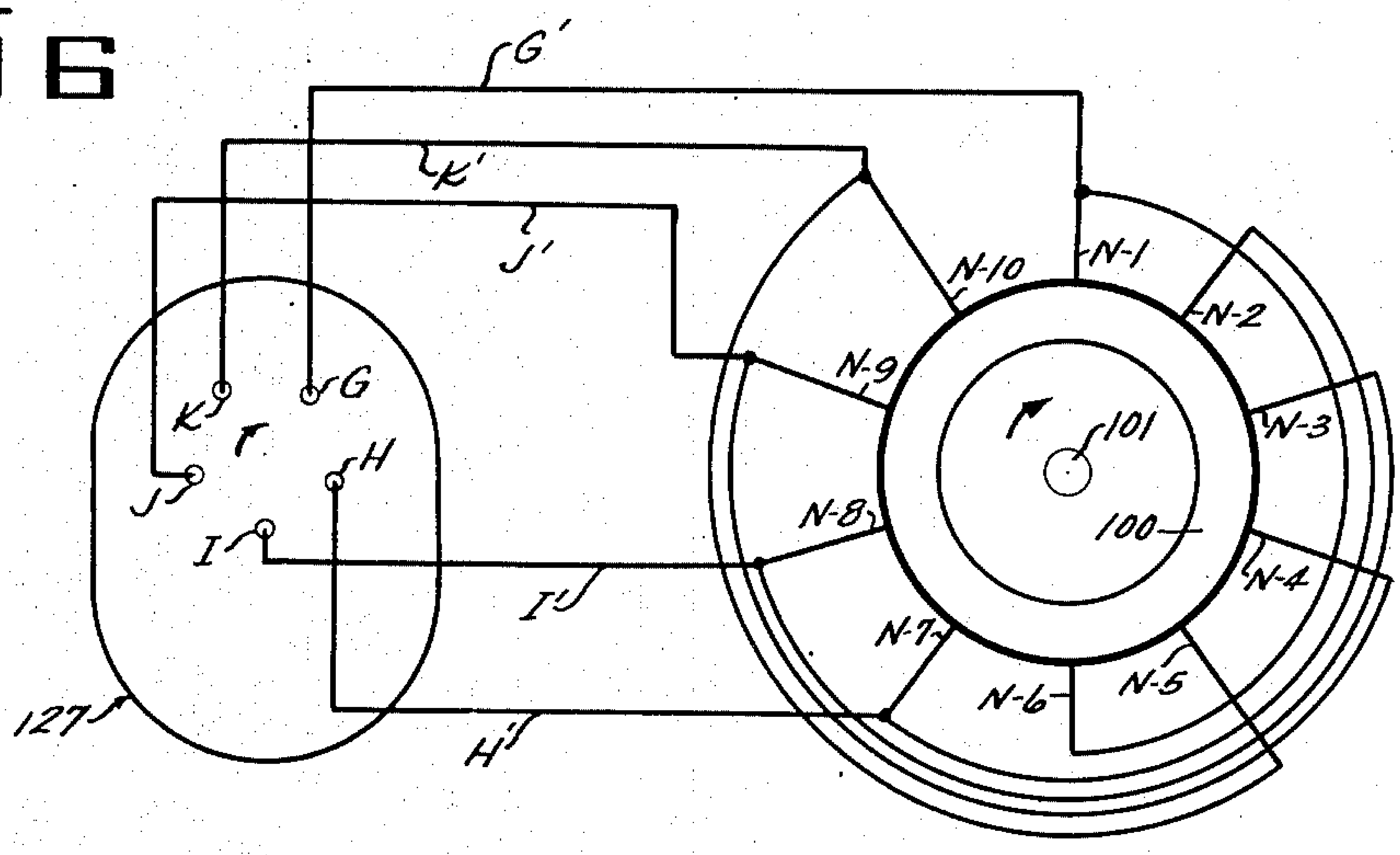


FIG 4

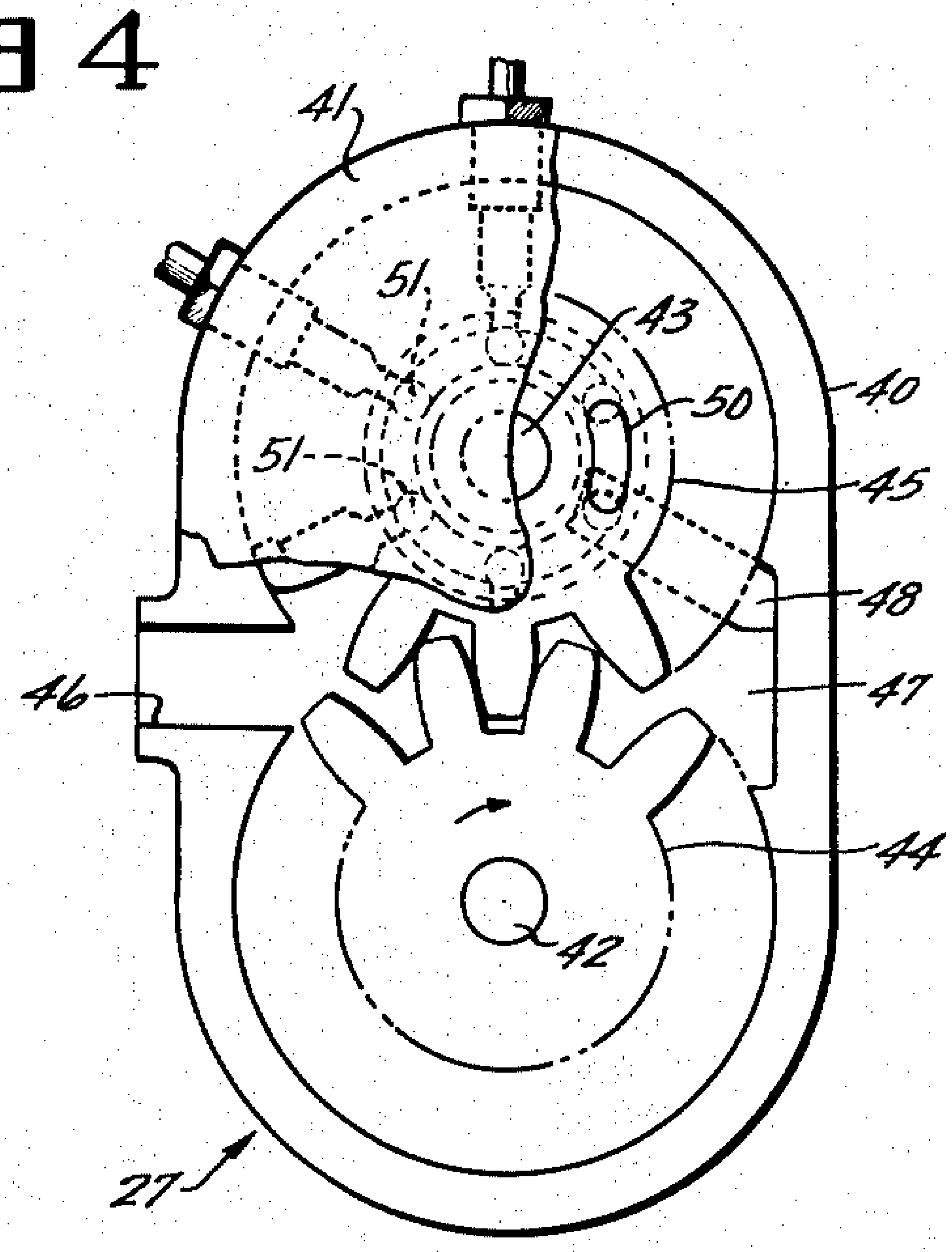
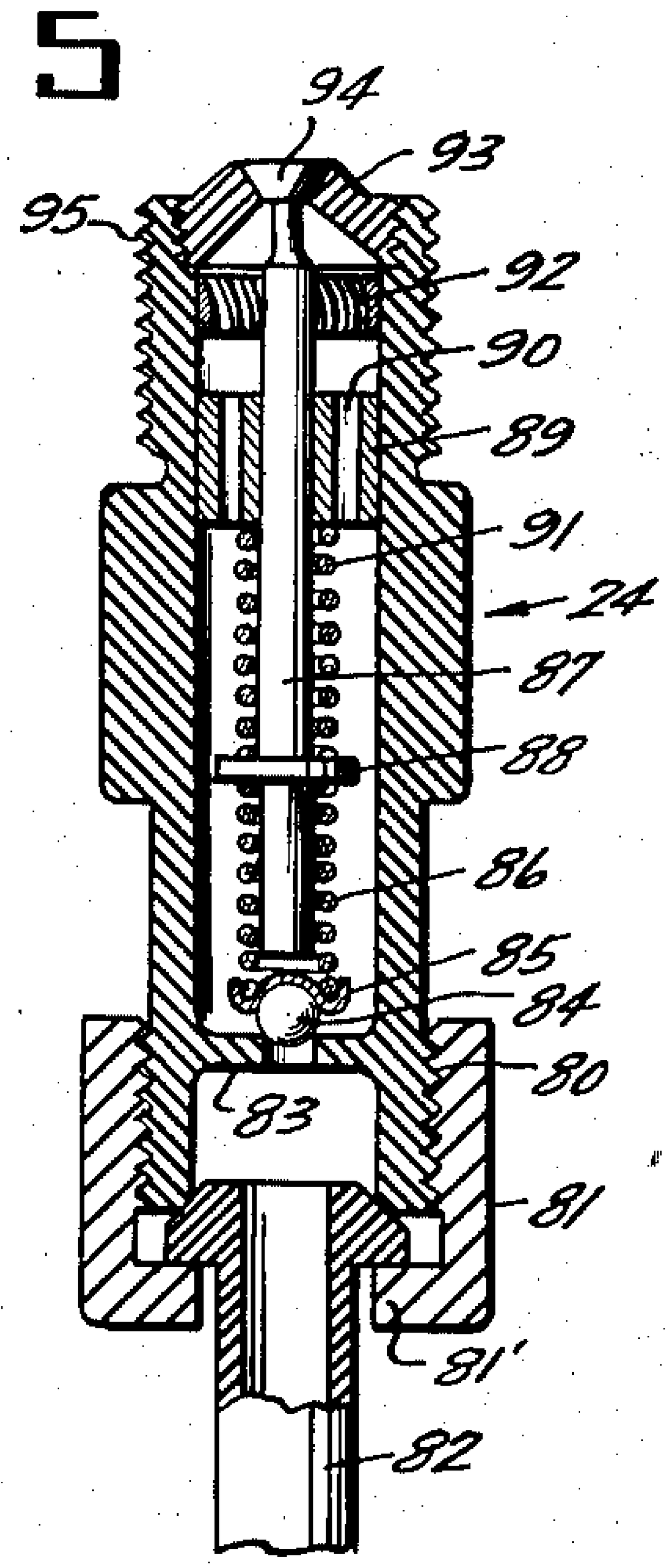


FIG 5



INVENTOR.
ROLF M. AMMANN
BY Wade Koontz
ATTORNEY and
Charles L. Burgoyne.
AGENT-

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UNITED STATES PATENT OFFICE

2,629,225

PULSE FLOW FUEL INJECTION SYSTEM FOR TURBOJET ENGINES

Rolf M. Ammann, Patterson Field, Ohio

Application March 8, 1948, Serial No. 13,733

3 Claims. (Cl. 60—35.6)

(Granted under Title 35, U. S. Code (1952), sec. 266)

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The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to me of any royalty thereon.

The present invention relates to a fuel injection system or apparatus for use with jet engines and combustion turbines.

The primary object of the invention is to provide a fuel injection system or apparatus for operative association with a turbojet engine wherein the injection apparatus provides means to force the fuel through the fuel feed pipes and injection nozzles and means to distribute the fuel intermittently to the various injection nozzles, and wherein the latter means operates in a predetermined cyclic manner to effect fuel distribution according to a definite pattern or plan depending on the type of engine, number of fuel injection nozzles and power output desired.

A secondary object of the invention is to provide a fuel injection system for use in a turbojet engine wherein the fuel injection nozzles are of a type having a self-cleaning action when actuated intermittently by fuel flowing therethrough in surges or impulses.

A further object of the invention is to provide a fuel injection system for use in a turbojet engine wherein there is provided a combined fuel pump and fuel distributor having drive means which is capable of substantial speed regulation and wherein the fuel distributor is adapted to supply uniform quantities of fuel to a plurality of fuel nozzles in an intermittent and predetermined manner.

A further object of the invention is to provide a fuel injection system for a turbojet engine in which said system includes a multiplicity of intermittently actuated fuel injection nozzles which are supplied with fuel in a predetermined sequence and at pressures which will ensure proper atomization of the fuel in spite of variations in the power setting of the fuel injection pump or engine power selector.

Another object of the invention is to provide an improved turbojet engine suitable for use on high speed aircraft and characterized by a fuel injection system which is reliable in operation and which requires a minimum of maintenance service over long periods of operation.

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Another object of the invention is to generally improve the dependability and operating characteristics of turbojet engines and fuel injection systems therefor.

The above and other objects of the invention will become apparent upon reading the following detailed description in conjunction with the drawings, in which:

Fig. 1 is a longitudinal side elevation view partly in cross section of turbojet engine provided with a fuel injection apparatus embodying the principles of the present invention.

Fig. 2 is a diagrammatic view of the fuel injection system as used with the engine of Fig. 1.

Fig. 3 is a schematic view partly in cross section and showing the principal operating components of the present fuel injection and distribution system.

Fig. 4 is an interior view of the combined pump and distributor component of the fuel injection and distribution system.

Fig. 5 is a longitudinal cross section of a fuel injection nozzle adapted for use in the present fuel injection system.

Fig. 6 is a diagrammatic view of the fuel injection system as applied to a turbojet engine having a single annular combustion chamber provided with a plurality of uniformly spaced fuel injection nozzles.

In turbojet engines and combustion turbines there is normally provided one or more combustion chambers equipped with fuel injection nozzles, which are adapted to atomize a liquid fuel delivered under pressure to the nozzles. The fuel is usually kerosene, which requires fairly high pressure for proper atomization. In employing open nozzles a high pressure should be maintained on the fuel at all times, since the combustion process will not proceed rapidly or efficiently without complete fuel atomization. Thus the atomizing function of the open nozzle depends on continuous high pressure fuel flow. Therefore the combustion and engine efficiency will be very good when large fuel volumes are being supplied to the engine, but will be very poor when small fuel volumes are being supplied. As a result the engine performance will tend to be unreliable and unsatisfactory at starting and idling speeds. The poor atomization at starting speed is further aggravated by the fact that the engine is cold when starting. Efficient performance of the engine at moderate rates of fuel flow is important, because in cruising at high altitudes the turbojet engine may run for long periods at moderate power output. Also in gliding from high altitudes the engine may be at idling speed for some time and if combustion is inefficient the combustion chambers may be cooled to such an extent as to cause cessation of combustion, thus stalling the engine.

Various solutions for the above stated difficulties have been proposed. As an example it has been proposed to use nozzles having two or three fuel openings of different size with means to select a fuel opening consistent with the power setting of the fuel pump. An alternative arrangement is the provision of two or more fuel injection nozzles in a group with an automatic selector valve to allow operation of as many nozzles simultaneously as required for the instant power setting of the fuel pump or fuel throttle valve. Thus it may be possible to operate each nozzle at an optimum injection pressure to avoid incomplete atomization of the liquid fuel. It has also been found that the open type of injection nozzle is often subject to "coking up," and thus becomes clogged as the carbon accumulations build up around the fuel opening. This is especially apt to occur at low rates of flow of the fuel, when there is little chance for the fuel itself to blow the carbon out of the way.

Fuel injection system for use on engine having multiple combustion chambers

Since the advantages of the present fuel injection system will become clear when its operation has been explained, reference will now be made to Fig. 1 for a description of one example of the system. Fig. 1 shows the essential elements of a turbojet engine having a radial flow compressor and a typical arrangement of multiple "can type" combustion chambers. Starting from the left hand end, the engine includes a fuel injection and accessory section I, an air compressor section II, a combustion section III, a turbine section IV, and an exhaust section V.

The compressor section II comprises a one-piece rotor **20** of duplex design and capable of drawing air from outside the engine according to the direction of the arrows and thus building up air pressure in the annular pressure chamber **21**. Leading from the outer edge of the chamber **21** there are a number of combustion chambers **22**, each of which encloses a retort or muffle chamber **23** having air inlet and outlet passages at the opposite ends thereof. At the air inlet end of the retort **23** there is provided a pair of fuel injection nozzles, indicated at **24**, which discharge liquid fuel in the direction of the air flow and which are supplied with fuel oil by means of a pair of fuel lines **25** and **26**. The fuel lines extend to a centrally located fuel distributing and pumping unit forming part of the accessory section I. This unit will be described in detail below but its function is to supply fuel to the various fuel lines in high pressure surges or pulses in a predetermined cyclic manner. One possible arrangement or plan for the firing cycle is shown in Fig. 2, where the numerals **1** to **9** denote separate combustion chambers corresponding in structure to the chamber **22** of Fig. 1. In Fig. 2 the separate nozzles are indicated by the letters L and R, meaning left and right. Thus the nozzles for chamber **1** may be denoted L–**1** and R–**1**, for chamber

2 the nozzles may be denoted L–**2** and R–**2** for example. The pump and distributor unit **27** is provided with six fuel outlets A to F which are active one at a time in rotation as indicated by the arrow, to supply fuel to the chambers **1** to **9** in clockwise rotation as shown by the arrow. The fuel lines A′ to F′ each connect to groups of three nozzles which are tabulated as follows:

Fuel Line	Nozzles
A′	L–1, L–4, L–7
B′	L–2, L–5, L–8
C′	L–3, L–6, L–9
D′	R–1, R–4, R–7
E′	R–2, R–5, R–8
F′	R–3, R–6, R–9

Since the lines are supplied with fuel in the order given above, the chamber firing order becomes obvious from the table of nozzle connections. It is understood that the firing sequence repeats itself at a rapid rate so that the combustion process is fairly continuous in each chamber. For example the distributor unit may be made to operate at one-half the engine speed if desired, although the speed relation may vary considerably in various engine designs. The spaced fuel injections in the chambers provide by combustion a continuous series of expansion waves following so closely on one another as to preclude the possibility of the spaced injections failing to ignite. At the beginning of each injection the fuel pressure builds up rapidly in order to open the fuel nozzle. When the nozzle opens the fuel is under high pressure and is therefore projected far enough to ensure ignition by the previously injected fuel charge as well as by radiation from the heated combustion chamber. Of course each chamber is provided with a spark igniter for starting the engine, but this feature is not illustrated because it is so well known. By using a plurality of fuel nozzles in each combustion chamber the reliability of the engine is increased and furthermore this arrangement permits the separate nozzles to completely close between fuel injections. By the firing plan used in the diagram of Fig. 2, each fuel nozzle is operated only once while the combustion chambers are going through two complete injection or firing cycles. Each cycle may be considered a firing sequence beginning with the firing of chamber **1** and ending with the firing of chamber **9**. Since the rapid action of the fuel distributor provides an ebb and flow of fuel pressure in the separate fuel lines A′ to F′, the present system may be aptly termed a pulse flow fuel injection system. The fuel feed lines connecting groups of three nozzles in three spaced combustion chambers and supplying fuel thereto simultaneously may be termed common rail fuel distributing conduits.

The combustion waves starting in the chambers **1** to **9** proceed toward the outlet ends of the chambers (see Fig. 1), and pass between guide vanes **30** of the turbine section IV. These vanes give the hot gases the proper direction so that they may act with greatest effect on the blades **31′** of turbine wheel **31**. The turbine wheel is mounted rigidly on a central shaft **32** which drives the compressor rotor **20** and also the units of the accessory section I. The rapid expansion of air and products of combustion in the combustion chambers, and also rearwardly thereof to some extent, provides a reaction effect to drive the engine in a direction opposite to that of the flowing gases. Of course the escaping hot gases must be allowed to flow freely from the exhaust section V with a minimum of turbulence, or hindrance to free flow. The central interior portion of the exhaust section is filled by a cone 33 which promotes smooth exhaust flow of the gases. The outer wall of the section V may be termed the exhaust nozzle or jet nozzle 34. The basic engine structure as shown in Fig. 1 is conventional, similar types of turbojet engines being shown in "Gas Turbines And Jet Projulsion For Aircraft" by G. Geoffrey Smith (fourth edition—1946). However such an engine equipped with a fuel injection system as proposed by the present invention has certain advantages which may be listed as follows:

(1) Greater efficiency at low speeds.
(2) Greater operating economy over the normal range of power outputs.
(3) More reliable operation because of self-cleaning fuel nozzles.
(4) Decreased maintenance costs due to improved fuel nozzle action.
(5) Better control of power output because of fuel cycling system and driving means therefor.
(6) More uniform fuel pressures at fuel nozzles because of direct fuel lines from pump to nozzles, or to small groups of nozzles.
(7) More uniform distribution of fuel results in better distribution of heat and less danger of structural failure due to localized overheating.

These various advantages will become more obvious as the details of the fuel injection system are described but it is noted that Figs. 1 and 2 are shown by way of example. The particular firing plan or sequence may obviously be varied considerably within the scope of the invention. It is preferred to have the firing progression of the chambers or groups of chambers proceed around the engine in the same direction that the turbine wheel 31 and main shaft 32 rotate, this direction in the example shown being indicated by a curved arrow. In operation the combustion in each chamber 22 proceeds more or less continuously, though with a wave-like action caused by the rapid sequence of the fuel injection surges. When a fuel nozzle opens to inject a new charge of fuel, the fuel pressure is at a maximum behind the nozzle and the fuel is well atomized. Moreover it is projected into the chamber with a maximum impulse the thus distribute itself over a greater volume of the space enclosed by the combustion chamber. The interior of the retort 23 may be provided with swirl vanes or mixing vanes to promote more thorough combustion and mixing of the products of combustion with the excess air normally supplied to augment the total volume and to promote cooling of the turbine blades.

Fuel pump and distributor

The fuel pump and distributor 27 is illustrated in Figs. 3 and 4, and one possible speed control means therefor is also shown in Fig. 3. The pump and distributor includes a housing 40 and cover plate 41. Rotatably mounted in the housing by means of parallel shafts 42 and 43 are mating pump rotors 44 and 45. The rotors form the impeller elements of a gear pump, which produces a pressure increase from the pump inlet 46 to the pump outlet 47. Connected to the outlet 47 is a fuel channel 48 extending toward the rotor shaft 43. The rotor 45, which covers a portion of the channel 48, has a circular channel 49 in its contiguous face. The groove 49 communicates with a fuel passage 50 extending to the opposite face of the rotor 45 and adapted to connect with the distributor passages 51 provided in the cover plate 41. As seen in Fig. 4 the passage 50 may be of such a size as to connect for a brief instant with two adjacent distributor passages 51, indicated in their relative positions by dotted lines. This prevents closing off the passage 50 completely and thus tends to prevent excessive thrust on the rotor 45, as well as preventing undesired fuel leakage and variations in power consumed by the pump. The distributor passages 51 connect with check valve chambers 52 threaded to receive fuel line couplings 53. The check valve chambers 52 contain ball check members 54 held in the positions shown by means of coil springs 55. The couplings 53 retain the various fuel lines A' to F' in connected relation with respect to the respective fuel distributor passages.

The pump shaft 43 being keyed to the rotor 45, the pump and distributor is thus adapted to be driven by this shaft through a differential 56. A power shaft 57 is driven by the engine main shaft 32 through reduction gearing. The ratio may vary according to the design of the engine but a suggested ratio from shaft 32 to shaft 57 is 4 to 1. The power shaft 57 is rigid with a carrier plate 58 on which is rotatably carried a plurality of planetary spur gears 59 meshing both with a sun gear 60 and a ring gear 61. The sun gear 60 is keyed to the pump shaft 43, while the ring gear 61 is keyed to a gear 62 located outside the differential housing 63. The ring gear 61 has no direct driving connection with the power shaft 57 but is freely journaled thereon, as well as in the boss 63' on housing 63, by means of the hollow boss 61' on the ring gear. The gear wheel 62 is driven by means of a spur gear 64 directly connected to a small control motor 65, which is adapted to have its speed varied in response to adjustment of the armature resistance 66. The armature circuit of the motor being in series with the resistance 66, an increase in the value of the resistance will reduce the current in the armature windings thus slowing down the motor 65. Also the power circuit to the motor may be opened by means of a switch to stop the motor 65 altogether. The wiper of resistance 66 is controlled through a lever 67 mounted to turn with respect to an eccentric 68. The relative rotative position of the eccentric 68 is determined by means of a link 69 and barometric bellows 70. Thus changes in atmospheric pressure with changes in altitude will affect the speed of motor 65 and accordingly change the speed of the pump and distributor unit 27. In turbojet engine operation the fuel-air ratio on a weight basis should remain fairly constant, and therefore at altitudes where the air is relatively thin the fuel flow should be reduced for efficient operation of the engine. For manual control of the speed regulating motor 65 within wide limits, the lever 67 is connected to a link 71 adapted for actuation by a hand lever 72 pivoted at its lower end. For indicating the setting of manual control lever 72, a pointer 73 is rigidly connected to the lever and is adapted to show on an indicia scale 74 just what the manual setting is at any time. When the manual control is manipulated, the end of link 69 connected to eccentric 68 becomes a relatively fixed point and the lever 67 merely turns on the fixed eccentric. When the manual control is stationary, the end of link 71 connected to lever **67** becomes a relatively fixed point and the lever **67** turns slightly in response to movement of the eccentric **68** by link **69** and bellows **70**.

Considering the action of differential **56** more in detail, it will be seen that the power shaft **57** rotates in a clockwise direction thus turning the carrier plate **58** at the same speed and in the same direction. The planetary gears **59** are of course carried around with the plate **58** and are adapted to rotate on their own pivots by reason of their engagement with the ring gear **61**. Now with the ring gear **61** stationary the pinions **59** will be driven in a counterclockwise direction about their own pivot shafts, looking at the lower side of the differential. The pinions **59** will in turn cause the shaft **43** to turn clockwise by their driving engagement with sun gear **60**. However looking at the upper side of the pump and distributor unit, as in Fig. 2, the shaft **43** and rotor **45** will be rotating in a counterclockwise direction. Now if the control motor **65** is turned on and acts through gears **62** and **64** to rotate the ring gear **61** in the same direction as the power shaft **57** and pump shaft **43**, the planetary pinions **59** will be speeded up thus increasing the rotative speed of gear **60** and shaft **43**. As the value of the armature resistance **66** is decreased the motor **65** will go faster and the pump shaft **43** will also be rotated faster to step up the fuel injection pressure and the amount of fuel injected in the combustion chambers at each actuation of the fuel nozzles. Expansion of the bellows **70** by the effect of increased altitude or movement of the manual lever **72** to the right will increase the instant value of resistance **66** to reduce the speed of motor **65** and also reduce the speed of the fuel pump. The speed control means for the pump and distributor involving a differential gearing assembly is shown by way of example, it being understood that other types of variable speed transmissions may be substituted as desired.

Fuel injection nozzle

The various fuel lines A′ to F′ terminate in fuel injection nozzles of the spring-closed type, such as shown in Fig. 5. Each fuel injection nozzle **24** is threaded as at **80** to engage similar threads formed internally of a member **81** which is flanged at **81′** to retain the fuel line **82** in connected relation to the nozzle. The hollow nozzle is provided with a transverse wall **83** centrally apertured to provide a valve seat engaged by a ball valve member **84**. On the opposite side of the ball there is a spring retainer **85** having a coil spring **86** seated therein. Extending within the spring **86** is a valve stem **87** having a flange **88** thereon adapted to be engaged by the upper end of spring **86**. Secured within the nozzle is a plug member **89** having a number of fuel passages **90** arranged in circular manner about the valve stem **87**. Seated between the plug member **89** and the flange **88** is a coil spring **91**, which acts to hold the nozzle closed as will be explained below. As the fuel flows outward under pressure through the fuel passages, it impinges on a series of swirl fins **92** to give the fuel a definite rotary motion before it leaves the nozzle and thus assist in more thorough atomization of the fuel. The outer end of the hollow nozzle is closed by an end closure **93** screw threaded into secured position as shown. The closure **93** is provided with a conical valve seat to receive the conical head portion **94** on the valve stem **87** in closely engaging relation.

The action of the fuel injection nozzle is fairly obvious but it is noted that the liquid fuel always fills the interior spaces of the nozzle. When pressure is put on the fuel by the action of the fuel pump and distributor, the fuel displaces the ball check member **84** and also forces the stem **87** outwardly against the compression of coil spring **91**. Thus the valve stem head portion **94** is lifted off its seat and the fuel is forced out in a swirling spray until the fuel pressure again falls to zero by action of the fuel distributor. The exact structure or formation of the valve stem head portion **94** and seat therefor may be varied considerably. For instance the parts may have curved mating faces, with the head portion **94** approximating a hemisphere. This will prevent the spray of fuel from spreading out too much as it enters the combustion chamber. It is seen also that the nozzle 24 is threaded at **95** to permit easy securing thereof in the combustion chamber wall.

The self-closing fuel injection nozzle as used in the present invention is a vital part of the fuel injection system. Even though carbon may collect on the end portions of the nozzle in the combustion chamber, the valve seat and complemental closure therefor are protected from the action of combustion except when the valve is open. At that time however the outflow of liquid fuel under high pressure effectively prevents any combustion products from reaching the valve seat or closure **94**. Also any crust or particles around the edges of these parts are blown off by the flowing liquid fuel when the valve opens under fuel pressure. As explained previously the spraying or atomizing action of fuel nozzle is always efficient, because the nozzle does not open until substantial pressure is put on the fuel entering the nozzle. Since the fuel pump and fuel distributor are engine driven the supply of fuel for combustion will always keep pace with engine speed. By providing a variable speed transmission between the engine and the fuel pump and distributor unit, the fuel quantities delivered to the combustion chambers may be varied sufficiently to provide flexible operation and precise engine control.

The fuel nozzle design as shown and described is only one example of a self-closing fuel injection valve. Other types and constructions may be substituted according to performance requirements. For instance a number of present day fuel nozzles for diesel engines would be suitable in many instances. One such fuel injection nozzle is shown on page 66 of "Diesel Fuel Injection Systems" by Louis R. Ford (1945). Others are shown on pages 119 to 122 of "Gemischbildung und Verbrennung im Dieselmotor" by Anton Pischinger and Otto Cordier.

Fuel injection system for use on engine having an annular combustion chamber

While the shape and form of the combustion section of a turbojet engine may vary it is to be understood that the pulse flow fuel injection system is adapted for use on all types of turbojet engines, since the system involves the cyclic distribution of liquid fuel to a plurality of spring-closed fuel injection nozzles regardless of the type of combustion chamber. In Fig. 6 there is shown in diagrammatic form a possible arrangement of fuel nozzles and fuel distribution plan for use with a turbojet engine having a single annular combustion chamber 100 and central engine shaft 101. The constructional details of such an engine may be found on page 117 of "Gas Turbines and Jet Propulsion for Aircraft" by G. Geoffrey Smith (fourth edition—1946). For purposes of illustration the engine combustion chamber 100 is provided with evenly-spaced fuel injection nozzles N-1 to N-10 all of which discharge into the same combustion chamber 100 in a direction more or less from the air inlet end to the gas outlet end. In some engines of this type there may be twice as many nozzles as shown in Fig. 6, since increase in the number of such nozzles gives more uniform distribution of heat and smoother gas flow to the turbine located just behind the combustion chamber. It is understood that the fuel injection nozzles N-1 to N-10 inclusive are of the self-closing type discussed hereinabove.

In the fuel distribution plan as shown in Fig. 6 the nozzles are combined in opposite pairs and supplied by fuel lines G' to K' The fuel lines connect to the fuel pump and distributor unit 127 at the fuel outlets G to K arranged in circular manner to receive fuel one at a time, in the same way as described with respect to Figs. 2 and 4. In this case the fuel distribution is in a clockwise direction as shown by the arrow on the unit 127. Also the fuel lines are connected so that the fuel nozzles are supplied in this same direction of rotation. The fuel lines G' to K' connect to pairs of nozzles as tabulated thus:

Fuel Line	Nozzles
G'	N-1, N-6
H'	N-2, N-7
I'	N-3, N-8
J'	N-4, N-9
K'	N-5, N-10

The firing plan of the combustion process becomes obvious from the table and from an inspection of Fig. 6. Just as in the first described embodiment of the invention the fuel pump and distributor unit 127 is controlled by a differential mechanism, but is driven by power from the engine main shaft 101 through a reducing gear. All the essential details of the fuel injection apparatus are the same in both examples. However with an annular combustion chamber the sequential combustion waves tend to cause a rotative effect on the products of combustion as the fuel injections proceed around the chamber in the same direction. This will obviate the necessity of mixing vanes in the chamber and will also result in slightly higher turbine speeds for the same flow of fuel. While there may be the usual "flame anchors" or dividing walls between the fuel injection nozzles, these will not extend more than a few inches rearwardly of the nozzles. As in the construction of Figs. 1 and 2, the turbine will be so built as to produce rotation of the turbine wheel and shaft in the same direction as the sequence of injection of fuel and order of firing of the nozzles. This direction is indicated by an arrow between the shaft 101 and the annular combustion chamber 100.

The present pulse flow fuel injection system for turbojet engines provides a controllable means to meter liquid fuel to a plurality of fuel injection nozzles in an orderly and positive manner. Moreover it is emphasized that the fuel injection nozzles require a positive fuel pressure

for actuation and this pressure guarantees adequate fuel injection pressure capable of atomizing the fuel even at low rates of fuel flow, as in starting and idling the engine. The self-closing fuel nozzles are also less subject to clogging by carbon accumulations, as explained above. The invention is not limited to the use of the specific fuel distribution apparatus shown, but may be practiced with various types of sequentially operated fuel injectors capable of forcing liquid fuel through the injection nozzles in a predetermined cyclic manner. The injection pattern to provide a logical firing sequence may be planned according to the particular engine and power requirements. The differences in cyclic firing order in the two illustrated embodiments demonstrate the possible wide variations in the specific details of the system.

The embodiments of the invention here shown and described are to be regarded as illustrative only and it is to be understood that the invention is susceptible to variations, modifications and changes within the scope of the appended claims.

I claim:

1. A fuel injection system for use in a turbojet engine having in consecutive series an air compressor section, a combustion chamber section including a plurality of combustion chambers circumferentially arranged around the central axis of said engine, a turbine section for supplying power through a central shaft to said air compressor section, and an exhaust section to conduct the exhaust gases from said turbine to the atmosphere, said fuel injection system comprising a pair of adjacent fuel injection nozzles extending into each combustion chamber at the up-stream end thereof, each of said nozzles including a tubular body having an injection aperture at the end of said body within said chamber and a spring-actuated member in said body to close said aperture when the pressure of the fuel within said body is reduced below the counter-pressure exerted by said spring-actuated member, a fuel distributor having a rotatably mounted member provided with a fuel distributing passage therethrough, means to continuously connect said fuel distributing passage to a source of liquid fuel under pressure, a relatively stationary fuel distributing plate contiguous to said rotatably mounted member and provided with a plurality of fuel passages equidistant from the center of rotation of said rotatably mounted member adapted to connect in consecutive order with said fuel distributing passage, and fuel conduits connecting said fuel passages and said nozzles to provide for sequential injection of fuel through one nozzle of the combustion chambers proceeding around the engine in one direction before sequential injection of fuel through the other nozzle of the combustion chambers proceeding around the engine in said one direction, the firing sequence in said combustion chambers being so rapid as to maintain continuous combustion in each chamber whereby there is a continuing series of expansion waves moving through each chamber toward the turbine section of said turbojet engine to produce rotation of the turbine and air compressor thereof.

2. A fuel injection system for use in a turbojet engine having in consecutive series an air compressor section, a combustion chamber section including a plurality of combustion chambers circumferentially arranged around the cen-

tral axis of said engine, a turbine section for supplying power through a central shaft to said air compressor section, and an exhaust section to conduct the exhaust gases from said turbine to the atmosphere, said fuel injection system comprising a pair of adjacent fuel injection nozzles extending into each combustion chamber at the up-stream end thereof, each of said nozzles including a tubular body having an injection aperture at the end of said body within said chamber and a spring actuated member in said body to close said aperture when the pressure of the fuel within said body is reduced below the counter pressure exerted by said spring-actuated member, a fuel distributor having a rotatably mounted member provided with a fuel distributing passage therethrough, means to continuously connect said fuel distributing passage to a source of liquid fuel under pressure, a relatively stationary fuel distributing plate contiguous to said rotatably mounted member and provided with a plurality of fuel passages equidistant from the center of rotation of said rotatably mounted member adapted to connect in consecutive order with said fuel distributing passage as said member is rotated in one direction about its center of rotation, a plurality of common rail fuel distributing conduits each connected to a separate fuel passage and also connected to a separate group of single nozzles of at least two spaced combustion chambers, with said fuel passages being thus connected in the order of their connection with said fuel distributing passage to successive groups of nozzles proceeding around the engine in one direction, whereby to complete fuel injection through all nozzles only after two complete injection cycles wherein the first cycle covers injection through one nozzle of each chamber, and the second cycle covers injection through the other nozzle of each chamber.

3. A fuel injection system for use in a turbojet engine having a plurality of combustion chambers therein comprising a plurality of fuel injection nozzles extending into each combustion chamber at the upstream end thereof, each of said nozzles having an injection aperture and a spring biased member normally closing the aperture, a fuel distributor operatively associated with said injection nozzles and having a rotatably mounted member with a fuel distributing passage therethrough, means providing a continuous connection between said passage and a source of liquid fuel under pressure, a relatively stationary distributing plate arranged contiguous to said rotatably mounted member and having a plurality of passages therethrough each adapted to be consecutively aligned with the fuel distributing passage, fuel distributing conduits, each connecting one of said plurality of passages and a plurality of single nozzles, each in separate spaced combustion chambers whereby the respective connected nozzles will be simultaneously and sequentially operated to maintain continuous combustion.

ROLF M. AMMANN.

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