Feb. 20, 1940. E. T. TURNER 2,190,957

METHOD AND APPARATUS FOR GENERATING POWER

Filed Nov. 26, 1937 3 Sheets-Sheet 1

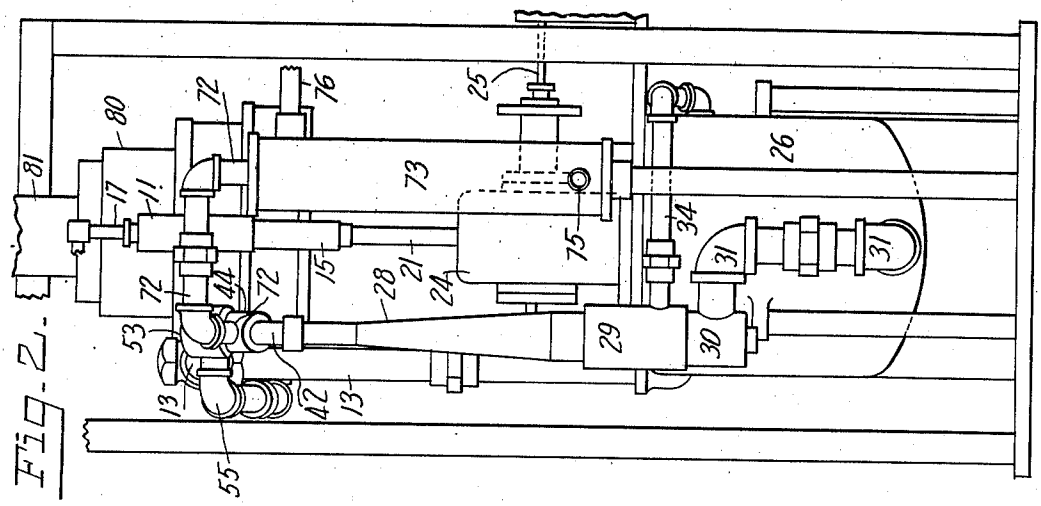


Fig. 2.

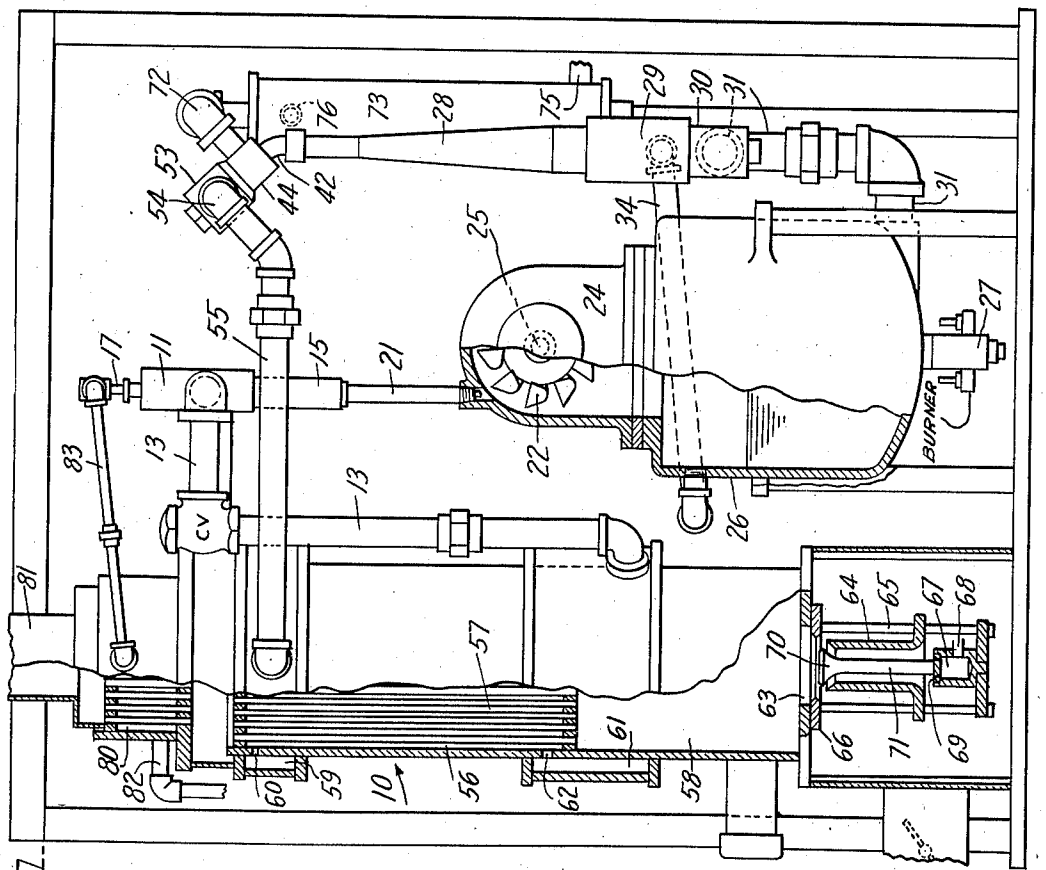


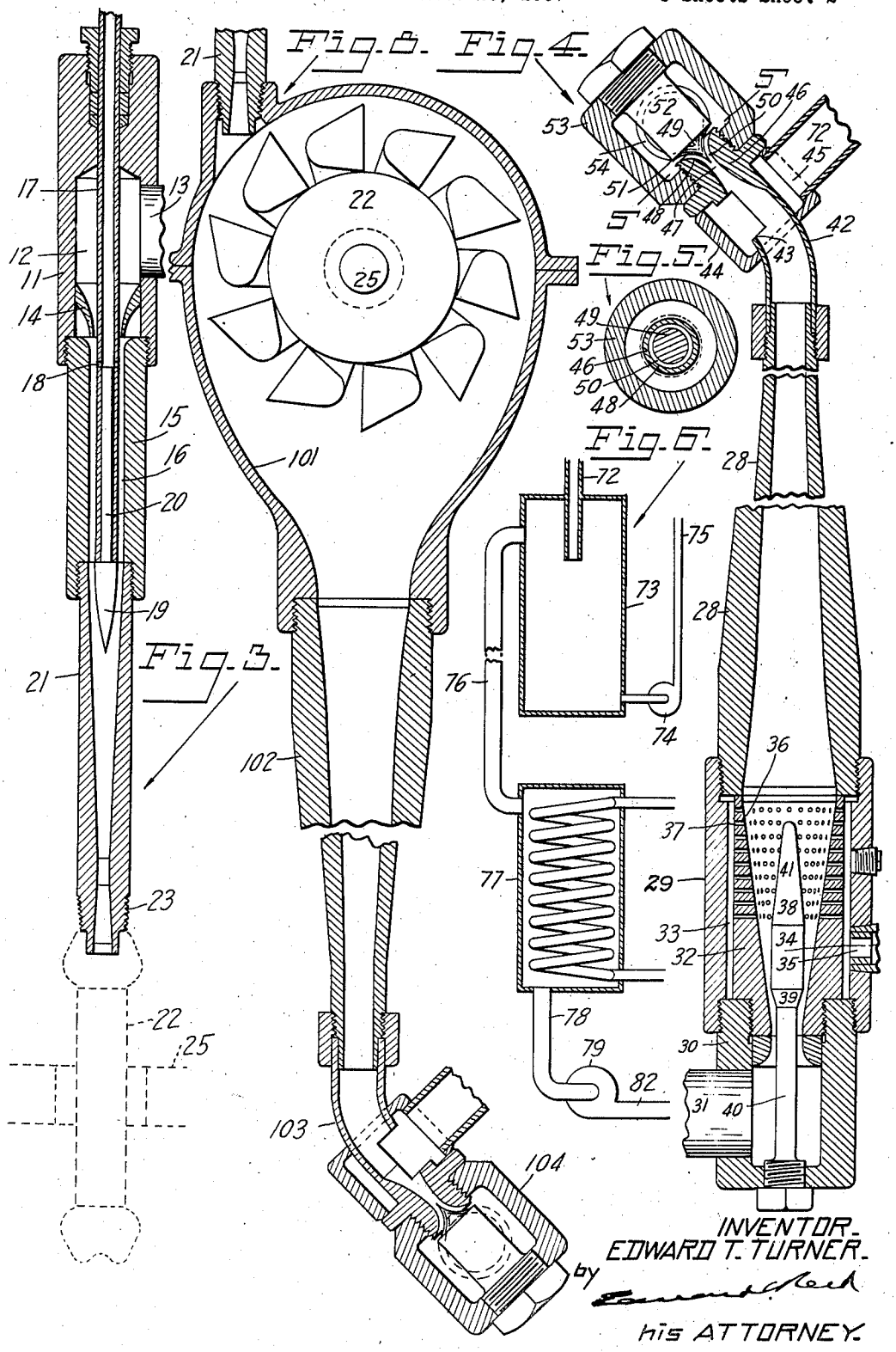
Fig. 1.

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METHOD AND APPARATUS FOR GENERATING POWER

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METHOD AND APPARATUS FOR GENERATING POWER

Filed Nov. 26, 1937 3 Sheets-Sheet 3

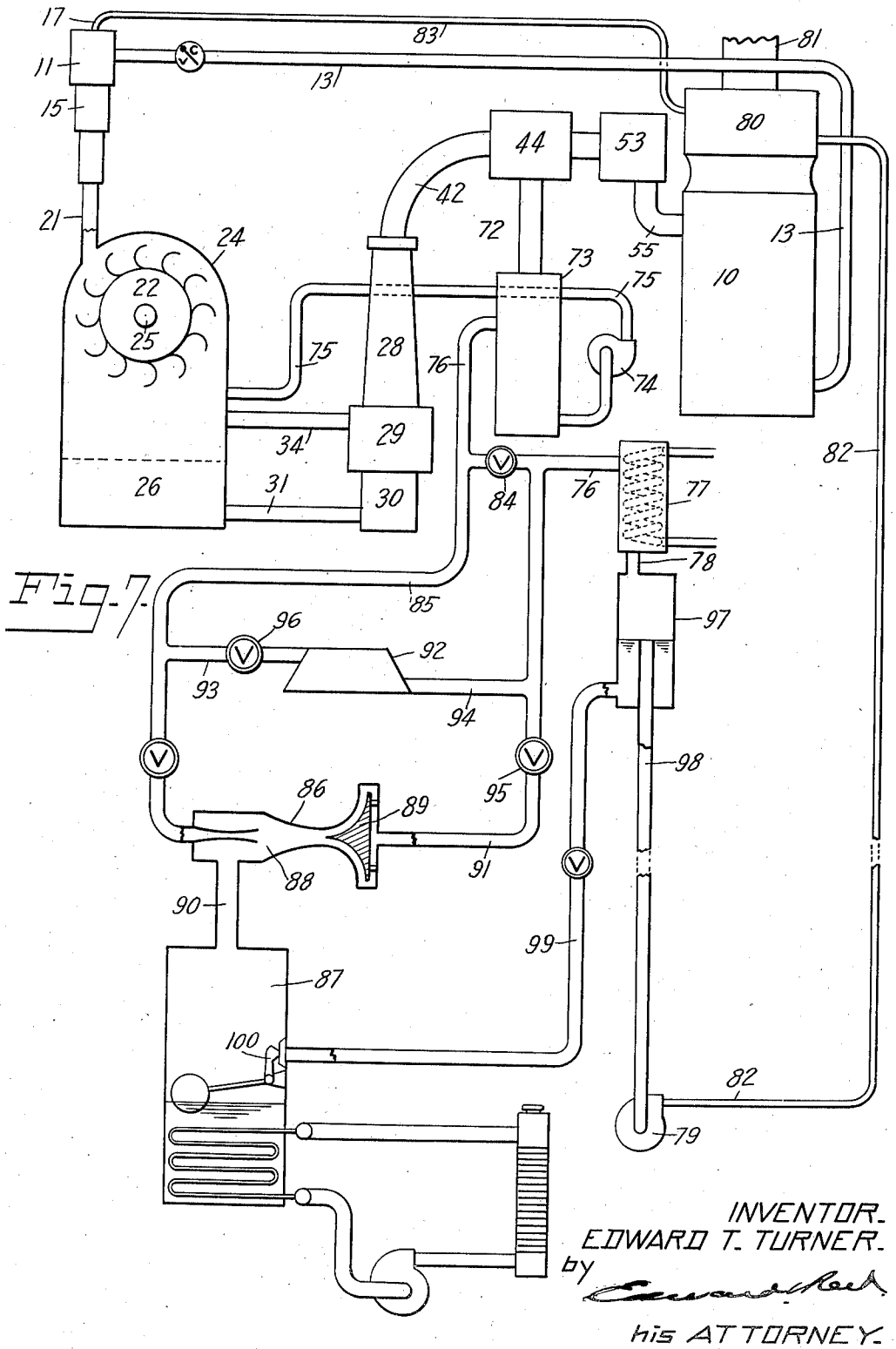


Fig-7.

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Patented Feb. 20, 1940 2,190,957

UNITED STATES PATENT OFFICE

2,190,957

METHOD AND APPARATUS FOR GENERATING POWER

Edward T. Turner, Dayton, Ohio

Application November 26, 1937, Serial No. 176,506

35 Claims. (Cl. 60—40)

This invention relates to a method and apparatus for generating power and is designed more particularly for converting heat energy into mechanical energy. The invention is a further development of, and in some respects an improvement on, the method and apparatus described and illustrated in my Patent No. 2,151,949, issued March 28, 1939.

One object of the invention is to provide a simple method of converting heat energy into mechanical energy which will have a high degree of efficiency.

A further object of the invention is to provide such a method in which steam is expanded in a propellant to convert pressure energy into velocity energy and is then separated from the propellant in a manner and at a time which will result in the minimum loss in efficiency.

A further object of the invention is to provide such a method by which the pressure energy of the propellant will be greatly increased after the propellant has acted on a power element.

A further object of the invention is to provide an improved method of generating steam and utilizing the same to convert pressure energy into velocity energy.

A further object of the invention is to provide a simple and efficient apparatus for performing the aforesaid method.

A further object of the invention is to provide an improved compression nozzle for converting fluid velocity energy into pressure energy.

A further object of the invention is to provide an improved device for mixing steam and a liquid propellant at relatively low pressures and converting the pressure energies thereof into velocity energy.

A further object of the invention is to provide a device for separating steam from a liquid propellant moving at high velocity with a minimum loss of energy.

A further object of the invention is to provide means for utilizing a highly heated propellant to generate steam in a closed circuit and for mixing the steam with said propellant.

Other objects of the invention will appear as the same is described in detail.

In the accompanying drawings Fig. 1 is a front elevation, partly in section, of an apparatus embodying my invention; Fig. 2 is a side elevation of the apparatus of Fig. 1; Fig. 3 is a longitudinal section of the steam generator and expansion nozzle; Fig. 4 is a longitudinal section of the apparatus for separating propellant from the steam and for increasing the pressure of the propellant; Fig. 5 is a section taken on the lines 5—5 of Fig. 4; Fig. 6 is a sectional view of the supplemental separator and the condenser; Fig. 7 is a diagrammatic view of a complete installation embodying my invention, partly in section; and Fig. 8 is a sectional view of a modified form of that part of the apparatus which separates the steam from the propellant and imparts increased pressure to the latter.

In carrying out my invention a highly heated propellant under pressure is circulated through a closed circuit and relatively small quantities of water are introduced into the propellant in one part of said circuit and converted into steam by the heat of the propellant. This steam is intimately mixed with the propellant and is expanded within and about the same to convert the pressure energies of the steam and propellant into propellant velocity energy. The propellant at high velocity is caused to act on a power element to generate power and after the propellant and steam have acted on the power element the steam is again caused to expand within and about the propellant to convert the pressure energies of the steam and propellant into velocity energy. If desired, the steam and propellant may be separated after they pass the power element and are at relatively low pressures and then again intimately mixed one with the other before expanding the same and converting pressure energy into velocity energy. Thus the steam is first expanded to a relatively low pressure and after it has passed the power element is again expanded to a still lower pressure. The propellant moving at high velocity is delivered to a separator which separates the same from the steam. Preferably the high velocity of the propellant is utilized to effect the separation by centrifugal force, and the separated propellant is then compressed to convert its velocity energy into pressure energy and is returned under relatively high pressure to the first mentioned part of the circuit, where water is again mixed with the same. The propellant is maintained at its high temperature by applying heat thereto, preferably while it is being returned from the separator to the first mentioned part of the circuit. The steam which is separated from the propellant is condensed and returned to the propellant circuit but the condensate is preferably first preheated to expedite its conversion into steam by the propellant.

The method may be performed by any suitable apparatus and the propellant may be of any suitable character, such as an oil. The term

"water" as herein used is intended to include any suitable liquid which may be vaporized by the application of heat thereto, and the term "steam" as herein used is intended to include any vapor which may be generated by heating such liquid. In that particular embodiment of the apparatus here illustrated the propellant is heated in a heater 10, which will be hereinafter specifically described, and is delivered from said heater, at a high temperature, to a combined steam generating and expanding device. As here shown, that device is in the form of a tubular element comprising three sections, and is mounted in a vertical position but obviously it may be arranged in any suitable position. The uppermost section 11 is provided with a relatively large chamber 12 which is connected with a propellant supply pipe 13 leading from the heater. Arranged in the chamber 12 beneath the pipe 13 is a nozzle 14 having its smaller end directed downwardly and of a diameter substantially less than the diameter of the chamber 12. The second section 15 of this element is provided with a longitudinal passageway 16 substantially smaller in diameter than the chamber 12 and arranged in line with the lower end of the nozzle 14, the upper end of the passageway being preferably slightly flared. A water pipe 17 extends through the upper section 11 and nozzle 14 into the passageway 16 of the second section and is provided near the upper end of said passageway with a series of relatively small apertures 18. The pipe is closed at a point below the apertures but, in the present instance it extends to a point near the bottom of the section 15 and forms a support for a conical element 19, the shank 20 of which is inserted in the pipe and extends to a point just below the apertures 18. The water pipe 17 is connected with a suitable source of water supply, as will be hereinafter described, and water is supplied thereto under sufficient pressure to cause the same to be discharged from the apertures 18 and into the body of highly heated propellant, which is directed downwardly in close contact with the pipe by the nozzle 14, and the water thus discharged into the propellant is very quickly converted into steam which is intimately mixed with the propellant. This mixture of steam and propellant is discharged from the lower end of section 15 into the third or lowermost section 21 of the tubular element which constitutes an expansion nozzle and is so shaped that the steam will be caused to expand isothermally within and about the propellant as the latter travels through the nozzle, thereby converting steam and propellant pressure energies into propellant velocity energy. The tapered element 19 which is supported by the water pipe extends into the upper end of the expansion nozzle to prevent the formation of swirls and eddies in the latter.

The steam and propellant are discharged from the nozzle at high velocity into a casing in which is mounted a power element, such as a Pelton wheel 22. The casing which encloses the power element may take various forms. As shown in Fig. 1 it comprises a relatively small upper portion 24 and the Pelton wheel 22 is mounted on a shaft 25 journaled in the side walls of this part of the casing, the shaft projecting beyond one side of the casing where it may be connected with a device to be operated. The lower portion 26 of the casing is of a size considerably larger than the upper portion thereof and constitutes a receptacle which receives the steam and propellant after they have passed the power element and confines the same at a relatively low pressure. In the arrangement here shown a burner 27 is associated with the receptacle 26 for the purpose of providing preliminary heat when the apparatus is first placed in operation and for maintaining the propellant at the desired temperature during intervals between operations.

After the steam and propellant have passed the power element they are delivered to a low pressure expansion nozzle 28 in which the steam is again expanded within and about the propellant to convert the pressure energies of the steam and propellant into propellant velocity energy. When the casing is of the type shown in Fig. 1 the propellant will separate from the steam, the latter rising to the top of the receptacle due to its lower specific gravity, and it is therefore desirable to provide means for again mixing the steam with the propellant before delivering the same to this low pressure expansion nozzle. For this purpose I have provided a mixer which, in the form illustrated, comprises a cylindrical shell 29 supported at its lower end in a hollow structure 30 which is connected by a pipe 31 with the lower part of the receptacle 26, the shell 29 being connected at its upper end with the lower portion of the expansion nozzle 28. Arranged within the shell is a tubular member 32 which is also supported upon the hollow member 30 and is connected at its upper end to the expansion nozzle. This tubular member 32 is spaced from the shell 29 to provide between the two elements an annular chamber 33 which is connected with the upper portion of the receptacle 26 by a pipe 34 which is provided with restricted orifice shown at 35. The inner member 32 has a rearwardly tapered passageway 36 which opens into the hollow member 30 and the upper portion of this inner member is provided with a plurality of relatively small apertures 37, through which the steam passes from the annular chamber 33 to the passageway 36. Arranged in the smaller rear portion of the passageway 36 is a spreader 38, the rear end of which is tapered, as shown at 39, and serves to spread the incoming propellant and cause the same to flow through the passageway 36 in close contact with the wall thereof, so that the steam entering the passageway through the apertures 37 will be intimately mixed with the propellant. This spreader is in the present instance supported by a rod 40 which is mounted in the hollow member 30, and the forward end of the spreader is tapered, as shown at 41, to prevent the formation of eddies or swirls within the passageway. The intimately mixed propellant and steam are discharged from this mixer into the lower end of the low pressure expansion nozzle 28 and the pressure energies thereof are converted into propellant velocity energy.

The steam and propellant, which are discharged from the low pressure expansion nozzle at high velocity, are delivered to a separator where the steam is separated from the propellant. This separator is preferably of such a character that the high velocity of the propellant will cause the same to be separated from the steam by centrifugal force. For this purpose the separator comprises a curved tubular element 42, the lower end of which is connected with the discharge end of the expansion nozzle 28, and it is provided in that side thereof having the shorter radius with an opening 43. This opening is enclosed by an exhaust chamber 44 which is here shown as a short sleeve extending entirely about the tubular element 42, and provided with an outlet

45. As the propellant and steam pass through the tubular element 42 at high velocity the propellant, due to its greater weight, will be held in contact with the outer wall of the separator while the steam will separate from the propellant and escape through the opening 43 to the exhaust chamber.

The propellant which has been separated from the steam is delivered at high velocity to a compression nozzle 46 which is adapted to convert the velocity energy of the propellant into pressure energy. I have here shown a novel form of compression nozzle which will effect the conversion in a space very much shorter than that in which it can be accomplished with the ordinary type of compression nozzle. As shown the passageway through the nozzle has its intermediate portion 47 of reduced diameter and the passageway flares both forwardly and rearwardly from this intermediate constriction. The circumferential wall of the forwardly flared portion of the passageway, as shown at 48, is curved about a relatively short radius. A cone-shaped element 49 is inserted in this flared forward end of the passageway with its apex adjacent to the constricted intermediate portion of that passageway. The surface of this cone-shaped element is curved to conform to the curvature of the wall of the passageway and is spaced from that wall a substantially uniform distance throughout its circumference, thus forming between the wall of the passageway and the cone-shaped element an annular channel 50 which rapidly increases in diameter from the apex of the cone to the discharge end of the channel. In this particular arrangement the cone-shaped element 49 has a transverse flange 51 which overhangs but is spaced from the forward end of the body of the nozzle 46, the space between this flange and the body of the nozzle forming a continuation of the annular channel. Thus the cross sectional area of the channel 50 at its discharge end is very much greater than the cross sectional area thereof adjacent the apex of the cone 49, thus effecting a reduction in the velocity of the fluid and an increase in the pressure thereof. The cone-shaped element may be supported in any suitable manner and, as here shown, it is carried by a plug 52 mounted in the end wall of a hollow member 53 into which the annular channel 50 of the compression nozzle discharges and which thus constitutes a pressure chamber. This chamber is provided with an outlet 54 which is connected by a pipe 55 with the heater 10.

The heater may be of any suitable character and is here shown as of an upright construction and as comprising a propellant receptable 56 through which extend flues 57 for products of combustion arising from the combustion chamber 58. Arranged about the upper portion of the propellant receptacle 56 is an exterior circumferential channel 59 which communicates with the interior of the receptacle through a series of apertures, one of which is shown at 60, and the pipe 55, which returns the propellant under pressure from the expansion nozzle to the heater, is connected with this circumferential channel 59. A second exterior circumferential channel 61 is arranged about the lower portion of the propellant receptacle 56 and is connected with the interior thereof by a series of apertures one of which is shown at 62. The channel 61 is provided with an outlet which is connected by the pipe 13 with the section 11 of the steam generating and expanding device. The circumferential channel 61 extends below the bottom of the propellant receptacle 56 and surrounds a substantial part of the combustion chamber 58 and the flow of the propellant through this channel 61 serves as a cooling medium to prevent the overheating of the wall of the combustion chamber.

The heater is provided with a suitable burner which, as here shown, is located below the combustion chamber, the bottom of the latter having a central opening 63 through which the fuel mixture may enter the combustion chamber and be burned therein. In the particular construction illustrated this burner comprises a tubular element 64 supported beneath the combustion chamber and in line with the opening 63 in any suitable manner, as by suspension rods 65 which are carried by a ring 66 secured to the bottom of the combustion chamber. This tubular element constitutes a mixing chamber and arranged beneath and spaced from the lower end thereof is a hollow fuel inlet element 67 which is connected by a pipe 68 with a suitable source of fuel supply and is provided in its top wall with a series of apertures 69 arranged to discharge the fuel into the tubular element 64. The spacing of this inlet element from the tubular element permits a certain amount of air to enter the tubular element along with the gas or other fuel and to mix therewith. A substantially conical spreader 70 is arranged in the upper end of the tubular element to spread the fuel into a diverging annular jet which is projected through the opening 63 into the combustion chamber. The upper end of the tubular member or mixing chamber 64 being spaced from the ring 66 enables additional air to enter the combustion chamber along with the fuel mixture which is discharged from the tubular element 64 and thus provides air in the proper quantity for efficient combustion. The spreader 70 may be supported in any suitable manner and, as here shown, it is provided with a rod 71 which is mounted on the fuel inlet element 67.

The steam that is separated from the propellant by the separator 42 is condensed and returned to the water supply pipe 17. Small quantities of propellant may escape from the separator along with the steam and in order to remove any such propellant the outlet 45 of the separator is connected by a pipe 72 with a supplemental separator 73 and any propellant which may enter this supplemental separator with the steam will settle to the bottom thereof and will be removed and returned to the circuit by a pump 74, the discharge pipe 75 of which preferably leads to the lower portion 26 of the casing for the power element, as shown in Fig. 7. The steam is removed from the separator 73 by a pipe 76 which communicates therewith, preferably above the lower end of the pipe 72, and is conducted to a condenser 77. The condensate is taken from the condenser by a pipe 78 and is returned to the water pipe by means of a pump 79. It is preferable, however, that this condensate should be preheated before it is returned to the water pipe 17 so as to expedite the vaporization thereof. For this purpose a heating element 80 is interposed between the condenser and the water pipe. As here shown, this heater is supported above the propellant heater and is provided with flues through which the products of combustion pass from the flues 57 of the propellant heater to the stack 81. The pump 79 is connected with this

heater by a pipe 82 and the heater is connected with the water pipe by a pipe 83.

If desired the steam, after having been isothermally expanded and separated from the propellant and prior to its condensation, may be further utilized to perform useful work, such as operating a fluid operated device, and so utilizing the steam that it is expanded adiabatically. The overall efficiency of the apparatus is increased by effecting a partial expansion of the steam isothermally and a further expansion thereof adiabatically. In Fig. 7 I have shown diagrammatically an arrangement whereby the separated steam may be so used and, as there shown, the construction and operation are the same as above described down to the point where the steam is delivered from the supplemental separator 73 to the condenser 77. In Fig. 7 there are interposed between the supplemental separator and the condenser certain devices to be operated by the adiabatic expansion of the low pressure steam from the separator, these devices being typical of various devices which may be so operated. In the arrangement illustrated the pipe 76, which connects the supplemental separator 73 with the condenser is provided with a valve 84 and a pipe 85 leads from the pipe 76 in advance of the valve 84 to a fluid operated device 86 which is here shown in connection with the evaporator 87 of a refrigerating apparatus and comprises a nozzle 88 through which the steam is discharged to a compression device 89, preferably of the type shown at 47—48, said nozzle causing the steam to draw vapor from the water in the evaporator 87 through the pipe 90. The steam entering the nozzle 88 is expanded adiabatically to a pressure below the pressure in the evaporator and the steam and withdrawn vapor are then compressed in the compressor 89 to condenser pressure. The pipe 91 leads from the compressor 89 to the pipe 76 between the valve 84 and the condenser, thus carrying the steam back to the condenser.

The installation here shown also comprises a second fluid operated device which may be operated alternately with the device 86, and which is shown conventionally as a turbine 92 which is connected by a pipe 93 with the pipe 85 and by a pipe 94 with a pipe 91. The pipe 91 is provided with a valve 95 in advance of its connection with the pipe 94 and the pipe 93 is provided with a valve 96. The steam is expanded adiabatically in the turbine to a pressure approximating condenser pressure.

Consequently by a proper adjustment of the valves the steam may be taken directly from the supplemental separator to the condenser or it may be taken to the condenser through either one of the two fluid operated devices. It will be obvious that when the steam is to be utilized to operate an auxiliary device, as above described, the apparatus must be designed to maintain in the supplemental separator 73 a pressure somewhat higher than condenser pressure. When the device 86 is used a portion of the condensate from the condenser 77 may conveniently be used to replenish the water in the evaporator. For that purpose the pipe 78 which leads from the condenser is connected with a receptacle 97 which in turn is connected by a pipe 98 with the pump 79, the inner end of the pipe 98 extending some distance above the bottom of the receptacle so as to maintain the body of liquid in the latter. A pipe 99 leads from the lower portion of the receptacle 97 to the evaporator where it is controlled by a float operated valve 100.

In some installations it may not be desirable to separate the low pressure steam and propellant prior to expanding the steam in the low pressure expansion nozzle. Under such circumstances the receptacle 26 may be omitted and the casing for the power element may take the form shown at 101 in Fig. 8, in which it converges downwardly and is connected directly with the intake end of the low pressure expansion nozzle 102 which is connected with a separator 103 and expanding nozzle 104 similar to those above described. With this arrangement there would be no separation of the steam from the propellant in the casing 101 but the mixture of steam and propellant would pass directly to the expansion nozzle 102.

While I have shown and described one embodiment of my invention, together with a minor modification thereof, I wish it to be understood that I do not desire to be limited to the details thereof as various modifications may occur to a person skilled in the art.

Having now fully described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. A method of converting heat energy into mechanical energy which comprises heating a liquid propellant to a high temperature, subjecting the heated propellant to pressure in a conduit, introducing water into said propellant in such quantity that the water will be converted into steam by the heat of the propellant, expanding said steam within and about said propellant and converting the steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy to actuate a power element, and then separating the steam from the propellant and utilizing the separated steam for restoring said propellant to its initial pressure.

2. A method of converting heat energy into mechanical energy which comprises heating a liquid propellant to a high temperature, subjecting the heated propellant to pressure in a conduit, introducing water into said propellant in such quantity that the water will be converted into steam by the heat of the propellant, expanding said steam within and about said propellant and converting the steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy to actuate a power element, again expanding the steam within and about the propellant to convert pressure energy into velocity energy, then separating the steam from the propellant, and converting the velocity energy of said propellant into pressure energy.

3. A method of converting heat energy into mechanical energy which comprises heating a liquid propellant to a high temperature, subjecting the heated propellant to pressure in a conduit, introducing water into said propellant in such quantity that the water will be converted into steam by the heat of the propellant, expanding said steam within and about said propellant and converting the steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy to actuate a power element, again expanding said steam within and about said propellant to convert pressure energy into velocity energy, then separating the steam from the propellant, converting the propellant velocity energy into propellant pressure energy, and again heating said propellant.

4. A method of converting heat energy into mechanical energy which comprises heating a liquid propellant to a high temperature, subjecting

the heated propellant to pressure in a conduit, introducing water into said propellant in such quantity that the water will be converted into steam by the heat of the propellant, expanding said steam within and about said propellant and converting the steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy to actuate a power element, again expanding said steam within and about said propellant to convert pressure energy into velocity energy, utilizing a portion of said propellant velocity energy to separate the propellant from the steam by centrifugal force, and converting the remaining velocity energy of said propellant into pressure energy.

5. A method of converting heat energy into mechanical energy which comprises heating a liquid propellant to a high temperature, subjecting the heated propellant to pressure in a conduit, introducing water into said propellant in such quantity that the water will be converted into steam by the heat of the propellant, expanding said steam within and about said propellant and converting the steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy to actuate a power element, separating steam from the propellant at relatively low pressure, again mixing the steam with the propellant, expanding the steam within and about the propellant and converting pressure energy into propellant velocity energy, separating the propellant from the steam, and converting the velocity energy of the propellant into pressure energy.

6. A method of converting heat energy into mechanical energy which comprises subjecting a heated liquid propellant to pressure in an endless circuit, expanding steam within and about said propellant in a part of said circuit and converting steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy in the production of mechanical energy, again expanding said steam within and about said propellant in another part of said circuit and converting the steam and propellant pressure energies into propellant velocity energy, separating the propellant from the steam and converting propellant velocity energy into propellant pressure energy.

7. A method of converting heat energy into mechanical energy which compsises subjecting a heated liquid propellant to pressure in an endless circuit, expanding steam within and about said propellant in a part of said circuit and converting steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy in the production of mechanical energy and separating the steam from the propellant at a relatively low pressure, again mixing said steam with said propellant in another part of said circuit, expanding said steam within and about said propellant and converting steam and propellant pressure energies into propellant velocity energy, separating the propellant from the steam and converting propellant velocity energy into propellant pressure energy.

8. The method of converting heat energy into mechanical energy which comprises subjecting a highly heated liquid propellant to pressure in an endless circuit, mixing water with said propellant in one part of said circuit and converting the water into steam, expanding said steam within and about said propellant and converting steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy in the production of mechanical energy, then separating the steam from the propellant, converting propellant velocity energy into propellant pressure energy, condensing the separated steam and returning the condensate to said circuit.

9. The method of converting heat energy into mechanical energy which comprises subjecting a highly heated liquid propellant to pressure in an endless circuit, mixing water with said propellant in one part of said circuit and converting the water into steam, expanding said steam within and about said propellant and converting steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy in the production of mechanical energy, then separating the steam from the propellant, converting propellant velocity energy into propellant pressure energy, condensing the separated steam, heating the condensate and returning the same to said circuit.

10. The method of converting heat energy into mechanical energy which comprises subjecting a highly heated liquid propellant to pressure in an endless circuit, mixing water with said propellant in one part of said circuit and converting the water into steam, expanding said steam within and about said propellant and converting steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy in the production of mechanical energy, expanding said steam within and about said propellant in another part of said circuit and converting steam and propellant pressure energies into propellant velocity energy, separating the steam from the propellant, converting propellant velocity energy into propellant pressure energy, condensing the separated steam and returning the same to said circuit.

11. The method of converting heat energy into mechanical energy which comprises subjecting a highly heated liquid propellant to pressure in an endless circuit, mixing water with said propellant in one part of said circuit and converting the water into steam, expanding said steam within and about said propellant and converting steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy in the production of mechanical energy, expanding said steam within and about said propellant in another part of said circuit and converting steam and propellant pressure energies into propellant velocity energy, separating the steam from the propellant, converting propellant velocity energy into propellant pressure energy, utilizing the separated steam to actuate a fluid operated device, then condensing said steam and returning the same to said circuit.

12. In a power apparatus, a conduit including a casing, a power element in said casing, means for delivering a heated liquid propellant under pressure to one part of said conduit, means for introducing water into said heated propellant in said part of said conduit and thereby converting said water into steam, said part of said conduit having means for expanding said steam within and about said propellant and converting propellant and steam pressure energies into propellant velocity energy and for delivering said propellant at high velocity to said power element, another part of said conduit being arranged to receive said steam and propellant from said casing and having means to again expand said steam within and about said propellant and convert steam and propellant pressure energies

into propellant velocity energy, said last mentioned part of said conduit also having means for separating said propellant from said steam and for converting propellant velocity energy into propellant pressure energy, and means for returning the propellant under pressure to the first mentioned part of said conduit, and means associated with said conduit to maintain said propellant at a high temperature.

13. In a power apparatus, a casing, a power element in said casing, means for mixing steam under pressure with a highly heated liquid propellant under pressure and expanding said steam within and about said propellant to convert the pressure energies of said steam and said propellant into velocity energy and for delivering the mixture of steam and propellant to said power element at high velocity, means beyond said casing for separating said propellant from said steam, and means for converting velocity energy of the separated propellant into pressure energy and returning the propellant under pressure to the first mentioned means.

14. In a power apparatus, a power element, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, a separator arranged beyond said power element to separate steam from propellant, means interposed between said power element and said separator to again expand said steam within and about said propellant and convert the pressure energies thereof into propellant velocity energy and to deliver said propellant and said steam to said separator, and means beyond said separator to receive said propellant, convert the velocity energy thereof into pressure energy and to return said propellant to the first mentioned means.

15. In a power apparatus, a power element, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, a separator arranged beyond said power element to separate steam from propellant, means interposed between said power element and said separator to again expand said steam within and about said propellant and convert the pressure energies thereof into propellant velocity energy and to deliver said propellant and said steam to said separator, means beyond said separator to receive said propellant, convert the velocity energy thereof into pressure energy and to return said propellant to the first mentioned means, a condenser to receive steam from said separator, and means to return the condensate to the first mentioned means.

16. In a power apparatus, a power element, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, a separator arranged beyond said power element to separate steam from propellant, means interposed between said power element and said separator to again expand said steam within and about said propellant and convert the pressure energies thereof into propellant velocity energy and to deliver said propellant and said steam to said separator, means beyond said separator to receive said propellant, and convert the velocity energy thereof into pressure energy, and a heater connected with the last mentioned means to receive said propellant therefrom and connected with the first mentioned means to deliver heated propellant thereto.

17. In a power apparatus, a casing, a power element mounted in said casing, said casing having a part below said power element forming a fluid receptacle, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, a mixer to receive said steam and said propellant from said receptacle, means connected with said mixer to expand said steam within and about said propellant and convert the pressure energies thereof into propellant velocity energy, means to separate said propellant from said steam, to convert propellant velocity energy into propellant pressure energy and to return said propellant under pressure to the first mentioned means.

18. In a power apparatus, a casing, a power element mounted in said casing, said casing having a part below said power element forming a fluid receptacle, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, a mixer comprising inner and outer tubular members spaced apart to form an annular chamber between them, said inner member having a rearwardly tapered passageway and having a series of apertures in its forward portion, means for delivering propellant from said receptacle to the rear end of said inner member, means for delivering steam from said receptacle to said chamber, means connected with the forward end of said passageway to expand said steam within and about said propellant and convert pressure energies thereof into propellant velocity energy, means to separate said propellant from the steam, to convert propellant velocity energy into propellant pressure energy and to return said propellant under pressure to the first mentioned means.

19. In a power apparatus, a casing, a power element mounted in said casing, said casing having a part below said power element forming a fluid receptacle, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, a mixer comprising inner and outer tubular members spaced apart to form an annular cham-

ber between them, said inner member having a rearwardly tapered passageway and having a series of apertures in its forward portion, means for delivering propellant from said receptacle to the rear end of said inner member, a spreader in the rear portion of said passageway to cause said propellant to flow along the apertured wall of said inner member, mean for delivering steam from said receptacle to said chamber, means connected with the forward end of said passageway to expand said steam within and about said propellant and convert pressure energies thereof into propellant velocity energy, means to separate said propellant from the steam, to convert propellant velocity energy into propellant pressure energy and to return said propellant under pressure to the first mentioned means.

20. In a power apparatus, a casing, a power element mounted in said casing, said casing having a part below said power element forming a fluid receptacle, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, a mixer to receive said steam and said propellant from said receptacle, means connected with said mixer to expand said steam within and about said propellant and convert the pressure energies thereof into propellant velocity energy, a centrifugal separator to separate said propellant from said steam, and means to convert the velocity energy of the separated propellant into pressure energy and to return said propellant to the first mentioned means.

21. In a power apparatus, a power element, means for mixing steam under pressure with a highly heated liquid propellant under pressure and expanding said steam within and about said propellant to convert the pressure energies of said steam and said propellant into propellant velocity energy and for delivering the mixture of steam and propellant to said power element at high velocity, means for again imparting velocity energy to said mixture of steam and propellant after it has acted on said power element, a centrifugal separator to separate said propellant from said steam, and means to convert propellant velocity energy into pressure energy and return said propellant to the first mentioned means.

22. In a power apparatus, a power element, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, means beyond said power element to again expand said steam within and about said propellant and convert steam and propellant pressure energies into propellant velocity energy, a separator comprising a curved tubular element connected with said expanding means and having an opening in that side thereof which has the shorter radius, and a casing enclosing said opening and provided with an outlet, and means to convert propellant velocity energy into pressure energy and return said propellant to the first mentioned means.

23. In a power apparatus, a power element, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, means beyond said power element to again expand said steam within and about said propellant and convert steam and propellant pressure energies into propellant velocity energy, a separator to separate the propellant from the steam, an expanding device connected with said separator and having in its forward portion an annular passageway of gradually increasing diameter and means for connecting said annular passageway with the first mentioned means.

24. In a power apparatus, a power element, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, a heater comprising a propellent receptacle, a combustion chamber beneath said receptacle, an exterior channel extending about and communicating with said receptacle and overlapping said combustion chamber, an outlet conduit leading from said channel to the first mentioned means, and means beyond said power element for separating the propellant from the steam and for delivering the separated propellant under pressure to the propellant receptacle of said heater.

25. In a power apparatus, a power element, means for introducing water into a highly heated liquid propellant under pressure and converting said water into steam, means for expanding said steam within and about said propellant and converting the pressure energies of said steam and said propellant into propellant velocity energy and for delivering said propellant to said power element at high velocity, a heater comprising a propellant receptacle having an outlet connected with the first mentioned means, means beyond said power element for separating the propellant from the steam and for delivering the propellant to said receptacle, and a burner beneath said receptacle including an upright tubular element, a fuel inlet element beneath and spaced from said tubular element and provided with apertures arranged to discharge fuel into said tubular element, and a spreader at the upper end of said tubular element.

26. A method of converting heat energy into mechanical energy which comprises circulating a heated liquid propellant through a conduit, isothermally expanding steam within and about said propellant and converting steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy to perform work, separating the steam from the propellant, and adiabatically expanding the separated steam and utilizing the same to perform work.

27. In a power apparatus, a power element, means for mixing steam under pressure with a highly heated propellant under pressure and expanding the same in and about said propellant to convert pressure energies of said steam and said propellant into velocity energy and for delivering said propellant to said power element at high velocity, means beyond said power element for

separating said propellant from said steam, a compression nozzle arranged to receive the separated propellant and having a longitudinal passageway, the intermediate portion of which is of reduced diameter and the forward portion of which is annular in form and gradually increases in diameter from the intermediate portion to the discharge end thereof to convert velocity energy of said propellant into pressure energy, and a conduit connecting the discharge end of said compression nozzle with said first mentioned means.

28. In a power apparatus, a power element, means for mixing steam under pressure with a highly heated liquid propellant under pressure and expanding said steam in and about said propellant to convert pressure energies of said steam and said propellant into velocity energy and for delivering said propellant to said power element at high velocity, means beyond said power element for separating said propellant from said steam, and a compression nozzle having a longitudinal passageway the intermediate portion of which is of reduced diameter, one end of said passageway being arranged to receive the separated propellant and the other end portion of said passageway being flared, a substantial cone-shaped element inserted in said flared portion of said passageway and spaced a substantially uniform distance from all parts of the wall thereof to convert velocity energy of said propellant into pressure energy, and a conduit connecting the discharge end of said compression nozzle with said first mentioned means.

29. In a power apparatus, a casing, a power element mounted in said casing, said casing having a part below said power element forming a liquid receptacle, means for mixing steam under pressure with a highly heated liquid propellant under pressure and expanding said steam within and about said propellant to convert pressure energies of said steam and propellant to propellant velocity energy and for delivering said propellant to said power element at a high velocity, a mixer to receive said steam and propellant from said receptacle, means connected with said mixer to expand said steam within and about said propellant and convert the pressure energies thereof into propellant velocity energy, means to separate said propellant from said steam, and means to convert propellant velocity energy into propellant pressure energy and to return said propellant under pressure to the first mentioned means.

30. In a power apparatus, a conduit including a casing, a power element in said casing, means for mixing steam under pressure with a heated liquid propellant under pressure in one part of said conduit and expanding said steam within and about said propellant to convert propellant and steam pressure energies into propellant velocity energy and to deliver said propellant at high velocity to said power element, another part of said conduit being arranged to receive said steam and propellant from said casing and having means to again expand said steam within and about said propellant to convert steam and propellant pressure energies into propellant velocity energy, said last mentioned part of said conduit also having means for separating said propellant from said steam and for converting propellant velocity energy into propellant pressure energy, means for returning the propellant under pressure to the first mentioned part of said conduit, and means associated with said conduit to maintain said propellant at a high temperature.

31. In a power apparatus, a power element, means for mixing steam under pressure with a highly heated liquid propellant under pressure and expanding said steam within and about said propellant to convert steam and propellant pressure energies into propellant velocity energy and for delivering said propellant to said power element at high velocity, a separator arranged beyond said power element to separate steam from the propellant, means interposed between said power element and said separator to again expand said steam within and about said propellant and convert the pressure energies thereof into propellant velocity energy and to deliver said propellant and said steam to said separator, and means beyond said separator to receive said propellant, convert the velocity thereof into pressure energy and to return said propellant to the first mentioned means.

32. In a power apparatus, a casing, a power element mounted in said casing, said casing having a part below said power element forming a liquid receptacle, means for mixing steam under pressure with a highly heated liquid propellant under pressure and expanding said steam within and about said propellant to convert steam and propellant pressure energies into propellant velocity energy and to deliver said propellant to said power element at high velocity, a mixer comprising inner and outer tubular members spaced apart to form an annular chamber between them, said inner member having a rearwardly tapered passageway and having a series of apertures in its forward portion, means for delivering propellant from said receptacle to the rear end of said inner member, means for delivering steam from said casing to said chamber, means connected with the forward end of said passageway to expand said steam within and about said propellant and convert pressure energies thereof into propellant velocity energy, means to separate said propellant from the steam, convert propellant velocity energy into propellant pressure energy and return said propellant under pressure to the first mentioned means.

33. In a power apparatus, a power element, means for mixing steam under pressure with a highly heated liquid propellant under pressure and expanding said steam within and about said propellant to convert steam and propellant pressure energies into propellant velocity energy and to deliver said propellant to said power element at high velocity, means beyond said power element to again expand said steam within and about said propellant and convert the steam and propellant energies into propellant velocity energy, a separator comprising a curved tubular element connected with said expanding means and having an opening in that side thereof which has the shorter radius, and a casing enclosing said opening and provided with an outlet, and means to convert propellant velocity energy into pressure energy and return said propellant to the first mentioned means.

34. The method of converting heat energy into mechanical energy which comprises mixing steam under pressure with a highly heated liquid propellant, expanding said steam within and about said propellant to convert steam and propellant pressure energies into propellant velocity energy, utilizing said propellant velocity energy to actuate a power element, again expanding the steam within and about propellant to convert pressure energy into velocity energy, then sepa-

rating the steam from the propellant and converting the velocity energy of said propellant into pressure energy.

35. The method of converting heat energy into mechanical energy which comprises mixing steam under pressure with a highly heated liquid propellant under pressure, expanding the steam in and about said propellant to convert steam and propellant energies into propellant velocity energy, utilizing said propellant velocity energy to actuate a power element, separating steam from the propellant at relatively low pressure, again mixing the steam with the propellant, expanding the same within and about the propellant and converting pressure energy into propellant velocity energy, separating the propellant from the steam and converting the velocity energy of the propellant into pressure energy.

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