United States Patent [19]

Sisson

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[45] **Sept. 3, 1974**

[54] **HOT GAS APPARATUS FOR RECOVERY OF OIL VALUES**

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[73] Assignee: **Motco Inc.,** Charlotte, Tex.

[22] Filed: **Feb. 12, 1973**

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[52] **U.S. Cl.** **166/57,** 166/75, 166/303, 431/202

[51] **Int. Cl.** **E21b 43/24**

[58] **Field of Search** 166/272, 303, 57, 75; 431/202

[56] **References Cited**

UNITED STATES PATENTS

956,058	4/1910	Elten	166/303
2,421,528	6/1947	Steffen	166/303
2,823,752	2/1958	Walter	166/272
3,386,508	6/1968	Bielstein et al.	166/272

Primary Examiner—James A. Leppink

Attorney, Agent, or Firm—Mr. Robert G. McMorrow

[57] **ABSTRACT**

A hot gas process and apparatus for extraction of highly viscous oil from subterranean deposits which employs a rocket engine for generating hot gases which are conveyed into the interior of the oil well to heat the oil deposits. The rocket engine is supplied with compressed air and fuel through a control unit to regulate the pressure of the exhaust gases exiting from the engine. A back-pressure control valve and an orifice metering valve are connected in the exhaust conduit between the engine and oil well to control the pressure and flow of the exhaust gases into the well. A plurality of automatically controlled heat exchangers and cooling units are connected with the back-pressure control valves exhaust gas conduit, and orifice metering valve to maintain the exhaust gas temperature and back pressure at desired predetermined levels for high temperature operation, resulting in highly efficient operation and a low fuel consumption.

8 Claims, 12 Drawing Figures

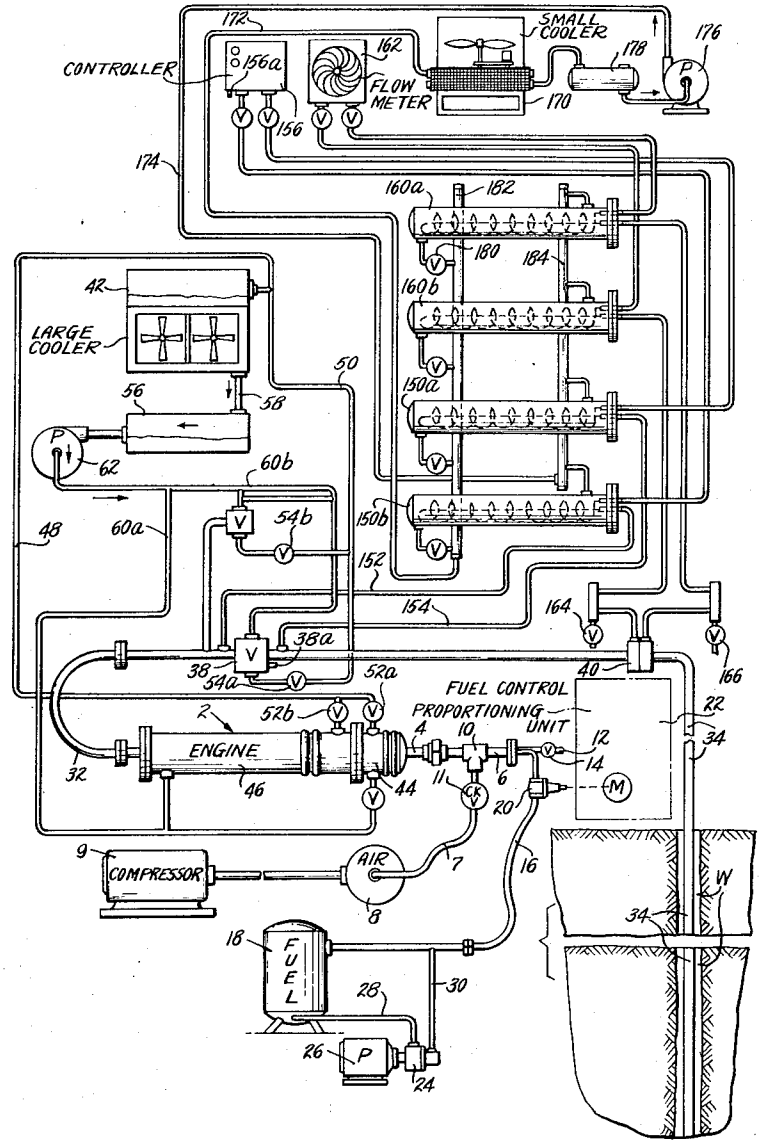


Fig. 1.

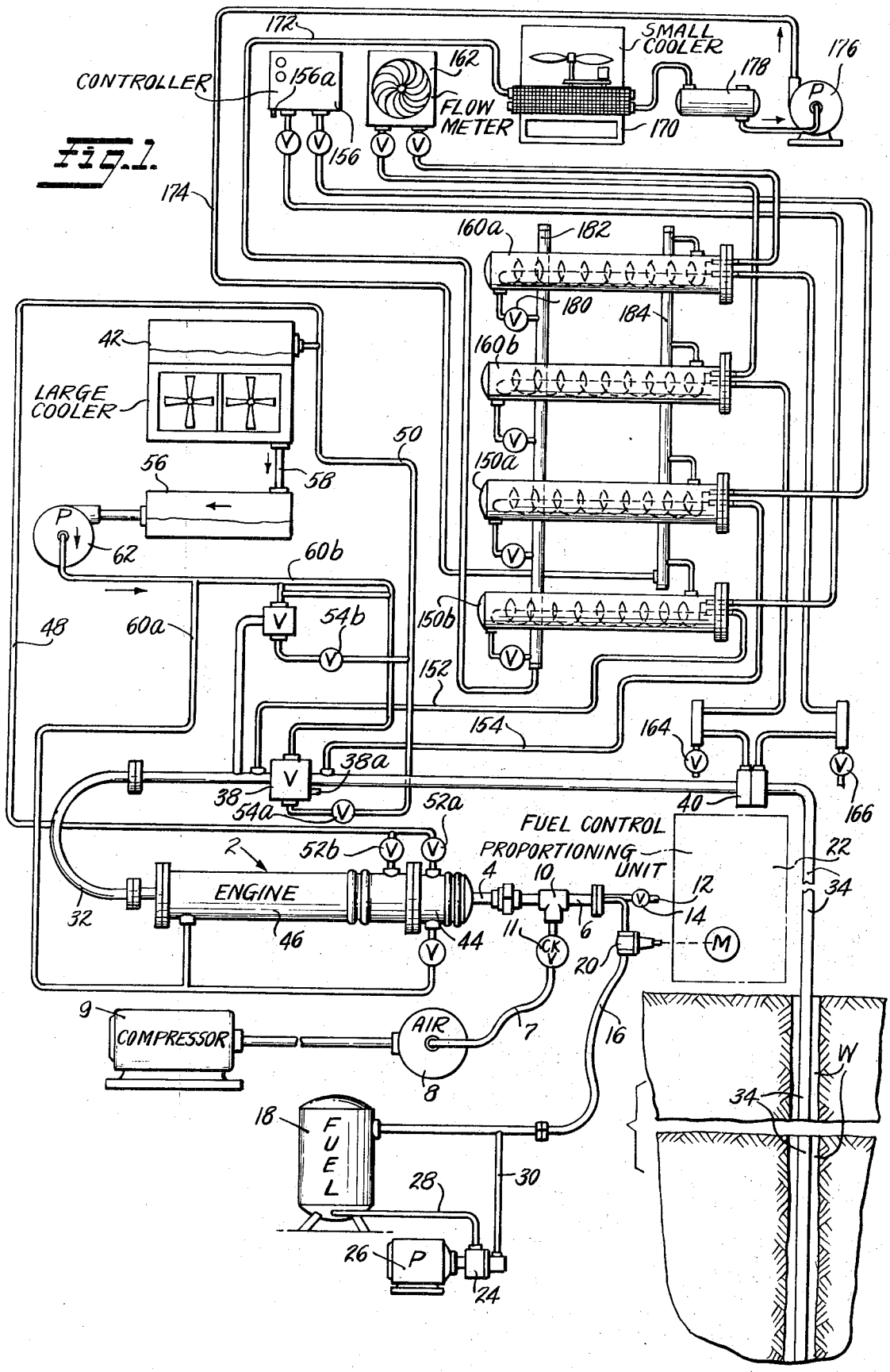
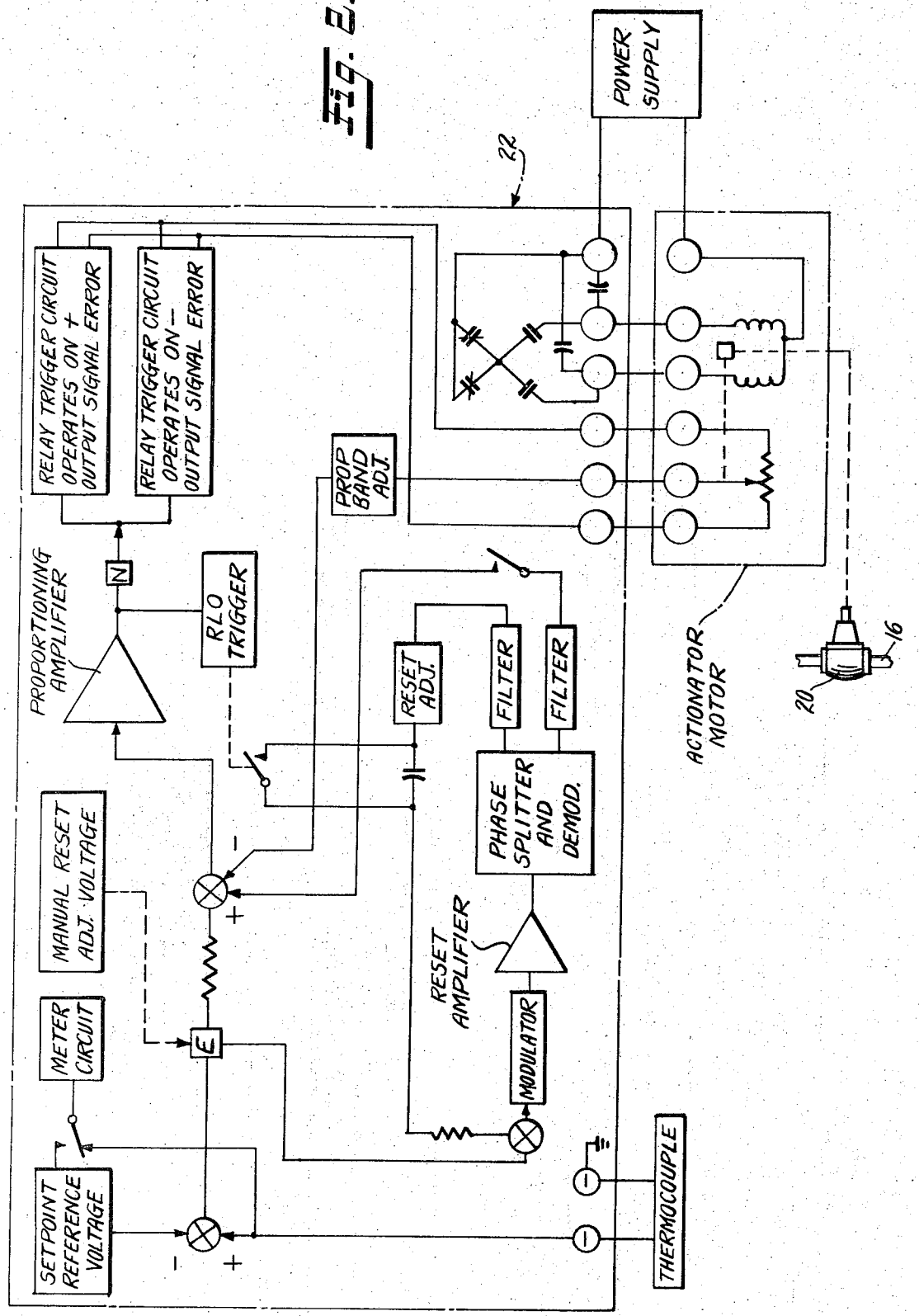

CONTROLLER
156a
156
172
162
FLOW METER
SMALL COOLER
178
176
170
174
160a
182
180
184
160b
42
LARGE COOLER
50
56
58
62
150a
60b
48
60a
54b
150b
152
154
164
166
38a
38
54a
52a
40
FUEL CONTROL PROPORTIONING UNIT
22
52b
2
ENGINE
4
10
12
14
34
32
46
44
11
6
20
M
9
COMPRESSOR
AIR
7
16
8
W
18
FUEL
28
30
26
P
24

Fig. 2.


22
POWER SUPPLY
RELAY TRIGGER CIRCUIT OPERATES ON + OUTPUT SIGNAL ERROR
RELAY TRIGGER CIRCUIT OPERATES ON − OUTPUT SIGNAL ERROR
PROP BAND ADJ.
N
PROPORTIONING AMPLIFIER
RLO TRIGGER
RESET ADJ.
FILTER
FILTER
ACTIONATOR MOTOR
20
16
MANUAL RESET ADJ. VOLTAGE
PHASE SPLITTER AND DEMOD.
METER CIRCUIT
E
RESET AMPLIFIER
MODULATOR
SETPOINT REFERENCE VOLTAGE
THERMOCOUPLE

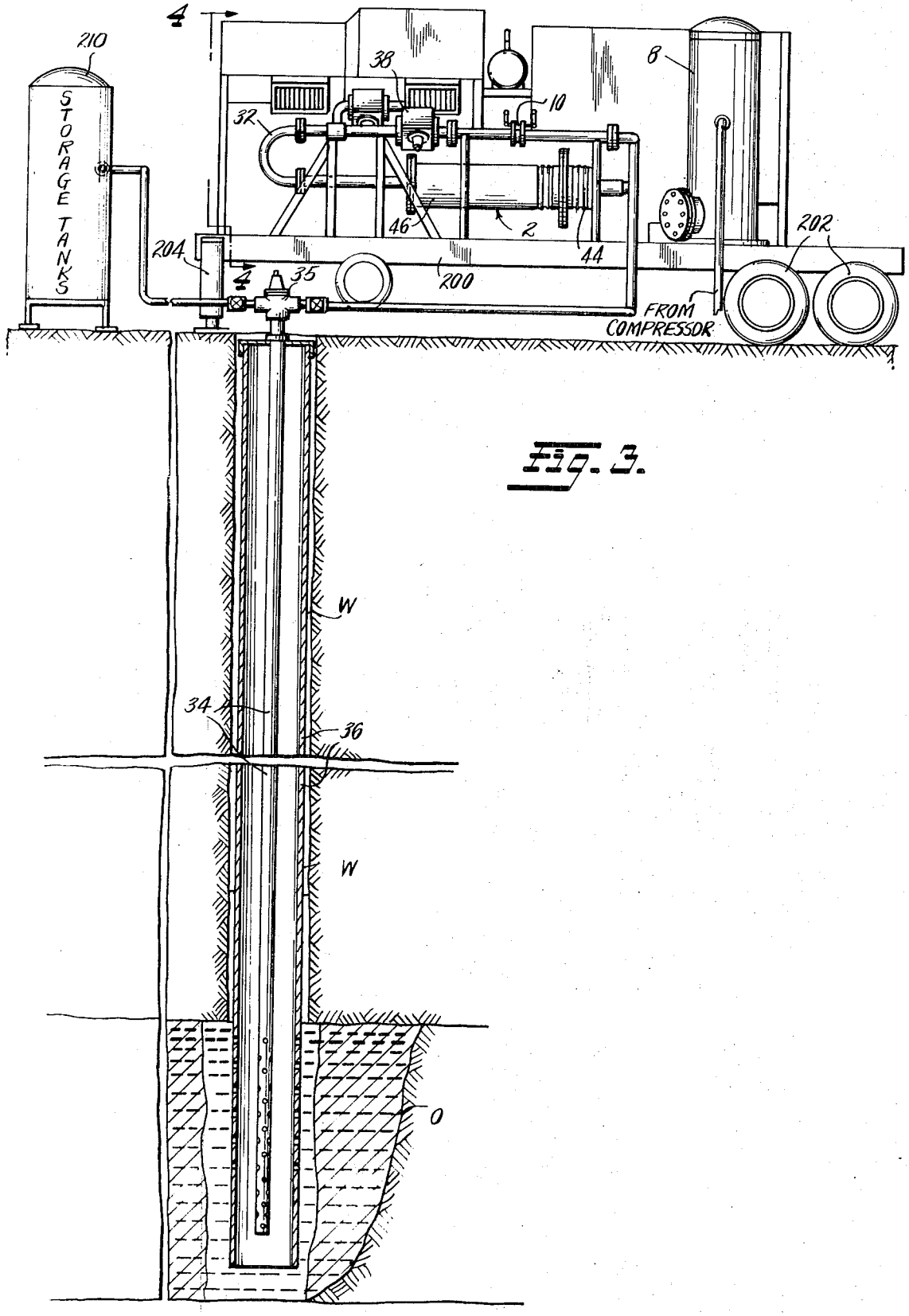
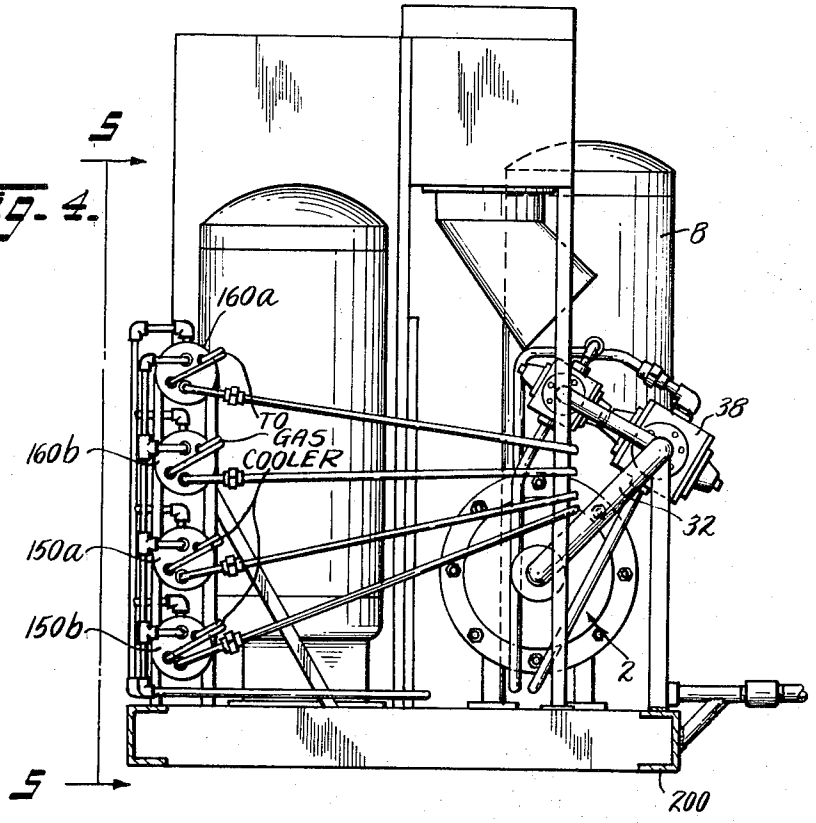

4
210
STORAGE TANKS
38
8
10
32
46
2
44
202
204
4
35
200
FROM COMPRESSOR
W
34
36
W
O

Fig. 3.

Fig. 4.


5
5
8
160a
160b
150a
150b
TO GAS COOLER
38
32
2
200

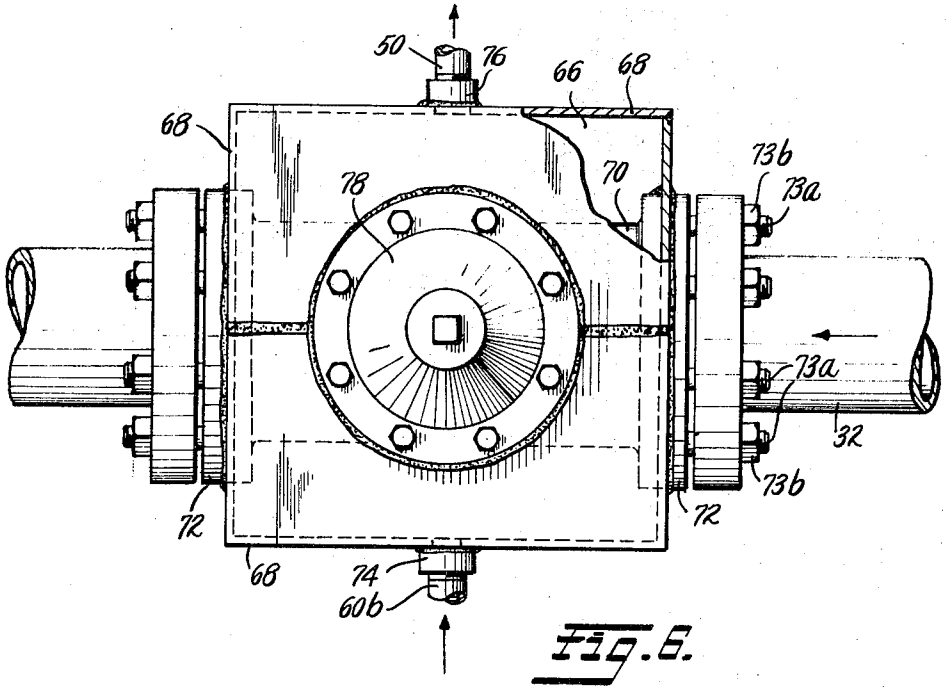

50
76
66
68
68
70
78
73b
73a
73a
32
73b
72
72
68
74
60b

Fig. 6.

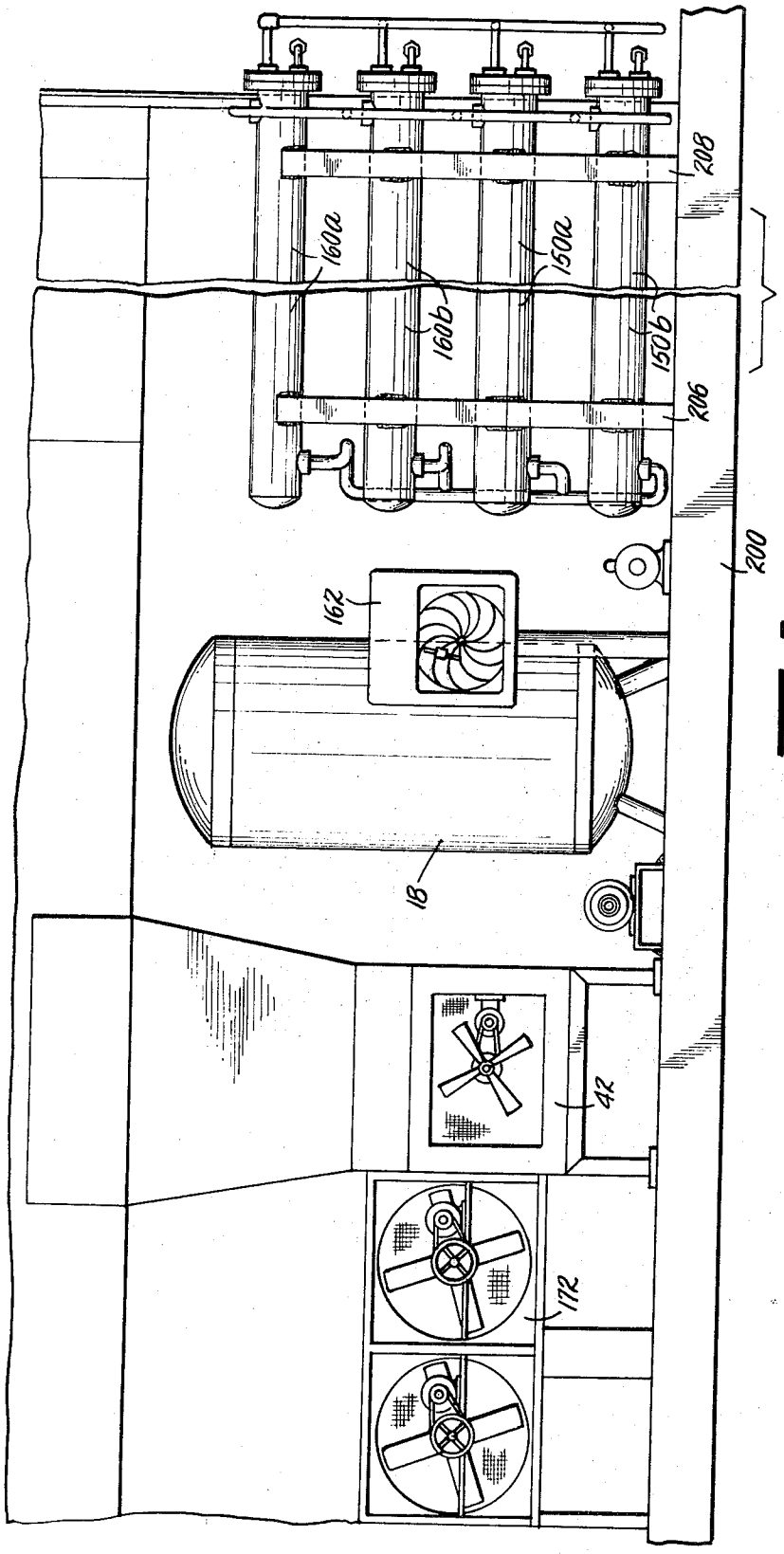


Fig. 5.

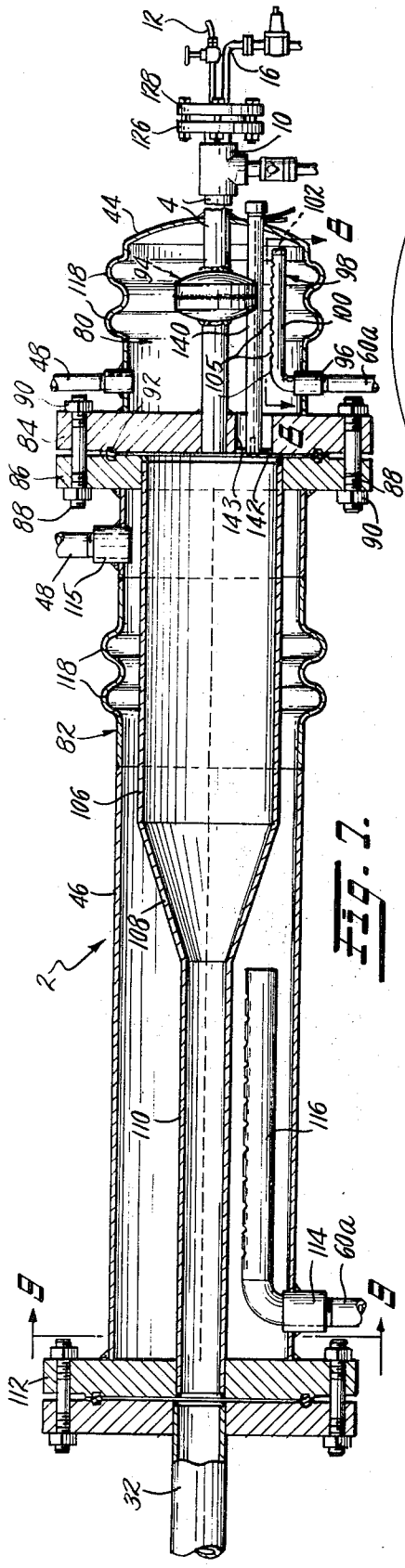


Fig. 7.

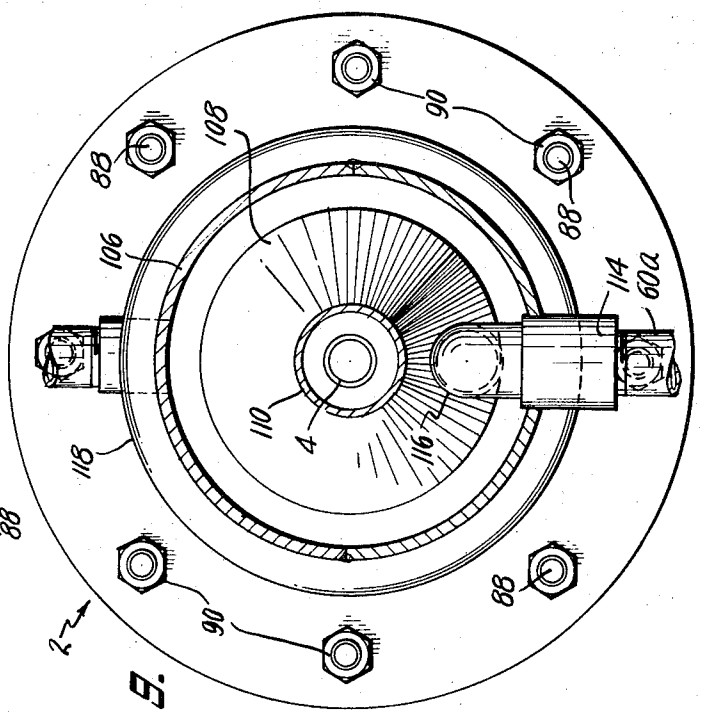


Fig. 9.

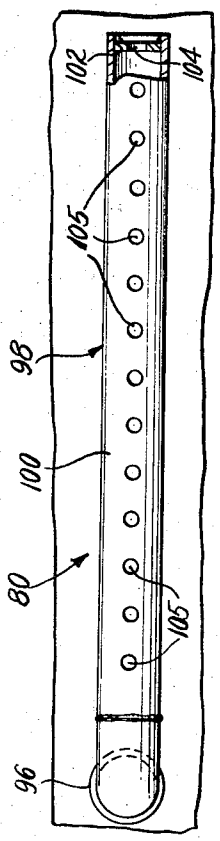


Fig. 8.

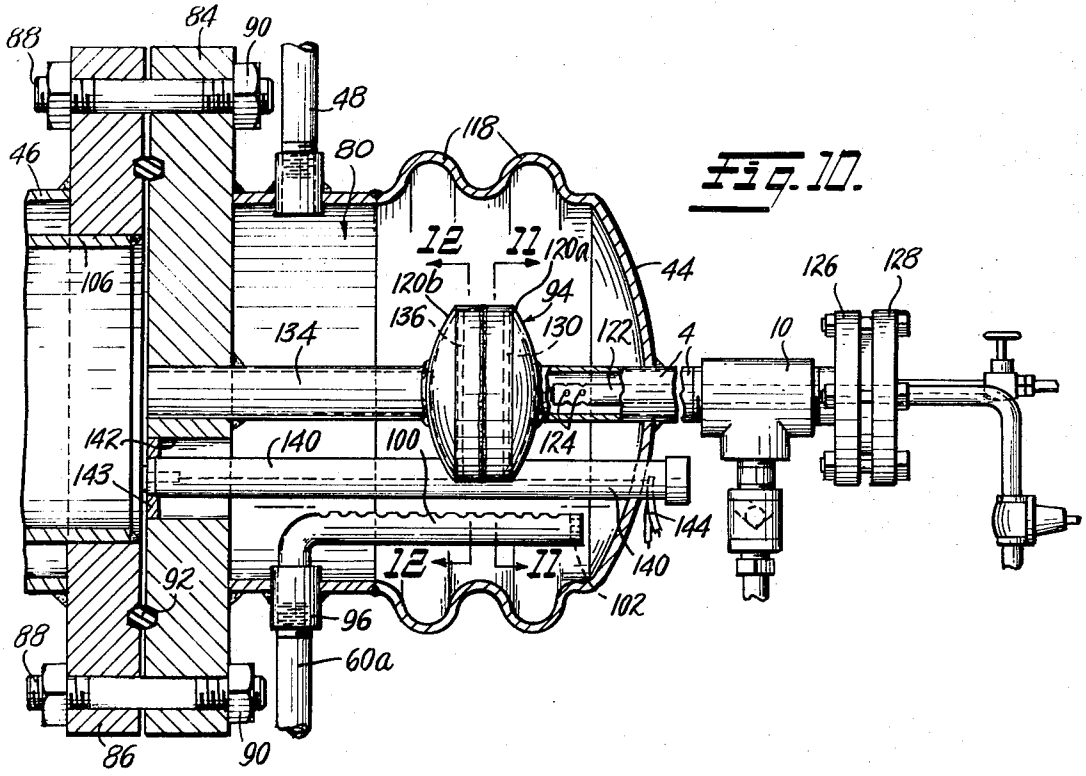


Fig. 10.

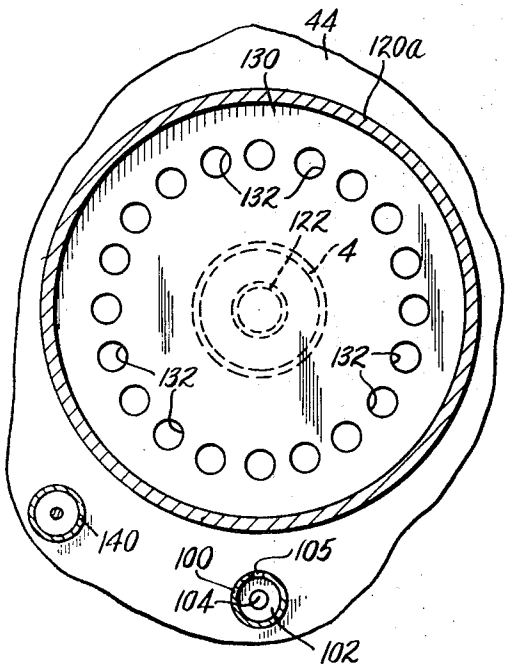


Fig. 11.

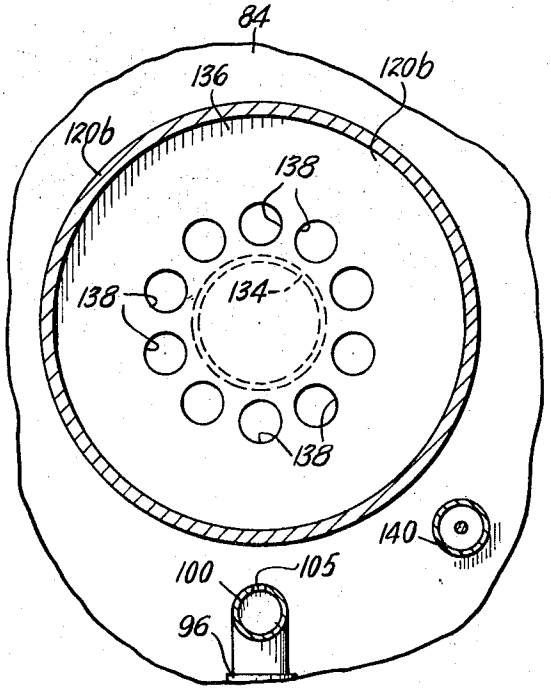


Fig. 12.

HOT GAS APPARATUS FOR RECOVERY OF OIL VALUES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a process and apparatus for recovering highly viscous oil from subterranean deposits, and more specifically, to a process and apparatus utilizing a rocket engine for generating the hot gas conveyed into the oil well. The temperature and pressure values of the hot gas are accurately controlled to predetermined values by means of automatic flow control means operatively connected to heat exchangers and controlled by means of automatic control systems.

2. Description of the Prior Art

The recovery of highly viscous oil from subterranean deposits has long been a problem in the oil industry. Oftentimes it is not economical to use conventional oil well pumps to pump the highly viscous oil to the ground surface since it is very difficult, if not impossible to obtain a reasonable flow rate due to the high viscosity of the oil.

It is old and well known in the petroleum art that heat reduces the viscosity of the oils. Accordingly, many proposals have been made for applying heat to subterranean oil deposits for heating the oil to reduce the viscosity thereof prior to pumping the oil to the surface.

Many different processes and devices have been proposed for supplying the necessary heat to the subterranean oil deposits for heating the oil to reduce its viscosity. Some of the earlier proposals have been to connect the exhaust pipe of an internal combustion engine with a pipe extending into the well to convey the hot exhaust gases into the oil deposit for the purpose of heating the oil to reduce its viscosity. More recently, it has been found that the use of gas turbine engines for generating the desired hot gases, as taught by U.S. Pat. No. 3,522,843 to New can be used with greater efficiency.

One of the most recent developments has been the use of a heated gas generating system employing a heater having an insulated combustion chamber into which the desired air and fuel are conveyed and ignited with the hot gases obtained from the ignition of the air-fuel mixture being conveyed directly into the oil well. Such a system is shown in U.S. Pat. No. 3,605,885 to Leeper.

The major drawback of the prior art processes and devices for supplying heated combustion gases into oil bearing strata for the purpose of reducing the viscosity of the oil deposit has been the inability to accurately control the temperatures and pressures of the exhaust gases supplied to the oil deposit to obtain a highly efficient operation of the exhaust gas generating system. The prior art systems merely generate the hot gases and convey the hot gases directly into the oil well. Furthermore the structures of the prior art proposals are generally of a stationary nature and have a very high rate of fuel consumption.

SUMMARY OF THE INVENTION

The present invention overcomes many of the disadvantages of the prior art hot gas processes and devices for recovering high viscosity oil from subterranean deposits by employing a continuous combustion rocket engine for generating the hot gases with sufficiently high pressure and temperature necessary to obtain an efficient heating of the subterranean oil deposit and recovery thereof.

The process and apparatus of the subject invention is adapted for operation on low cost jet engine fuel and is designed to be supplied with a high volume of compressed air which greatly reduces the amount of fuel required to obtain high temperature exhaust gases. The use of the high volume of air in combination with the high temperature exhaust gases also enables the process and apparatus according to the present invention to be used to initiate fire flood conditions within the interior of an oil well, if necessary to aid in recovery of the oil deposits.

The present invention further includes control valves and heat exchanger means connected in the exhaust gas conduits for automatically and accurately regulating the temperatures and pressures of the exhaust gases as required to obtain an efficient operation of the subject system.

The structure of the present invention is generally self-contained so that the system can be mounted as a self-contained mobile unit on a trailer for easy transportation to the desired oil well site.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of the present invention showing the piping interconnections used therewith.

FIG. **2** is an electrical circuit diagram of one type of commercially available fuel control proportioning unit which can be used with the present invention.

FIG. **3** is a diagrammatic fragmentary side elevational view of a mobile apparatus of the present invention for oil production.

FIG. **4** is an enlarged transverse sectional view, taken on the line **4—4** of FIG. **3.**

FIG. **5** is an enlarged fragmentary rear elevational view of the apparatus of FIG. **3,** taken on the line **5—5** of FIG. **4.**

FIG. **6** is an enlarged fragmentary elevational view, partly in seciton, of one of the jacketed valves used with the apparatus of FIG. **1.**

FIG. **7** is an enlarged fragmentary vertical sectional view through the rocket engine used with the apparatus of FIG. **1.**

FIG. **8** is an enlarged plan view of a coolant injector, partly in seciton, employed with the rocket engine taken on the line **8—8** of FIG. **7.**

FIG. **9** is an enlarged vertical sectional view of the interior of the rocket engine, taken on the line **9—9** of FIG. **7.**

FIG. **10** is an enlarged fragmentary vertical sectional view of the air and fuel injection chamber of the rocket engine of FIG. **7,** according to the present invention.

FIG. **11** is an enlarged fragmentary vertical transverse sectional view taken on the line **11—11** of FIG. **10.**

FIG. **12** is a fragmentary vertical transverse sectional view taken on the line **12—12** of FIG. **10.**

DESCRIPTION OF THE PREFERRED EMBODIMENT

The preferred embodiment of the present invention will now be described with reference to FIGS. **1** and **3** of the drawings. A constant combustion rocket engine

2 is used to generate the hot exhaust gases conveyed into an oil well W and oil deposit 0, shown in FIG. 3. The internal structural details of the rocket engine 2 are shown in FIG. 7 and will be described hereinafter. A fuel-air inlet conduit 4 is connected to one end of the rocket engine 2 for supplying fuel and air to the combustion chamber of the engine 2 from a fuel supply source and a source of compressed air.

A fuel supply conduit 6 and a compressed air conduit 7 are connected to the fuel-air inlet conduit 4 by means of a T-fitting 10, as shown in FIG. 1. The fuel supply conduit 6 has two separate fuel lines connected therewith. One fuel line 12 is connected to a source of starting fuel, such as LP gas, also known as Propane gas, through a control valve 14 with a second line 16 being connected to a source of operating fuel, such as jet engine fuel, known as JP4 jet fuel, contained in storage tank 18. A suitable control valve 29 is connected in the operating fuel line 16 is operatively connected to an automatic fuel control proportioning unit 22 for regulating the amount of fuel being supplied to the rocket engine 2 during operation of the system of the present invention.

A circuit diagram of one type of automatic fuel control proportioning unit 22 which may be used with the system of the present invention is illustrated in FIG. 2. This automatic proportioning control unit is a commercially available unit identified as

Model R 7161F (N).

This specific control unit does not form a part of the present invention and any commercially available equivalent proportioning control unit or system may be used.

The fuel storage tank 18 is pressurized by a suitable pressurizing pump 24, driven by an electric motor 26, and connected to the operating fuel storage tank 18 by means of a conduit 28 to maintain a supply of fuel to the rocket motor 2 at the required pressure for efficient operation. A fuel by-pass line 30 is connected between the supply line 16 and the return port of pump 24 to recirculate the fuel through the tank 18 when the control valve 20 is closed.

The compressed air conduit 7 for supplying compressed air to the rocket engine 2 is connected to a compressed air storage tank 8, which, in turn, may be supplied with compressed air from an air compressor 9. A one-way check valve 11 is connected in the compressed air conduit 7 between the storage tank 8 and the T-fitting 10 to prevent the flow of pressurized fuel back into the compressed air tank 8.

The exhaust port of the rocket engine 2 is connected to an exhaust gas conduit 32 for conveying the hot exhaust gases to the oil well W. The opposite end of the exhaust pipe 32 is connected to a well pipe 34 which extends into the well bore W, as shown in FIGS. 1 and 3 of the drawings. As shown in FIG. 3 the open end of the well pipe 34 opens into the subterranean oil deposit O. The end of the well pipe 34 extending into the oil deposit O can be perforated, if desired, to increase the flow of hot exhaust gases into the oil deposit O. The walls of the well bore W are prevented from collapsing by means of a conventional well jacket 36.

Referring again to FIG. 1 jacketed back pressure control valves 38 and an orifice metering device 40 which may be a valve or other similar means, are connected in the exhaust gas conduit 32 for controlling the pressure and flow of the exhaust gases from the engine 2 to the well pipe 34.

The present invention employs two separate cooling systems for automatically and accurately maintaining the temperature of the hot exhaust gases of the rocket engine 2, and the temperature of the back pressure control valves 38 and orifice metering device 40 at the desired values necessary to maintain an efficient high-temperature operation of the overall system. The first cooling system, a large capacity system, is connected to the rocket motor 2 and to each of the flow control valves 38, while a second, smaller capacity system is connected to the exhaust gas conduit 32 and the orifice control means 40. The details of the two cooling systems will now be described with reference to FIG. 1 of the drawings.

The large capacity cooling system includes a large cooler 42 connected with cooling jackets 44 and 46 of the rocket motor 2 by a hot coolant return conduit 48. The first cooling jacket 44 surrounds the fuel and air inlet injection portion of the rocket motor 2. The second cooling jacket 46 surrounds the combustion chamber portion of the motor 2. The structural details of the rocket motor 2 and the cooling jackets 44 and 46 will be explained more fully hereinafter with reference to FIG. 7. Control valves 52*a* and 52*b* are connected in conduit 48 to control the flow of coolant from cooling jackets 44 and 46 of the rocket engine 2 to the large cooler 42.

The large capacity cooler 42 is also connected to the back pressure control valves 38, the internal details of which will be described more fully hereinafter with reference to FIG. 6, through a second hot coolant return conduit 50. A second set of coolant flow control valves 54*a* and 54*b* are connected between the back pressure control valves 38 and conduit 50 for controlling the coolant flow from valves 38 to the cooler 42 to regulate the temperatures of the valves 38.

The cooled liquid coolant passes from the large cooler 42 into a reservoir tank 56 through a conduit 58. If desired, the reservoir tank 56 may be constructed integrally with the large capacity cooler 42. thereby eliminating the need for a separate return conduit 58. The cooled liquid coolant is conveyed to the cooling jackets 44 and 46 of the rocket engine 2 and to the back pressure control valves 38 through conduits 60*a* and 60*b*, respectively, by means of pump 62. If desired, an additional flow control valve 64 may be connected in the cooled liquid conduit connected with the cooling jacket 44 for the engine air and fuel injection chamber to aid in controlling the fluid flow therethrough.

Referring now to FIG. 6, the construction of the liquid cooled back-pressure control valves 38 will now be described. Each of the valves 38 has a coolant cavity 66 formed by a plurality of rigid walls 68 surrounding the central conduit portion 70. The central conduit portion 70 has a flange 72 attached to each end thereof for coupling the valve assembly 38 to the exhaust gas conduit 32 by any suitable means, such as threaded studs 73*a* and nuts 73*b*. The coolant is supplied into the cavity 66 through coolant line 60*b* and attached to one wall of the housing by means of a fitting 74. The hot coolant is returned to the cooler 42 through return conduit 50 which is connected to the cavity 66 through an opening and fitting 76 in a wall 68 positioned opposite the coolant inlet fitting 74. The valve control mechanism 78 extends through cavity 66 into the central conduit portion

70 to regulate the flow of exhaust gas through the exhaust gas pipe 32 by means of the automatic control system to be described hereinafter.

By providing the cooling jacket 68 around the flow control valve 38, the temperature of the flow control valve is maintained at a temperature which insures accurate control and operation of the valve 38 and, accordingly, the flow of exhaust gases therethrough.

The internal construction of the rocket motor 2, including the structural details of the cooling jacket 44 and 46 thereof, will now be described in detail with reference to FIGS. 7–12 of the drawings. Referring specifically now to FIG. 7, the rocket motor 2 is constructed in two sections, including a fuel-air inlet, mixing and injection section 80 and a combustion chamber and exhaust section 82. The sections 80 and 82 of the rocket motor 2 are joined together by means of flanges 84 and 86, which may be held in assembled relationship by any conventional means, such as a plurality of threaded studs 88 and nuts 90. Alternatively, the two flanges 84 and 86 may be welded together, if desired. An "O" ring seal 92, or other suitable seal means is positioned between the two flanges 84 and 86 to assure a fluid tight seal therebetween.

As shown in FIG. 7, the fuel-air mixing and injection section 80 includes a fuel-air mixing and injection nozzle assembly 94, the details of which will be described more fully hereinafter with reference to FIGS. 10–12. The fuel-air mixing and injection nozzle assembly 94 is attached to and extends through an opening in the flange 84 to inject a fuel-air mixture into the combustion chamber section 82. The cooling jacket 44 for the engine air - fuel mixing and injection section 80 is sealingly joined to the flange 84 and surrounds the fuel-air mixing and injection nozzle assembly 94. The cooling fluid inlet conduit 60a is attached to the cooling jacket 44 by any suitable means, such as a threaded pipe fitting 96. The cooling liquid is distributed into the interior of the cooling jacket 44 by means of a fluid distributor 98, which is shown in detail in FIG. 8.

Referring now to FIG. 8 the cooling fluid distributor 98 consists of a tubular conduit 100 having one end formed at right angles to the longitudinal axis of the tube for connection with the inlet pipe fitting or connecting member 96. The other end of the tubular conduit 100 has a plug 102 rigidly secured therein, with the plug having an opening 104 therethrough to allow the cooling liquid to flow from the end of the conduit 100. In addition to the opening 104 in the plug located in the end of the tubular conduit 100, a plurality of openings 104 are located along the length of the conduit 100 to provide for distribution of the cooling liquid along the entire length of the chamber formed by the cooling jacket 44 to provide for even cooling of the elements of the fuel-air injection section 80.

Referring again to FIG. 7, the combustion chamber and exhaust section 82 of the rocket motor 2 includes a cylindrical shaped combustion chamber 106 having one end thereof secured to the mounting flange 86 and opening therethrough for communication with the fuel-air mixing and injection nozzle assembly 94 of the fuel-air injection section 80. The down-stream exhaust end of the combustion chamber 106 has a tapered portion 108, to which is connected one end of a tubular exhaust conduit 110. The opposite end of the exhaust gas conduit 110 is attached to a coupling flange 112 which has an opening therethrough for connection with the exhaust conduit 32.

The combustion chamber cooling jacket 46 is of a generally cylindrical configuration having its ends sealingly secured to the coupling flanges 86 and 112, respectively, as shown in FIG. 7. The cooling fluid inlet conduit 60*a* communicates with the interior of the combustion chamber cooling jacket 46 by way of pipe fitting 114 extending through the cooling jacket 46 at the end thereof adjacent the exhaust pipe coupling flange 112. A cooling fluid distributor 160 is positioned within the cooling jacket 114 and communicates with the coolant inlet conduit 60*a* to distrubute the coolant liquid within the interior of the cooling jacket 46 in the same manner as the coolant fluid distributor 98 positioned within the cooling jacket 44 of the fuel-air mixing and injection section 80. The construction and configuration of the cooling fluid distributor 116 is the same as that of the fluid distributor 98, shown in detail in FIG. 8. Accordingly, no further detailed explanation of the structural details of the cooling fluid distributor 116 is required.

The cooling fluid return conduit 48 is connected with the cooling jacket 46 by way of pipe fitting 114 or other desired means at a point adjacent the flange 86. By arranging the cooling fluid inlets and outlets in the combustion chamber and exhaust section 82 in the manner shown and described a counter-flow relationship between the hot combustion exhaust gases within the combustion chamber 106 and tubular exhaust gas conduit 110 and the cooling fluid within the engine combustion chamber cooling jacket 46 is obtained. This counterflow relationship results in a more efficient cooling of the combustion chamber 106 and more accurate control and regulation of the exhaust gas temperatures and pressure.

As seen in FIG. 7 and 10 the cooling jackets 44 and 46 include corregated sections 118 to compensate for the expansion and contraction of the cooling jackets as a result of the high temperature differentials applied thereto to prevent possible damage to the jackets and motor structure and leakage thereof.

Referring now to FIGS. 10–12 the structural details of the fuel-air mixing and injection section 80 of the rocket motor 2 according to the present invention will now be described. As shown in FIG. 10, the fuel-air mixing and injection assembly 94 includes two hollow cup-shaped members 120*a* and 120*b* attached to each other by any suitable means, such as welding, to form a closed chamber. One of these cupshaped members 120 cup-shaped attached to the end of the fuel-air inlet conduit 4. The second cup-shaped element 120*b* is attached to one end of a fuel-air mixture injection pipe 134. The other end of the pipe 134 opens into the combustion chamber 106 through an opening in flange 84 for injecting the fuel-air mixture into the combustion chamber 106 of rocket motor 2.

The end of the fuel-air inlet conduit 4 opposite the assembly 94 extends from the cooling jacket 44 and is attached to the T-fitting 10, as was described previously with reference to FIG. 1. Within the fuel-air inlet conduit 4 is positioned a fuel atomizing nozzle tube 122. The end of the fuel inlet nozzle extending into the interior of the conduit 4 in the direction of the cup-shaped members 120 has a plurality of holes 124 drilled therein for atomizing the fuel and mixing the fuel with the air in the conduit 4. The opposite end of the fuel at-

omizing nozzle tube **122** extends through the T-fitting **10** and is attached to a flange **126** for connection with the fuel lines **12** and **16.** The fuel lines **12** and **16** are, in turn, attached to a second flange **128** and joined together at the flange **128** for communication with the fuel atomizing nozzle tube **122.**

The cup-shaped member **120***a* attached to the end of the fuel-air inlet conduit **4** has a baffle plate **130** positioned therein across its interior, as shown in FIG. **11.** A plurality of holes or openings **132** are formed in the baffle plate **130** circumferentially around its center to obtain a complete mixing of the fuel and air and even distribution of the fuel-air mixture. The second cup-shaped element **120***b* also has a baffle plate **136** positioned across the open end thereof, as illustrated in FIG. **12,** with the baffle plate **136** having a plurality of holes or openings **138** positioned circumferentially around the center of the baffle plate **136.** The holes in the baffle plate **136** are positioned radially inwardly of the holes **132** in baffle plate **130** to obtain a more efficient transfer of the atomized and completely mixed fuel-air mixture into the combustion chamber **106** through injection pipe **134.**

Extending through the interior of the cooling jacket **44** into the end of the combustion chamber **106** is an igniter means **140,** which may be any suitable spark generating device such as a spark plug or other type of igniting mechanism used to ignite the fuel-air mixture in a jet or rocket engine. The igniter means **140** extends into the interior of the combustion chamber **106** through an opening **142** in the coupling flange **84** and is sealed therewith by a suitable sealing means **142** to prevent the entry of cooling fluid into the interior of the combustion chamber **106.** The igniter means **140** is connected to a suitable electrical power source and control unit by means of electrical leads **144** in a well-known conventional manner.

Referring once again to FIG. **1,** the second cooling system, including heat exchangers a cooler and control units for regulating the temperature of the engine exhaust gases flowing through exhaust conduit **32** and the temperature of the orifice control means **40** will now be described. The exhaust gas and orifice metering means temperature control system includes a plurality of heat exchangers **150***a* and **150***b* connected to the hot exhaust gas conduit **32** across the back-pressure control valves **38** through a first conduit **152** connected to the exhaust gas conduit **32** on the upstream side of the valve **38** and a second, or return conduit **154** connected to the exhaust gas conduit **32** on the downstream side of the valve **38,** as shown in FIG. **1.** Although FIG. **1** shows two heat exchanger units **150***a* and **150***b* connected in series with each other, any number of heat exchanger units may be used, as long as the capacity of such units is sufficient to closely and accurately control the temperature of the exhaust gases flowing therethrough.

The heat exchangers **150***a* and **150***b* are connected in series with a pneumatic valve controller unit **156** for controlling the flow of exhaust gases through conduits **152** and **154.** The pneumatic valve control unit **156** is of a well-known, commercially available construction which can be preset to a desired temperature to maintain the temperature of the exhaust gases flowing through the heat exchanger **150***a* and **150***b* and the controller unit **156** at a desired temperature value. The controller unit **156** also has a pressure sensing port **156***a* which communicates with a pressure port **38***a* in one of the flow control valves **38** on the upstream side thereof. The pneumatic controller unit **156** is also responsive to the pressure in the exhaust gas conduit **32** between the rocket motor **2** and the flow control valves **38** to control the amount of exhaust gases being bypassed around the valve **38** to maintain the exhaust gas back-pressure in the rocket motor **2** at a desired level. The maintainance of the desired back pressure level is continued as long as it is necessary to pressure up the oil formation O in the oil well W.

A second set of heat exchanger units **160***a* and **160***b* are connected in series with each other and with the orifice metering device **40,** which may be in the form of a flow control valve. A flow meter **162** is connected in series with the second set of heat exchanger units **160***a* and **160***b* and the orifice metering device **40** to record the flow of exhaust gases therethrough. Valve means **164** and **166** may be employed in series with the orifice metering device **40** to regulate the flow therethrough, if necessary. The pneumatic controller unit **156** and the flow meter **162** are readily commercially available devices widely used in the industry for controlling and recording the outputs of heat exchanger and temperature control systems. Any suitable devices or their equivalents for accomplishing the desired results according to the present invention may be used. Accordingly, no further explanation of the structural or operational details of these components is required.

As shown in FIG. **1** both sets of heat exchanger devices **150***a* **150***b* and **160***a*, **160***b* are connected in parallel with each other and in series with a small capacity cooler unit **170** by way of conduits **172** and **174.** A pump unit **176** and coolant reservoir **178** are connected between the small cooler **170** and the coolant conduit **174** for circulation of the coolant fluid through the heat exchanger units **150***a*, **150***b*, **160***b* and the small capacity cooler unit **170.**

If desired, a flow control valve **180** may be connected between the heat exchanger units **150***a*, **150***b*, **160***a*, **160***b* and the conduits communicating therewith, these connecting conduits being shown as connection manifolds **182** and **184** in FIG. **1** of the drawings, so that the temperatures of the coolant fluid and the exhaust gases flowing through the heat exchanger units **150** and **160** may be more accurately controlled.

The system of the present invention illustrated in FIG. **1** is designed to be self-contained and is readily adaptable for mounting on a mobile trailer for easy movement from one location to another. A preferred embodiment of a mobile construction of the present invention is shown in FIG. **3** and will now be described with reference to FIGS. **3–5** of the drawings. As seen in FIG. **3** the rocket engine **2** is rigidly mounted on a conventional semi-trailer chassis **200** for movement of the desired oil well location by a conventional semi-trailer tractor or other applicable towing rig. The chassis **200** has a set of wheels **202** attached to the rear portion thereof in a conventional, well-known manner. A leveling jack assembly **204** is positioned under the front end of the trailer chassis **200** for leveling the chassis following its detachment from a towing vehicle.

Referring now to FIG. **4,** it will be seen that the rocket engine **2** is mounted on one side of the trailer chassis **200.** On the side of the trailer chassis **200** opposite the rocket engine **2** are mounted the heat exchangers unit **150***a*, **150***b*, **160***a* and **160***b*. The heat ex-

changer units are rigidly supported by means of a pair of rack rails **206** and **208**, as shown in FIG. **5**.

The cooler units **42** and **170** and their associated components, including the reservoirs **56**, **178** and pumps **62** and **176**, are mounted on the rear portion of the trailer chassis **200** on the side opposite the engine **2**, as may be seen in FIG. **5**. The flow meter recording unit **162** is also mounted on the side of the trailer chassis **200** opposite the engine **2** for easy accessability. The various fuel control proportioning units and temperature controllers are also mounted on the chassis **200** for easy accessibility.

In addition the rocket motor **2**, cooler units **42** and **170**, the compressed air storage tank **8**, as well as the fuel storage tank **18**, can also be mounted on the trailer chassis **200** so that the entire system can be transported to the oil well site. The mounting of the air and fuel storage tanks **8** and **18** on the trailer chassis **200** eliminates the requirement of connecting and disconnecting these storage tanks to the exhaust gas generating unit each time the unit is moved to a new location.

The operation of the preferred embodiment according to the present invention will now be described in detail with reference to the drawings, specifically, FIG. **1**.

The trailer **200**, with the rocket engine **2** and each of the components of the system according to the present invention illustrated in FIG. **1** mounted thereon, is transported to the location of the oil well W which has previously been drilled. At the site of the well W, which may have a well casing or jacket **36**, if required, a well pipe **34** is extended into the well W below the level of the oil deposit O, if such a well pipe has not been previously placed into the well W. The exhaust gas conduit **32**, having one end attached to the rocket motor is then connected to the well pipe **34** by a suitable connection means, such as a valve assembly **35** shown in FIG. **3**. Each of the control units, including the fuel control proportioning unit **22**, the pneumatic valve control unit **156**, and the flow unit meter **162**, are checked and set to the required predetermined values. Starting fuel, such as propane or LP gas is then supplied to the fuel-air inlet conduit **4** through the starting fuel supply line **12** and the starting fuel control valve **14**. Simultaneously, compressed air from the air storage tank **8** and air compressor **9** is supplied to the fuel-inlet conduit through the compressed air conduit **7** and one-way check valve **11**. The fuel control proportioning unit **14** then energizes the igniter device **140** to ignite the fuel-air mixture in the combustion chamber **106** of the rocket engine **2**.

The rocket engine **2** is warmed up to a temperature of approximately 1,000°F. When the engine **2** reaches the warm-up temperature of 1,000°F, the control valve **20** in the operating fuel supply line **16** is opened by the fuel control proportioning unit **22** to permit the flow of JP4 jet fuel from the fuel storage tank **18** into the fuel-air inlet conduit **4**. The JP4 jet fuel is atomized and injected into the fuel-air mixing and injection nozzle assembly **94** by the fuel atomizing nozzle tube **122**. The atomized fuel is mixed with the compressed air entering the assembly **94** and is injected into the combustion chamber **106** of the rocket engine **2** through the mixture injection pipe **134**.

When the sustained combustion of the jet fuel and air mixture in the combustion chamber **106** has been achieved the starting fuel control valve **14** is closed to shut off the supply of starting fuel to the rocket engine **2**.

The hot exhaust gases generated by the combustion of the JP4 jet fuel and air mixture in the combustion chamber **106** exit the rocket engine **2** through the exhaust gas passage **110** into the exhaust conduit **32**. The hot exhaust gases flow through the exhaust pipe **32**, the back pressure control valves **38** and the orifice metering device **40** into the well pipe **34**. The hot exhaust gases exit from the open end of the well pipe **34** and enter the subterranean oil deposit O to increase the temperature thereof and lower the viscosity of the oil to permit more efficient removal of the oil deposit.

As the rocket engine **2** is generating hot exhaust gases, the coolant circulating pumps **62** and **176** circulate liquid coolant through the respective systems in which these pumps are connected. The coolant pump **62** supplies coolant liquid from the reservoir **56** through coolant supply conduits **60***a* and **60***b* to the jacketed back-pressure control valves **38** and to the cooling jackets **44** and **46** of the rocket engine **2**.

The temperature of the exhaust gases flowing through the exhaust conduit **32** is accurately regulated by the heat exchangers **150***a* and **150***b*, with the flow of the exhaust gases being accurately measured by the flow metering device **40**. The second cooling system, including the cooler **170** pump **176** and reservoir **178** maintain the temperature of the exhaust gases being bypassed around the back-pressure control valves **38** through conduits **152** and **154** at the desired preset temperature, determined by the control unit **156**. When the back pressure control valves **38** are closed to obtain the predetermined back-pressure in the rocket engine **2**, the exhaust gases bypass the valve **38** through conduit **152** and are circulated through heat exchanger unit **150***b* and continue to flow through the controller unit **156**. The exhaust gases then flow from controller unit **156** into the heat exchanger unit **150***a* and return to the exhaust pipe **32** downstream of the valve **38** through conduit **154**.

Controller unit **156** has a pressure sensing port **156***a* which is connected with a pressure-receiving port **38***a* located on the back pressure control valve unit **38** for actuating the valve **38** to control the back pressure in the rocket engine **2** to a preset level. The back pressure control of the exhaust gases by way of the control ports **156***a* and **38***a* takes place as long as it is necessary to achieve the desired pressure in the oil formation O.

The temperature of the orifice metering device **40** is accurately controlled by means of the heat exchanger units **160***a* and **160***b* which are connected to the small cooling unit **170**, pump **176** and reservoir **178** in parallel with the heating exchanger units **150***a* and **150***b* through connecting manifolds **182** and **184**.

By accurately controlling the temperature and back-pressure of hot exhaust gases being supplied to a subterranean oil deposit through the use of a plurality of a heat exchanger, cooling and automatic control units in the manner according to the present invention described herein. a highly efficient hot gas process for the recovery of highly viscous oil from subterranean deposits can be achieved. Tests have shown that the apparatus and process according to the present invention can achieve exhaust gas temperatures in the range of 1,200°F – 1,050°F at pressures of 340–360 PSI, while consuming between 17½ and 28½ gallons per hour of JP4 jet fuel. The generation of exhaust gases at 1,540°F

at the fuel consumption rate of 28½ gallons per hour while using an air volume of 1,500,000 cubic feet per day is compared with conventional units which have a fuel consumption rate of 50–75 gallons per hour.

It has also been found that the device according to the present invention described hereinabove can be operated to start and maintain fire - flood conditions in an oil well, because of the large oxygen content remaining in the exhaust gases being forced into the oil formation. By adjusting the automatic controls to create an exhaust gas temperature of between 900° and 1,000°F, tests have shown that the fuel consumption rate is approximately 12–13 gallons of jet fuel per hour with an air volume of 1.5 million cubic feet per day. An analysis of the exhaust gases generated by those operating conditions indicates that the exhaust gases contain 80 percent nitrogen, 40 percent oxygen and 5½ percent carbon-dioxide (CO_2). By the generation of the exhaust gases having such a chemical analysis, it has been found that with the apparatus running at the low temperatures of between 900° and 1,000°F a fire - flood condition can be started and maintained in an oil well, due to the large oxygen content remaining in the exhaust gases being forced into the oil formation. The temperature of the exhaust gases and the oxygen contained therein are sufficient to start the fire in the oil formation. After the fire has been started in the oil formation, valves on the fuel supply conduits and the outlet of the system can be shut off and air from a separate air compressor or other air supply source, such as a separate tank **210,** shown in FIG. **3,** could then be connected to the well pipe **34** through valve **35** and supplied into the formation to maintain the fire - flood condition. The unit mounted on the trailer chassis, according to the present invention, could then be moved to another location for the same purpose.

It must be well understood that the invention is not limited to the described embodiment and that many changes may be introduced therein without departing from the scope of the present patent application.

What is claimed is:

1. An apparatus for the recovery of highly viscous oil values from oil deposits comprising, a constant combustion rocket engine for generating high temperature exhaust gases, conduit means for conveying hot exhaust gases generated by said engine to an oil deposit, pressure and flow control valve means operatively connected in said conduit means, cooling means operatively connected with said constant combustion rocket engine, said pressure and flow control valves means, and said conduit means, automatic control means operatively connected with said cooling means and said pressure and flow control valve means to automatically control the pressure build-up and temperatures of the hot exhaust gases generated by said constant combustion rocket engine for delivery to a highly viscous oil deposit for reducing the viscosity of the oil in said oil deposit.

2. An apparatus as set forth in claim **1** wherein said pressure and flow control valve means comprises an automatically controlled pressure control valve connected in said conduit means for controlling the passage of high temperature exhaust gases therethrough to regulate the pressure build-up in said rocket engine, and an orifice flow sensing and control connected in said conduit between said pressure control valve and an oil well being supplied with high temperature exhaust gases to sense and regulate the flow of exhaust gases to an oil deposit.

3. An apparatus as set forth in claim **1,** wherein said cooling means further comprises a first cooling system connected with said rocket engine and said pressure and flow control valve means for regulating the temperature thereof, and a second cooling system connected with said high temperature exhaust conduit means, said pressure and flow control valve means and said automatic control means for regulating the temperatures thereof separately and independently from said first cooling system.

4. An apparatus as set forth in claim **3,** wherein said second cooling system includes a plurality of heat exchangers connected with said exhaust gas conduit means, the inlet of said heat exchangers communicating with said exhaust gas conduit means between said rocket engine and said pressure and flow control valve means, the outlet of said heat exchangers being connected with said exhaust gas conduit means downstream of said pressure and flow control valve means, whereby a portion of the high temperature exhaust gases generated by said rocket engine is bypassed around said pressure and flow control valve means through said heat exchangers to regulate the temperature of the exhaust gases being supplied to an oil deposit.

5. An apparatus as set forth in claim **1,** further comprising a trailer chassis having ground engaging means attached thereto to allow movement of said chassis across a surface, said rocket engine, conduit means, pressure and flow control valve means, and automatic control means being permanently mounted on said trailer chassis to permit mobile transportation of said apparatus to a selective oil well site, said trailer chassis having an air and fuel supply source for said rocket engine mounted thereon, said fuel and air supply source being operatively connected with said rocket engine, wherein said apparatus forms a self-contained mobile unit.

6. An apparatus as set forth in claim **1,** wherein said constant combustion rocket engine comprises a generally cylindrical shape combustion chamber, a cooling jacket sealingly positioned around the exterior of said combustion chamber in a spaced relationship therewith to form a sealed cavity surrounding said combustion chamber, a fuel-air mixture injection means opening into one end of said combustion chamber, said fuel-air mixture injection means having a cooling jacket positioned therearound to form a sealed cavity around said fuel-air mixture injection means, said cavities formed within said cooling jackets being communicated with said cooling means to control the temperature of said rocket engine.

7. An apparatus as set forth in claim **6,** further comprising coolant distribution means positioned within said cavities surrounding said combustion chamber and said fuel-air mixture injection means to obtain an even distribution of coolant within said chambers.

8. An apparatus as set forth in claim **6,** wherein said fuel-air mixture injection means comprises a first tubular conduit having one end opening into said combustion chamber, a cup-shaped hollow member attached to the other end of said first tubular conduit, a second tubular conduit extending through said cooling jacket and having a second cup-shaped hollow member attached to the end thereof, said first and second cup-

shaped members being sealingly connected to form a chamber therewithin, each of said cup-shaped members having a baffle positioned transversely within the chamber formed therein, each of said baffles having a plurality of openings therethrough, and a fuel atomizing nozzle extending into said second tubular conduit for injecting atomized fuel into said conduit for mixing with air therein.

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