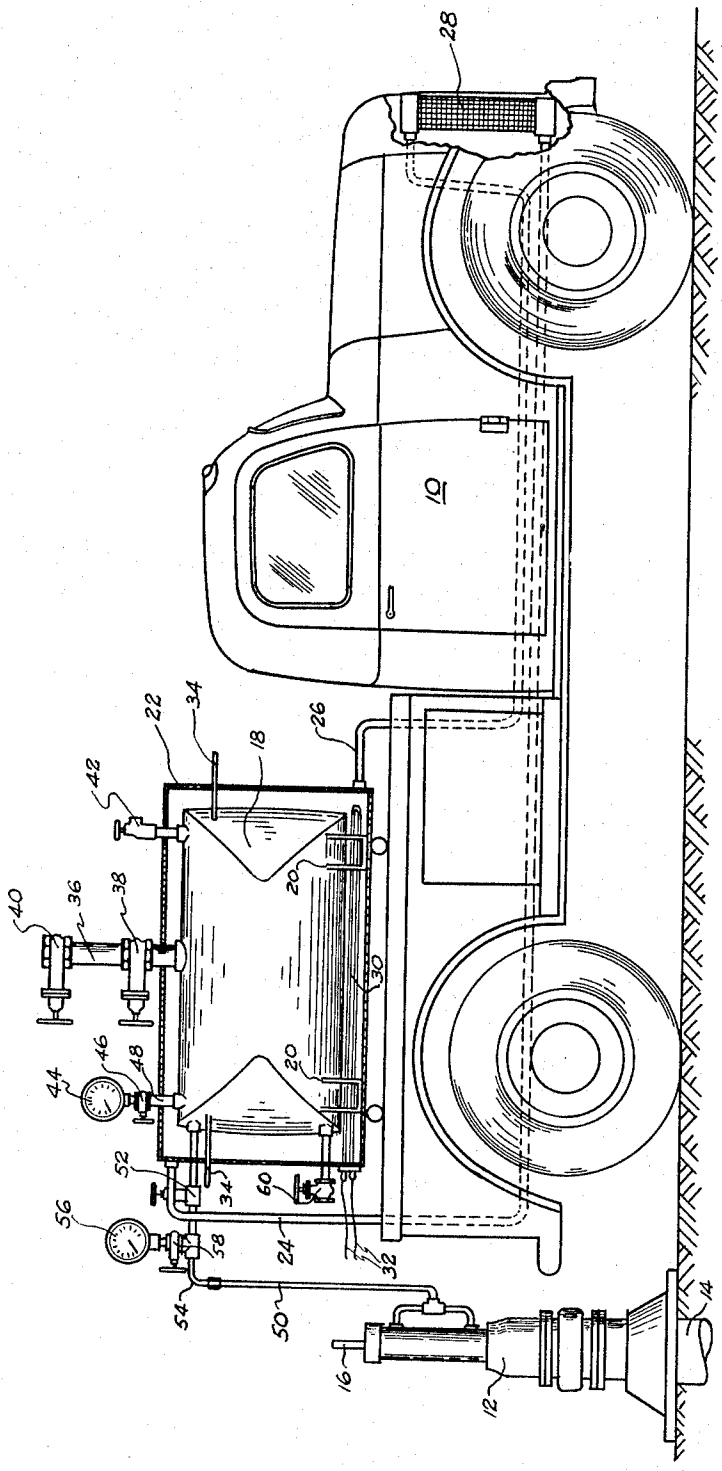
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METHOD AND APPARATUS FOR SUPPLYING GAS UNDER PRESSURE

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METHOD AND APPARATUS FOR SUPPLYING GAS UNDER PRESSURE

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ABSTRACT OF THE DISCLOSURE

A method and apparatus for supplying gaseous carbon dioxide to a wellhead in communication with an oil reservoir or the like, including a portable generator tank preferably mounted on a truck or other vehicle, a heating jacket surrounding the tank and adapted to receive a heating fluid at least in the lower part of the jacket, a heating element such as an electrical heating element or means for circulating hot water from a truck radiator or the radiator of another engine through the heating jacket, a carbon dioxide introduction system connected to the carbon dioxide generating tank, including a first valve adapted to pass a solid stick of carbon dioxide into a holding pipe or chamber and a second valve mounted below the chamber and adapted to pass the solid stick of carbon dioxide from the chamber into the generating tank, a gaseous carbon dioxide outlet connected to the vapor space of the generating tank and a gaseous carbon dioxide line leading from the carbon dioxide outlet to the wellhead. A pressure relief valve may also be mounted on the generating tank as well as a pressure gauge. A valve and pressure gauge may also be mounted in the line leading to the wellhead. One method of utilizing the apparatus in oil field operations is to apply the gaseous carbon dioxide to one side of the piece of well equipment, such as a casing and then observe any leakage of carbon dioxide to the opposite side of the casing.

The present invention relates to a method and apparatus for supplying gas under pressure. In a more specific aspect, the present invention relates to a method and apparatus for supplying gaseous carbon dioxide under pressure for oil field operations.

It is common practice in the drilling of wells and the produtcion of petroliferous fluids from subterranean earth formations to utilize various gases under pressure for the performance of well and formation treating operations, as well as in the testing and operation of a variety of well equipment. For example, gases have heretofore been used as a source of pressure to fracture a subsurface formation and thereby increase its permeability to fluids. For such operations, relatively small amounts of gas are utilized at pressures in the neighborhood of 500 to 3500 p.s.i. In other operations, such as the displacement of oil from subsurface reservoirs, both liquids and gases have been used individually and in various combinations. While most such secondary recovery operations require very substantial volumes of gas, there are certain operations of this character where a liquid can be aerated or foamed with a gas and thus produce an effective displacement medium having many of the advantages of gas displacement while using only limited amounts of gas. Aerated or foamed liquids have also been used in treating subsurface formations with acid to increase the permeability, as paraffin solvents to dissolve paraffin deposits from subsurface formations and well equipment, as surfactants or detergents for various formation and equipment cleaning purposes, as corrosion inhibitors, as fracturing fluids, etc. There is also a need in oil field operations for techniques and means for pressure testing various items of equipment at the well location, such as,

threaded joints of piping utilized in the control of the well and in the production of oil and other fluids from the subsurface formation to the surface of the earth. Certain types of fluid pumps and valves used in oil field operations also can be operated by gases under pressure; and devices such as packers and blow-out preventers, designed to seal a conduit against fluid transmission, are often fluid-expandable and can be conveniently operated by gases under pressure.

While a number of gases are available for use in the above-mentioned operations, a number of these gases are flammable, and thus present a hazard. For example, natural gas is readily available but is highly flammable and, when compressed, represents an explosive mixture. Likewise, normally gaseous hydrocarbon materials, such as, propane and butane, have been liquefied and utilized in a liquefied or gaseous state in various oil field operations. However, these materials are also flammable and explosive under the conditions of use encountered; and, therefore, great care is required in the handling of these materials. Another gas which has been suggested for use in both the gaseous and the liquefied form is nitrogen. Nitrogen in its essentially pure form, as opposed to its combination in air, is relatively inert and thus can be handled without the dangers incident in the use of flammable gases. However, nitrogen is not readily available. In addition, the liquefication of nitrogen requires the application of extremely high pressures in order to maintain the material in its liquid form so that extensive compression and/or cooling equipment must be available at the site of use or the liquefied nitrogen must be transported to the site in special high pressure vessels. Carbon dioxide, on the other hand, is a readily available and effective material for use in oil field operations, particularly because of its non-flammability. Also, carbon dioxide is non-corrosive and thus does not contribute to the very severe corrosion problems normally encountered in oil field operations. In addition, carbon dioxide has a critical temperature of about 88° F. and therefore can be liquefied and maintained in a liquid condition at a comparatively low pressure, the vapor pressure at the critical temperature being about 1,070 p.s.i. Accordingly, the use of liquefied carbon dioxide for certain of the above-mentioned oil field operations has been suggested. However, as is the case in the use of liquefied nitrogen, the use of liquefied carbon dioxide requires either the provision of rather expensive compression and/or cooling equipment at the well location, or the transport of the liquefied material in special containers, the only difference being that the transport container need not be capable of withstanding as high a pressure as is required for nitrogen. Accordingly, it is obvious that there is no present technique or equipment for readily supplying relatively small amounts of gases under pressure for use in oil field operations at remote well locations. Specifically, there is a great need for a simple and convenient method and means for supplying limited quantities of non-explosive gases under relatively low pressures for the testing and operation of oil field equipment and the conduct of oil field operations.

It is therefore an object of the present invention to provide an improved method and apparatus for supplying gas under pressure.

Another object of the present invention is to provide an improved method and apparatus for supplying gas under pressure to oil field operations.

Still another object of the present invention is to provide an improved method and apparatus for supplying gas under pressure to a well head located on a well leading to subsurface petroliferous deposits.

A further object of the present invention is to provide

an improved method and apparatus for pressure testing oil field equipment.

Another and further object of the present invention is to provide an improved method and apparatus for pressure testing joints in pipes used in oil wells.

Yet another object of the present invention is to provide an improved method and apparatus for supplying gaseous carbon dioxide under pressure.

A still further object of the present invention is to provide an improved apparatus for supplying gaseous carbon dioxide under pressure wherein solid carbon dioxide is readily converted to its gaseous form.

Another and further object of the present invention is to provide an improved apparatus for supplying carbon dioxide under pressure which includes improved means for introducing solid carbon dioxide to a tank in which it is converted to its gaseous form.

Still another object of the present invention is to provide an improved high pressure vessel and method of manufacturing the same.

These and other objects and advantages of the present invention will be apparent from the following detailed description when read in conjunction with the drawing wherein:

The drawing is a side elevational view, partially in section, of the apparatus of the present invention in use at a well site.

In accordance with the drawing, the portable gas pressure source is mounted on a suitable transport vehicle **10**. Transport vehicle **10** may be a flat-bed truck, as shown in the drawing, a panel truck, a trailer, or other motive means for readily moving the pressure source from one well location to another. As previously indicated, gas under pressure is supplied from the portable source to a well head **12**, where it is utilized in many and varied oil field operations. As illustrated in the drawing, well head **12** is attached to the top of a large casing **14**, which is disposed in a well drilled into the earth. A smaller pipe or tubing **16** is shown being inserted into the well through the well head and thence into casing **14**. Accordingly, in the illustrated use the portable gas pressure source of the present invention is being utilized to pressure test the joints of tubing **16**. High pressure vessel **18** is shown mounted on appropriate supports **20** within a low pressure vessel **22**. Low pressure vessel **22** is supplied with liquid through liquid inlet line **24** and discharges liquid through liquid outlet line **26**. In the embodiment shown, inlet line **24** and outlet line **26** pass to the radiator **28** of truck **10** and lines **24** and **26** therefore serve as conduits for the circulation of hot water from radiator **28** through low pressure vessel **22**. While normally conventional flow and the water pump of truck **10** will supply the necessary energy to circulate the hot water, it may be desirable in some cases to provide a booster pump on either of lines **24** or **26**. Fluid lines **24** and **26** are also preferably flexible hoses and are detachable from radiator **28**. This will permit the hoses to be connected to the radiator of any appropriate internal combustion engine at the well location. In many instances, there is available at the well head a suitable internal combustion engine utilized as a prime mover for some unit of equipment and this engine can be used to supply hot water to low pressure vessel **22**. An alternative means of heating the liquid contained in low pressure vessel **22** is shown as electrical heating coil **30**, which is disposed in low pressure vessel **22**. Heating coil **30** may be any appropriate resistance-type heating coil having connected thereto power lines **32** which may be connected to a suitable source of power. Accordingly, the fluid contained with in low pressure vessel **22** may be heated electrically where an appropriate source of electric power is available at the well site. Other sources of heat, such as a direct gas heater or a gas heater utilized to heat circulating water, may also be utilized. The significant point is that very little heat is required, because of the low sublimation temperature of carbon dioxide, and the present portable gas pressure source is therefore adaptable to use in any remote well location to supply gas under pressure. The portable gas pressure source of the present invention may also be readily removed from the transport vehicle because of its light weight, small size and the utilization of flexible hoses **24** and **26**. For this purpose, loop-type handles **34** are welded to the ends of high pressure vessel **18** and pass outwardly through low pressure vessel **22**. Mounted in the top of high pressure vessel **18** is upstanding charging pipe **36**. Pipe **36** passes through low pressure vessel **22** and is exposed outside vessel **22** where it will be readily accessible to the operator. Pipe **36** is provided with lower valve **38** and upper valve **40**. Valves **38** and **40** are appropriate gate-type valves and the utilization and importance of charging pipe **36** and valves **38** and **40** will be pointed out hereinafter in the description of the operation of the apparatus. Also attached to high pressure vessel **18** and in open communication therewith is a pressure relief valve **42**. Relief valve **42** is what is commonly referred to as a pop valve and, depending upon the desired internal pressure to be maintained in vessel **18**, pop valve **42** will operate to open and relieve the pressure when it exceeds the preselected pressure and automatically close when the pressure has been relieved and the preselected pressure in vessel **18** has again been attained. Such operation of pop valve **42** will occur rather frequently but it is not necessary that the valve remain open any length of time in order to maintain a safe pressure in vessel **18**. Also in communication with vessel **18** is main pressure gauge **44**. An appropriate valve **46** is mounted in line **48** leading from the interior of high pressure vessel **18** to pressure gauge **44**. When it is desired to monitor the pressure in high pressure vessel **18**, valve **46** will be opened, otherwise valve **46** may remain closed without altering the operation of the present apparatus. Gas is supplied to well head unit **12** from high pressure vessel **18** through gas line section **50**. Gas line section **54** is provided with shut off valve **52** adapted to open and close the supply line as desired. Gas line section **50** is preferably a flexible hose and therefore an appropriate metallic gas line section **54** is utilized for the mounting of valve **52**. Also in gas line section **54** is mounted an appropriate pressure gauge **56**. Pressure gauge **56** is adapted to measure the pressure of the gas actually being supplied to well head **12** and will be utilized at all times when gas under pressure is being supplied to the well head. An appropriate valve **58** is mounted between gauge **56** and line **54** to interrupt the flow of gas to gauge **56** when desired. High pressure vessel **18** is also supplied with a drain valve **60** for the discharge of condensed water, etc., which may accumulate in vessel **18** from time to time.

The high pressure vessel **18** is also relatively inexpensive and unique in construction. In oil field operations large metallic pipes, capable of withstanding extremely high pressures without rupture, are utilized to case a well and serve as a conduit for the production of fluids. This casing can be obtained either in a seamless or seamed structure. Accordingly, a length of this metallic high test-pressure casing can be utilized in the construction of high pressure vessel **18** and is ideally suited for this purpose. Vessel **18** is constructed by cutting a length of high test-pressure pipe to the desired ultimate length of the vessel and thereafter cutting generally V-shaped sections from opposing sides of both ends of this elongated section of pipe. A second section of the same cylindrical pipe generally equal in length to the diameter of the pipe is then cut and a pair of curved generally diamond-shaped sections are cut from the sides of this section of pipe transverse to its length. These diamond-shaped, curved sections are then welded in place in the V-shaped notches formed in the elongated section of pipe to thereby close the ends of the elongated section of pipe and form an appropriate high pressure vessel.

Solid carbon dioxide for use in accordance with the present invention is readily available and may be ob-

tained in the form of elongated sticks. In the use of the present apparatus, the apparatus is transported to the desired well site by an appropriate vehicle. A supply of solid carbon dioxide is fed to high pressure vessel **18** by closing valve **38** and opening valve **40** and inserting a stick of solid carbon dioxide in chamber **36** between the two valves. Thereafter, valve **40** is closed and valve **38** opened to drop the solid carbon dioxide into vessel **18**. This procedure is repeated during the use of the apparatus, and, accordingly, solid carbon dioxide may be added to replenish the supply in vessel **18** without interrupting the operation being carried out, since the inlet means permits one to maintain the vessel closed to the atmosphere at all times during charging of solid carbon dioxide. After the vessel **18** has been charged with sufficient solid carbon dioxide, heat is applied to the fluid contained in low pressure vessel **22**, either by activating electrical heating element **30** or by connecting lines **24** and **26** to the radiator of an internal combustion engine, such as, the engine of the vehicle used to transport the equipment. The hot water in the cooling system of the vehicle is then circulated through vessel **22**. Where the radiator of an internal combustion engine is not employed to supply hot water to vessel **22**, fluids other than water may be disposed in vessel **22** and used as a heating medium. For example, kerosene or other suitable liquids may be utilized and these fluids may be electrically heated as by coil **30**, or by a gas jet, either directly or indirectly. Such gas heating is convenient, since in most cases natural gas is available at the well location. It is also possible to circulate steam through vessel **22** if a suitable source of steam is available. Pop valve **42** is set at the desired pressure which is to be maintained within vessel **18** and which is to be supplied for use in the well operation and, to the extent that the pressure exceeds the set pressure, the pop valve will intermittently operate to relieve the excess pressure and maintain the pressure below the preselected pressure. Valve **46** is opened at the outset of the operation so that the pressure within vessel **38** may be observed on pressure gauge **44**. When the pressure has attained the preselected value, as observed on gauge **44**, line **50** is connected to an appropriate connection on well head **12** and valve **52** is open to supply gaseous carbon dioxide to well head **12**. While gaseous carbon dioxide is being supplied to well head **12**, valve **58** may be opened and gauge **56** utilized to monitor pressure in the supply line. As shown in the drawing, the gaseous carbon dioxide is being utilized to pressure test a string of tubing **16** being inserted through well head **12** and casing **14** into the well. By applying gaseous carbon dioxide under pressure to the outside of tubing **16**, leaks in the joints of tubing **16** or in the tubing itself may be detected. Various means of detection may be employed. Normally, orifice-type leaks of the character generally encountered can be readily detected, since the leakage of the high pressure gas through the orifice-type opening will create an audible sound. A leak may also be detected by observing a sudden pressure drop in the supply line to the well head or a sudden pressure increase in the interior of tubing **16**.

As previously indicated, the apparatus of the present invention provides a mobile, inexpensive source of gas under pressure for a wide variety of oil field operations which may be readily utilized at remote locations where it is too expensive, impossible or inconvenient to obtain suitable pressurized gases. Variations and modifications other than those specifically set forth herein by way of example will occur to one skilled in the art. Accordingly, the present invention is to be limited only in accordance with the appended claims.

I claim:

1. A mobile apparatus for supplying carbon dioxide for oil field operations at a pressure above atmospheric pressure, comprising:

(a) a vehicle adapted to be moved from one location to another;

(b) a first vessel, adapted to receive a liquid, mounted on said vehicle;

(c) an internal combustion engine having a cooling system containing a circulating liquid;

(d) liquid feed lines leading from said cooling system to said vessel and back to said cooling system for circulating hot liquid from said cooling system through said first vessel and back to said cooling system;

(e) a second vessel, adapted to withstand a preselected pressure above atmospheric pressure, mounted within said first vessel and at least partially submerged in liquid disposed in said first vessel;

(f) a vertically-disposed, elongated pipe mounted on the top of said second vessel and in open communication therewith;

(g) first valve means mounted in said pipe adjacent said second vessel;

(h) second valve means mounted in said pipe a sufficient distance above said first valve means to form a receiving chamber of sufficient length to temporarily accommodate pieces of solid carbon dioxide;

(i) a pressure regulator valve, adapted to maintain a substantially constant pressure within said second vessel, mounted on said second vessel and in open communication therewith;

(j) a first pressure gauge means mounted on said second vessel and in open communication therewith;

(k) well head means connected to the point of use of the pressurized carbon dioxide;

(l) a carbon dioxide supply line leading from the vapor space of said second vessel to said well head means;

(m) valve means mounted in said supply line and in open communication therewith; and

(n) a second pressure gauge means mounted in said supply line and in open communication therewith.

2. Apparatus in accordance with claim **1** wherein the internal combustion engine is also the motive power for the vehicle.

3. Apparatus in accordance with claim **1** which additionally includes an electrically operated heating element disposed in the fluid contained in the first vessel.

4. Apparatus for supplying carbon dioxide for oil field operations at a pressure above atmospheric pressure to a well head, comprising:

(a) a vessel adapted to withstand pressures above atmospheric pressure;

(b) inlet means communicating with the top of said vessel and including a first valve means adapted to pass solid carbon dioxide therethrough and into said vessel, adjacent said vessel and a second valve means adapted to pass solid carbon dioxide therethrough spaced a sufficient distance above said first valve means to form a chamber adapted to temporarily accommodate pieces of solid carbon dioxide;

(c) heating means for applying heat to said vessel to raise the temperature within said vessel above atmospheric temperature;

(d) gas outlet means communicating with the gas space of said vessel; and

(e) a carbon dioxide supply line means leading from said gas outlet means to a well head in communication with a well in the oil field.

5. Apparatus in accordance with claim **4** wherein the vessel is formed from a high test-pressure, metallic pipe.

6. Apparatus in accordance with claim **4** wherein the inlet means is a vertically disposed pipe having the first and second valve means mounted therein at spaced points.

7. Apparatus in accordance with claim **4** wherein the first and second valve means are gate-type valves.

8. Apparatus in accordance with claim **4** wherein the first vessel is mounted within a second vessel adapted to maintain a body of liquid about at least a part of said first vessel.

9. Apparatus in accordance with claim 8 which includes means for circulating a hot liquid through the second vessel.

10. Apparatus in accordance with claim 8 which includes an internal combustion engine having a cooling system containing a circulating liquid and said cooling system is connected to the second vessel in a manner to circulate said liquid through said second vessel.

11. Apparatus in accordance with claim 8 which includes an electrical heating means disposed in a body of liquid in said second vessel.

12. Apparatus in accordance with claim 8 which includes an electrical heating means disposed in a body of liquid in the second vessel and means for circulating a hot liquid through said second vessel.

13. A method of pressure-testing an item of equipment designed to withstand a substantial pressure differential on either side of the same, comprising:

(a) periodically introducing solid carbon dioxide to a vessel adapted to withstand pressures above atmospheric by closing an inlet immediately adjacent said vessel, introducing the solid carbon dioxide into a chamber immediately above said inlet, closing said inlet to said chamber, and thereafter opening said inlet immediately adjacent said vessel to permit said solid carbon dioxide to drop into said vessel from said chamber;

(b) heating said vessel to an elevated temperature above atmospheric temperature and sufficient to gasify said solid carbon dioxide; and

(c) applying the pressure of said gasified carbon dioxide to one side of the item of equipment being tested in a manner to permit the observance of the passage of carbon dioxide through said piece of equipment from said one side to the opposite side.

14. A method of pressure-testing an item of equipment designed to withstand a substantial pressure differential on either side of the same, comprising:

(a) periodically introducing solid carbon dioxide to a vessel adapted to withstand pressures above atmospheric pressure;

(b) heating said vessel to an elevated temperature above atmospheric temperature and sufficient to gasify said solid carbon dioxide by circulating heated cooling liquid from a liquid-cooled internal combustion engine about said vessel; and

(c) applying the pressure of the said gasified carbon dioxide to one side of the item of equipment being tested in a manner to permit the observance of the passage of carbon dioxide through said piece of equipment from one side to the opposite side.

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