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PATENT SPECIFICATION

(11) 1400549

1400549

- (21) Application No. 45141/72 (22) Filed 29 Sept. 1972
(31) Convention Application No. 7135002 (32) Filed 29 Sept. 1971 in (19)
(33) France (FR)
(44) Complete Specification published 16 July 1975
(51) INT CL² F23L 7/00 F23D 23/00 F23J 15/00//F23D 11/10
(52) Index at acceptance
F4T A2A12 A2C
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(54) METHODS AND APPARATUS FOR BURNING LIQUID HYDROCARBONS

(71) We, FLOPETROL SERVICES INC. A Corporation of Panama 8, Aquilino de la Guardia Street, Panama City, R.P. having a place of business at: 81 Piccadilly, 3rd Floor, London W1V 9HF, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to methods and apparatus for burning liquid hydrocarbons, and more particularly to new and improved methods and apparatus for burning the oil obtained during a test of an offshore well.

When drill stem or production tests are performed in offshore wells, many problems arise in connection with the disposal of the hydrocarbon products that are obtained. For safety reasons, it is highly undesirable to even consider the storage of these products on the drilling platform. In addition, the loading and transport of such products by tanker entails many technical problems and can be quite costly. Accordingly, on-site burning of crude oil and gases is generally considered to be the most desirable manner of disposal.

The disposal of gas by combustion does not present any great problems and can be achieved by means of a simple flare pit. On the other hand, crude oil burners must meet a certain number of requirements. First, they must be able to handle fluids containing solid particles and must be able to operate within a very wide range of flow rates, e.g. from a few cubic feet per hour to over 2400 cubic feet per hour. Moreover, the burning process generates a considerable amount of heat and it is necessary to protect the installations of the drilling platform. A paramount consideration is to avoid polluting the ocean through the release of unburned oil drops and to avoid polluting the atmosphere through the production of smoke.

Up to the present time, burners have been used that are capable of handling oils, even those containing solid particles, at a relatively high range of flow rates while releasing practically no unburned oil drops. Such burners utilize a screen of spray water to protect the platform or rig from the back radiation of an intensely hot flame, as described in U.S. Patent No. 3,565,562. These burners, while performing in a very satisfactory manner for the most part, have one drawback. As long as the flow of oil is small (less than 350 cubic feet per hour for example), it is possible to burn away the liquid hydrocarbons without any substantial production of smoke. However, for higher flow rates, the combustion of the crude oil can produce a large amount of thick smoke which is slow to dissipate and is consequently somewhat troublesome, particularly in circumstances where the drilling platform is located near to a coastline.

It is therefore an object of this invention to provide new and improved methods and apparatus for burning liquid hydrocarbons produced from a well by a substantially smokeless combustion process.

A further object of this invention is to provide new and improved methods and apparatus for burning away liquid hydrocarbons in a manner that considerably reduces the thermal radiation from combustion.

In accordance with one aspect of the present invention a method is provided for burning liquid hydrocarbons produced from a well during testing of the well, wherein an atomized spray of said hydrocarbon is formed and burnt to form a flame along the mean direction of said spray, and sprays of water droplets are injected into the flame in such a manner that substantially all of the water droplets penetrate into the flame but do not pass completely through it, the mean direction for each water spray forming an angle of less than 15° with the mean direction of the flame, and the half value of the opening

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angle of each water spray being no greater than the angle between the mean direction of the water spray and the line along which the outermost particles of burning hydrocarbons are travelling so that substantially all the spray water enters the flame, whereby to reduce the production of smoke. Preferably the angle between the mean direction of each water spray and the mean direction of the flame is substantially equal to 7° to 8° and the droplets forming the water sprays have a diameter of substantially 1 millimeter. Advantageously the ratio of water flow volume to liquid hydrocarbon flow volume lies between 1 and 1.8 and, preferably, is substantially equal to 1.2. According to another aspect of the present invention, there is provided a method of burning liquid hydrocarbons produced from a well during testing of the well. Wherein an atomized spray of said hydrocarbons is formed to form a flame along the mean direction of the spray, and sprays of water droplets are injected into the flame in such a manner that substantially all of the water droplets penetrate into the flame but do not pass completely through it, the ratio of water flow volume to liquid hydrocarbon flow volume lying between 1 and 1.8, preferably substantially 1.2, whereby to reduce the production of smoke. Conveniently, the rate of water flow is adjusted so as to obtain substantially the clearest possible flame with minimum production of smoke.

In accordance with another aspect of the invention, apparatus for use in burning away liquid hydrocarbons produced from an oil well during testing of the well comprises an atomizer having means to receive liquid hydrocarbons from the well for forming an atomized spray thereof which may be burned in a flame along and about the mean direction of said spray, and a water injection system comprising a plurality of water spray nozzles for injecting sprays of water droplets into the flame in such a manner that the droplets penetrate into the flame but do not pass completely therethrough, the spray nozzles being directed so that the mean direction of the respective spray of water droplets forms an angle of less than 15° with the mean direction of the flame, the half value of the opening angle of each spray of water droplets being no greater than the angle between the mean direction of the water spray and a line along which the outermost particles of burning hydrocarbons are travelling so that substantially all of the droplets enter the flame. Conveniently such apparatus may further include means for mounting the spray nozzles in annular array about the flame so as to project sprays of water droplets from all around the base of the flame. A preferred embodiment of the apparatus further includes shroud means mounted coaxially of said atomized spray of liquid hydrocarbons and

adapted to produce turbulence in air flow in a region adjacent to the outlet of said atomizer to improve the mixing of the atomized spray with air and wherein the water spray nozzles are mounted in an array around the downstream end of the shroud means. Preferably the shroud means is cylindrical and the apparatus may also further comprise an annular water supply tube arranged around the downstream end of the shroud means with the water spray nozzles being carried by the supply tube.

A further preferred embodiment of the invention comprises a plurality of atomizers arranged in a cluster and each having means to receive liquid hydrocarbons from the well for forming atomized sprays that are burnt along and about mean direction of each said spray and a water injection system associated with each atomizer, each water injection system including a plurality of water spray nozzles for injecting sprays of water droplets into the respective flame in such a manner that the droplets penetrate into the flame but do not pass completely therethrough, said nozzle being directed such that the mean direction of the respective array of water droplets forms an angle of less than 15° with the mean direction of the respective flame, the half angle of the opening angle of each spray of water droplets being no greater than the angle between the mean direction of the spray and the line along which the outermost particles of burning hydrocarbons of the respective spray are travelling so that substantially all of the water droplets enter the respective flame. Preferably the mean direction of a first atomized spray of liquid hydrocarbons is directed substantially horizontally and the mean directions of the other of said atomized sprays are directed to diverge outwardly from the said mean direction of the first atomized spray. A shroud means may, with advantage, be associated with each said atomizer, each said shroud means being adapted to produce turbulence in air flow around the outlet of its respective atomizer to improve the mixing of said atomized sprays with air. Such an embodiment may further include an annular water supply tube arranged around the downstream end of each shroud means, said plurality of nozzles for each water injection system being attached to the respective water supply tube.

Advantageously any of the embodiments described further comprises flow control means for adjusting the rate of flow to the water spray nozzles. Preferably the atomizer, or each of said atomizers, further comprises means to impart a rotary movement to said liquid hydrocarbons to improve the atomization thereof and may further comprise means to impinge gaseous fluid under pressure on

said hydrocarbons further to improve the atomization thereof.

Conveniently the apparatus further comprises a frame whereon said apparatus is mounted and a beam adapted for attachment to the side of a drilling platform and means for mounting the frame on the beam for rotation about a vertical axis. Such an embodiment may further include a multiple rotatable header joint aligned with said vertical axis and adapted to receive liquid hydrocarbons and to supply the hydrocarbons to the atomizer or to each atomizer and to receive water and to supply the water to the water injection nozzles.

Preferably any of the embodiments further comprise means for providing a generally vertically directed water screen to provide a projection against the back radiation of the burning hydrocarbons.

For a better understanding of the invention together with further objects and advantages thereof, reference may be made to the following description and to the drawings in which:

Figure 1 is a side view of an apparatus according to the invention;

Figure 2 is a front view of the apparatus of Figure 1;

Figure 3 is a schematic view to illustrate the geometrical relationships involved, in the apparatus of Figures 1 and 2, in injecting sprays of water droplets into the flame;

Figure 4 is a cross-sectional view of a water injection nozzle forming part of the apparatus of Figures 1 and 2;

Figure 5 is a longitudinal section of an atomizer of the apparatus of Figures 1 and 2; and

Figures 6 and 7 are cross-sections taken along lines 6—6 and 7—7 in Figure 5.

Referring initially to Figures 1 and 2, an apparatus in accordance with the present invention includes at least one burner assembly and may comprise, in general, a cluster of three identical burner assemblies 10a, 10b, and 10c mounted on a frame 11. The burner assembly 10a comprises an atomizer 12a, a cylindrical shroud or hearth 13a and a water injection system 14a. The burner assemblies 10b and 10c comprise the same elements bearing the same reference numbers assigned indices b and c respectively.

Each water injection system makes it possible to spray water into the flame of the sprayed oil, and tests have shown that the water injection provides very good results. The smoke is practically eliminated and the thermal radiation from the flame is considerably lowered. The theoretical explanation of the phenomenon is not well known. The elimination of smoke is probably due to a combined mechanical and chemical action of the water spray with the flame. From the mechanical standpoint, it is considered prob-

able that the impact of drops of sprayed water with the burning oil drops breaks up the latter and thus improves the atomizing of the oil. Moreover, there is probably a chemical reaction between the water and the oil yielding much lighter combustion products. In fact, with water injection, the flame obtained is very similar to that produced by burning natural gas. From the standpoint of the reduction of thermal radiation, as the water vaporizes it absorbs a relatively large amount of heat, and the vaporized water forms a protection against infrared rays. Further, it is possible that an endothermic reaction takes place between the water and the oil and thus lowers the temperature of the flame.

Be that as it may, tests have shown that the water injection method is particularly important. First of all, the water flow rate should be between 1 and 1.8 times the oil flow rate in volume. Without water injection, oil combustion produces a thick black smoke. On the other hand, with a water flow rate higher than 1.8 times the oil rate, a large amount of gray smoke with a water vapour base is let off. A water flow rate of the order of 1.2 times the oil rate yields in most cases a clear flame without any smoke.

The geometry and the kinetic energy of the water spray is such that substantially all the water penetrates deeply into the flame but does not go through it. Accordingly, the water supply pressure should be sufficiently high, of the order of 300 psi for example, and a suitable type of nozzle must be used. Each spray of water must be suitably directed, must have a small opening angle and must be made of water drops of given dimensions. The fact that the water droplets must penetrate deeply into the flame implies an appropriate drop size. Very finely sprayed water, obtained for example by means of compressed air, produces an ineffective cloud of water which is practically vaporized whereas too coarse a water spray falls like rain and entrains the oil drops with it, forming an oil slick on the water therebelow. In order for all the water to penetrate into the flame, the spray or opening angle of the spray, that is the angle defined by the spray, must be sufficiently small so that all the water converges toward the flame. It is also necessary for the angle between the axes of symmetry of the water sprays and the flame respectively, to be sufficiently small so that the droplets do not go through the flame. During tests, optimum conditions were obtained with water sprays having an opening angle of about 15°, the respective axes of symmetry of the water sprays forming an angle of about 7—8° with the axis of symmetry of the flame, and the nozzle sprays consisting of water with a diameter of the order of one millimeter.

Referring again to Figures 1 and 2, the burner assemblies 10a, 10b and 10c are mounted on a frame 11 composed, for example, of a square base 15 at the corners of which are fixed two rear uprights 16 and two front uprights 17 shorter than the rear uprights 16. A front upright 17 is shown cut away in Figure 1 to illustrate the water injection system 14a. An intermediate horizontal support is fixed to the upper end of the front uprights 17 and to an intermediate part of the rear uprights 16. This intermediate support is composed of three side members 20, 21 and 22 connected by means of three cross members 23, 24 and 25 perpendicular to the side members. The upper ends of the rear uprights 16 are connected by means of an upper cross member 26 in the middle of which is perpendicularly attached an upper side member 27 whose front end is itself attached to the cross member 25 by a central upright 28. The burner assembly 10a is attached under the intermediate support and the burner assemblies 10b and 10c over this support by means of right-angle brackets and bolts (not shown). Such a frame, of relatively small dimensions, allows easy disassembly of the upper burner assemblies 10b and 10c for transport.

Wheels 30 are mounted on the exterior of the base 15 and can move on a circular horizontal rail or track 31 attached to the end of a beam of square section and indicated generally at 32. This beam 32, which can be about 50 feet long, for example, allows the apparatus to be mounted on the side of a drilling platform beyond the outline of the platform in order to reduce heating of platform equipment. The beam 32 is of conventional construction with angle-irons and other structural members chosen in accordance with the force to be supported. The wheels 30 allow the apparatus to rotate around a vertical axis 33 for suitable positioning in relation to the direction of the wind. The rotation of the apparatus may be remote-controlled, even during production tests, by means of cables (not shown) or the like.

The atomizer 12a has a cylindrical form around an axis 34a which also forms the axis of symmetry of the flame. The atomizer 12a comprises an oil admission tube 35a arranged coaxial with this line and an air admission tube 36a arranged radially. The atomizer 12a, which will be described in greater detail below, is designed to produce a jet of sprayed oil along the axis 34a. The cylindrical shroud 13a, open on both ends, is mounted coaxially with the atomizer 12a, and therefore with the axis 34a, the rear face of the shroud being substantially within the plane of the front face of the atomizer. The shroud is preferably made of a refractory sheet metal and is designed to stabilize the flame of the oil jet. In fact, turbulences are

produced at the outlet of the atomizer and have the effect of moving back the burning oil drops which constantly ignite the oil jet near the outlet of the atomizer 12a. Also a pilot fitting 37a (Figure 2) fixed under the atomizer may be supplied with gas in order to provide a continuous pilot flame capable of reigniting the oil jet in the event of flame extinction due, for instance, to the momentary production of incombustible fluids.

The water injection system 14a includes a tubular ring 40a mounted around the front end of the shroud 13a and equipped with a plurality of nozzles 41a regularly spaced around the ring 40a, the ring being connected to a water admission tube 43a (Figure 1) at its lower part. As shown in Figure 4, each nozzle 41a includes a tube 10 with a central bore 71 and threads 72 and 73 at each end. A cap 74 is screwed into the outer end of the tube 76 and has a central orifice 75 as shown. A counterbore 76 is formed in the outer end of the tube 70, and the radial arms 77 of a flow needle 78 are trapped between the cap 74 and the end wall of the counterbore in order to fix the needle centrally within the flow path through the nozzle. A nozzle constructed as shown in Figure 4 is an example of a type of nozzle that will form a water spray having the proper spray- or opening-angle of about 15°. Each nozzle is symmetrical about an axis, such as that indicated at 42a which coincides with the axis of symmetry of the respective water spray produced by the nozzle, and the axes of the nozzles all converge toward the axis 34a.

As shown in Figure 3, the spray of atomized oil extends outwardly in front of the atomizer head 12a and burns along and about the axis of symmetry 34a in a generally cone-shaped flame, the flame front being about one foot ahead of the atomizer outlet. The line 38 may be considered as lying in the outer surface of the cone and therefore defining the path of travel of the outermost oil drops. In a typical example, the spray- or opening-angle of the oil spray cone, that is the angle defined by the oil spray, is about 15°. The axis of symmetry 42a of the water spray, also cone-shaped, converges toward the axis 34a and forms a small angle with the latter, the angle being less than about 15° and preferably 7° to 8°. Each nozzle, supplied through the tube 43a and the ring 40a, is arranged to project a slightly flared spray of water whose mean direction, which will usually be the axis of symmetry 42a, converges toward the axis 34a and whose opening angle is relatively small so that the outer water drops, that is to say those drops whose trajectory forms the smallest angle with the axis 34a converge toward the line 38. In other words, the half value of the water spray- or opening-angle is smaller than

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the angle formed by the line 42a and the line 38 along which the outermost oil drops are travelling. In this way, practically all the projected water penetrates into the flame of the burning oil. By way of further example, the parts in a typical embodiment are sized such that the axes of symmetry 42a of the water sprays intersect the axis of symmetry 34a of the oil spray at a point A that is located about 11 feet in front of the front face of the atomized head 12a. On the other hand the paths of travel of the innermost water droplets intersect the axis 34a at a point B that is located about 6.5 feet to the front of the outlet of the atomizer head 12a. In the geometrical arrangement shown in Figure 3, the angle between the line 38 and the axis 42a is about 14.5° which satisfies the condition that the half-value of the opening angle of the water spray be no greater than this angle. Of course it will be appreciated that the spray opening angle could be opened up somewhat to the neighbourhood of 28°—30° and still have substantially all of the water droplets moving toward the flame.

Referring again to Figures 1 and 2 the oil, air and water supply of the burner assemblies 10a, 10b and 10c takes place through a multiple rotation joint 45 mounted in the beam 32 along the vertical axis 33. This rotating joint has three fixed parts 46, 47 and 48 communicating respectively with three mobile parts 50, 51 and 52 in an intercalated arrangement. A pipe 53 carrying the oil coming from the well is connected to the fixed part 46. Two other pipes 54 and 55 respectively supplying water and air under pressure are connected to the fixed parts 47 and 48 of the rotating joint. The mobile part 50 is connected via a tube 56 to a distributing joint 57 that is connected via three pipes to the respective oil admission tubes 35a, 35b, and 35c. Two of the pipes 58a and 58b can be seen in Figure 1 and the pipe leading to the upper right hand burner assembly is not shown but may be visualized as extending upwardly and to the left of the joint 57 when viewed from the rear. The mobile part 51 is connected via a tube 60 to a distributing joint 61 that is connected to the water admission tubes 43a, 43b and 43c. The mobile part 52 is connected via a tube 63 to a distributing joint 64 that is connected to the air admission tubes 36a, 36b, and 36c of the atomizers. The water pipe 54 is equipped with a flow control valve 66 allowing water flow to be varied. This control is however not necessary if an adjustable flow pump is available.

If desired, a water spray screen may be set up between the burner assemblies and the equipment of the drilling platform. This water screen is obtained for example by means of a horizontal tube 67 fixed by suit-

able means on an intermediate part of the beam 32 and equipped with nozzles 68 directed in a vertical plane upward and downward. However, in general, this screen is not essential owing to the reduction in thermal radiation obtained by the injection of water into the flame. The burner assemblies 10a, 10b and 10c are mounted on the frame 11 so that their flame axes form an angle of about 10°, the lower flame axis being substantially horizontal. Two of the flame axes, namely 34a and 34b are indicated in Figure 1 and it will be appreciated that the flame axis for the burner assembly 10c projects slightly upwardly and to the left when viewed from the rear of the assembly as shown in Figure 2. Thus the respective sprays of atomized oil directed along the axes 34a, 34b and the axis of the atomizer 12c are directed in diverging directions.

Referring to Figures 5, 6 and 7 a detailed representation of one of the atomizers, 12a for example, is given. This atomizer includes a cylindrical body 80, having a bore 81 open toward the front end of the body. The body 80 also has, toward the rear end thereof, a transverse wall with an internally threaded opening 82. The opening 82 is designed to receive the oil admission tube 35a. The body 80 also includes, at the rear of the bore 81, a circular recess 83 designed to receive a mechanical atomizer head 84 of cylindrical shape which leaves between its outer surface and the bore 81 and annular chamber 85. Toward the back, the mechanical atomizer head 84 has a series of inclined passages 86 which bring the opening 82 into communication with the annular chamber 85 and, toward the front, it has passages 87 bringing the annular chamber 85 into communication with a bore 90 cut coaxially in the mechanical atomizer head 84. These passages 87, tangential to the bore 90 as shown in Figure 6, impart a rotary movement to the oil coming from the annular chamber 85 thereby creating a mechanical spraying of this oil.

A part 91 of approximately conical form bears against the mechanical atomizer head 84 and holds it in the axis of the body 80. The conical part 91 includes a central converging opening 92 and a peripheral recess 93 cut on its outer surface and designed to receive an O-ring seal 94. Downstream of the conical part 91, the body 80 includes an air inlet connection 95 having a radial passage 96 threaded at its outer end. On the front end of the body 80 is fixed, by means of screws 97, a ring 98 which, with its rear face, the bore 81 and the front face of the conical part 91, forms an annular chamber 100. A convergent-divergent opening is made at the centre of the ring 98 and tangential passages 101 (Figure 7) are made at the back of this ring between the chamber 100 and the central opening. The convergent passages

101 give the air entering through the opening 96 of the form of jets impinging at a given angle on the oil leaving the opening 92. In this manner, a second atomizing effect is obtained by the impact of air jets on the oil.

5 In operation, the crude oil produced by a well during a production test is sent through the pipe 53 to the three atomizers 12a, 12b and 12c. Likewise, compressed air or
10 gas produced by the well, if there is a sufficient amount of this gas, is sent via the pipe 55 to the three atomizers. Furthermore, water under pressure is sent through the pipe 54 to the water injection devices. With the pilot
15 lights 37a, 37b and 37c previously ignited, for example by means of a conventional electrical device (not shown), the jets of sprayed oil are ignited, the flames being stabilized by the action of the envelopes or shrouds
20 13a, 13b and 13c. Water flow is then adjusted by means of the control 66 in order to obtain the clearest possible flame and the smallest amount of smoke. Such a device can burn about 10,000 barrels of oil per day at
25 medium pressure of about 35 psi and up to 15,000 barrels per day if the oil pressure is high. With very small oil flow rates, it is possible to disconnect two burners and to send all the effluent into the burner assembly
30 10a for example.

Tests on this burner have shown that the atomizing obtained by the air is greatest at low oil flow rates, whereas at high flow rates, it is the mechanical atomizing provided by the mechanical atomizer 84 which is greatest. In fact for high rates the air or gas supply can be eliminated without changing the combustion. The two systems are thus complementary in providing suitable atomizing
35 whatever the flow rate. Furthermore, it will be noted that the oil flow through the atomizer 12a takes place through large openings allowing the passage of relatively large solid particles. This feature is particularly
40 valuable, as mentioned above, when handling oil coming directly from a well. Such an atomizer is thus particularly well suited to the spraying of crude oil that may contain solid particles and have a wide range of
45 flow rates.

50 While a specific embodiment of the invention has been shown and described, it will be understood by those skilled in the art that certain modifications and variations, both in
55 form and detail, can be made. For example, an assembly having only one atomizer and associated water injection system can be utilized for low flow rate applications or where otherwise desirable in view of a particular application. Owing to the previously
60 described advantages and particularly to the elimination of smoke, the apparatus of the invention may be used for applications other than offshore production tests. Such a burner
65 can be of value for burning oil coming

from land wells and, in general, wherever quick disposal of liquid hydrocarbons is desired, for example when transport or storage would be dangerous.

WHAT WE CLAIM IS:—

1. A method of burning liquid hydrocarbons produced from a well during testing of the well, wherein an atomized spray of said hydrocarbons is formed and burnt to form a flame along the mean direction of said spray, and sprays of water droplets are injected into the flame in such a manner that substantially all of the water droplets penetrate into the flame but do not pass completely through it, the mean direction for each water spray forming an angle of less than 15° with the mean direction of the flame, and the half value of the opening angle of each water spray being no greater than the angle between the mean direction of the water spray and the line along which the outermost particles of burning hydrocarbons are travelling so that substantially all of the spray water enters the flame, whereby to reduce the production of smoke.

2. A method according to claim 1, wherein the angle between the mean direction of each water spray and the mean direction of the flame is substantially equal to 7° to 8°.

3. A method according to either of claims 1 or 2, wherein the droplets forming the water sprays have a diameter of substantially one millimeter.

4. A method according to any of claims 1 to 3, wherein the ratio of water flow volume to liquid hydrocarbon flow volume lies between 1 and 1.8.

5. A method of burning liquid hydrocarbons produced from a well during the test of the wells wherein an atomised spray of said hydrocarbons is formed and burnt to form a flame along the mean direction of said spray, and sprays of water droplets are injected into the flame in such a manner that substantially all of the water droplets penetrate into the flame but do not pass completely through it, the ratio of water flow volume to liquid hydrocarbon flow volume lying between 1 and 1.8, whereby to reduce the production of smoke.

6. A method according to any of claims 1 to 5, wherein the ratio of water flow volume to liquid hydrocarbon flow volume is substantially equal to 1.2.

7. A method according to any preceding claim, further comprising the step of adjusting the rate of water flow to obtain substantially the clearest possible flame with the minimum production of smoke.

8. Apparatus for use in burning away liquid hydrocarbons produced from an oil well during testing of the well, comprising an atomizer having means to receive liquid



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20 13a, 13b and 13c. Water flow is then adjusted by means of the control 66 in order to obtain the clearest possible flame and the smallest amount of smoke. Such a device can burn about 10,000 barrels of oil per day at
25 medium pressure of about 35 psi and up to 15,000 barrels per day if the oil pressure is high. With very small oil flow rates, it is possible to disconnect two burners and to send all the effluent into the burner assembly
30 10a for example.

Tests on this burner have shown that the atomizing obtained by the air is greatest at low oil flow rates, whereas at high flow rates, it is the mechanical atomizing provided by the mechanical atomizer 84 which
35 is greatest. In fact for high rates the air or gas supply can be eliminated without changing the combustion. The two systems are thus complementary in providing suitable atomizing whatever the flow rate. Furthermore, it
40 will be noted that the oil flow through the atomizer 12a takes place through large openings allowing the passage of relatively large solid particles. This feature is particularly
45 valuable, as mentioned above, when handling oil coming directly from a well. Such an atomizer is thus particularly well suited to the spraying of crude oil that may contain solid particles and have a wide range of
50 flow rates.

While a specific embodiment of the invention has been shown and described, it will be understood by those skilled in the art that certain modifications and variations, both in
55 form and detail, can be made. For example, an assembly having only one atomizer and associated water injection system can be utilized for low flow rate applications or where otherwise desirable in view of a particular application. Owing to the previously
60 described advantages and particularly to the elimination of smoke, the apparatus of the invention may be used for applications other than offshore production tests. Such a burner
65 can be of value for burning oil coming

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WHAT WE CLAIM IS:—

1. A method of burning liquid hydrocarbons produced from a well during testing of the well, wherein an atomized spray of said hydrocarbons is formed and burnt to form a flame along the mean direction of said spray, and sprays of water droplets are injected into the flame in such a manner that substantially all of the water droplets penetrate into the flame but do not pass completely through it, the mean direction for each water spray forming an angle of less than 15° with the mean direction of the flame, and the half value of the opening angle of each water spray being no greater than the angle between the mean direction of the water spray and the line along which the outermost particles of burning hydrocarbons are travelling so that substantially all of the spray water enters the flame, whereby to reduce the production of smoke.

2. A method according to claim 1, wherein the angle between the mean direction of each water spray and the mean direction of the flame is substantially equal to 7° to 8°.

3. A method according to either of claims 1 or 2, wherein the droplets forming the water sprays have a diameter of substantially one millimeter.

4. A method according to any of claims 1 to 3, wherein the ratio of water flow volume to liquid hydrocarbon flow volume lies between 1 and 1.8.

5. A method of burning liquid hydrocarbons produced from a well during the test of the wells wherein an atomised spray of said hydrocarbons is formed and burnt to form a flame along the mean direction of said spray, and sprays of water droplets are injected into the flame in such a manner that substantially all of the water droplets penetrate into the flame but do not pass completely through it, the ratio of water flow volume to liquid hydrocarbon flow volume lying between 1 and 1.8, whereby to reduce the production of smoke.

6. A method according to any of claims 1 to 5, wherein the ratio of water flow volume to liquid hydrocarbon flow volume is substantially equal to 1.2.

7. A method according to any preceding claim, further comprising the step of adjusting the rate of water flow to obtain substantially the clearest possible flame with the minimum production of smoke.

8. Apparatus for use in burning away liquid hydrocarbons produced from an oil well during testing of the well, comprising an atomizer having means to receive liquid



hydrocarbons from said well for forming an atomized spray thereof which may be burned in a flame along and about the mean direction of said spray, and a water injection system comprising a plurality of water spray nozzles for injecting sprays of water droplets into said flame in such a manner that the droplets penetrate into the flame but do not pass completely therethrough, said spray nozzles being aligned so that the mean direction of each spray of water droplets forms an angle of less than 15° with the mean direction of said flame, the half value of the opening angle of each spray of water droplets being no greater than the angle between the mean direction of the water spray and the line along which the outermost particles of burning hydrocarbons are travelling so that substantially all of the droplets enter said flame.

9. Apparatus according to claim 8, further including means for mounting said spray nozzles in an annular array about said flame so as to project sprays of water droplets from all around the base of the flame.

10. Apparatus according to claim 8 or 9, further including shroud means mounted coaxially of said atomized spray of liquid hydrocarbons and adapted to produce turbulence in air flow in a region adjacent to the outlet of said atomizer to improve the mixing of said atomized spray with air and wherein said water spray nozzles are mounted in an array around the downstream end of said shroud means.

11. Apparatus according to claim 10, wherein said shroud means is cylindrical.

12. Apparatus according to claim 10 or claim 11, further comprising an annular water supply tube arranged about the downstream end of said shroud means, said water spray nozzles being carried by said tube.

13. Apparatus for use in burning away liquid hydrocarbons produced from an oil well during testing of the well, comprising a plurality of atomizers arranged in a cluster and each having means to receive liquid hydrocarbons from the well for forming atomized sprays that are burned along and about the mean direction of each said spray and a water injection system associated with each atomizer, each water injection system including a plurality of water spray nozzles for injecting sprays of water droplets into the respective flame in such a manner that the droplets penetrate into the flame but do not pass completely therethrough, said nozzles being aligned such that the mean direction of the respective spray of water droplets forms an angle of less than 15° with the mean direction of the respective flame, the half value of the opening angle of each spray of water droplets being no greater than the angle between the mean direction of the spray and the line along which the outermost

particles of burning hydrocarbons of the respective spray are travelling so that substantially all of the water droplets enter the respective flame.

14. Apparatus according to claim 13, wherein the mean direction of a first atomized spray of liquid hydrocarbons is directed substantially horizontally and the mean directions of the other of said atomized sprays are directed to diverge outwardly from said mean direction of said first atomized spray.

15. Apparatus according to claim 13 or claim 14, wherein a shroud means is associated with each said atomizer and each of said shroud means is adapted to produce turbulence in air flow around the outlet of its respective atomizer to improve the mixing of said atomized sprays with air.

16. Apparatus according to claim 15, further including an annular water supply tube arranged around the downstream end of each shroud means, said plurality of nozzles for each water injection system being attached to the respective water supply tube.

17. Apparatus in accordance with any of claims 8 to 16, further comprising flow control means for adjusting the rates of flow of water to said water spray nozzles.

18. Apparatus according to any of claims 8 to 17, wherein said atomizer, or each of said atomizers, further comprises means to impart a rotary movement to said liquid hydrocarbons to improve the atomization thereof.

19. Apparatus according to claim 18, wherein said atomizer or each of said atomizers further comprises means to impinge a gaseous fluid under pressure on said hydrocarbons further to improve the atomization thereof.

20. Apparatus according to any of claims 8 to 19, further comprising a frame wherein said apparatus is mounted and a beam adapted for attachment to the side of a drilling platform and means for mounting said frame on said beam for rotation about a vertical axis.

21. Apparatus according to claim 20, further including a multiple rotatable header joint aligned with said vertical axis and adapted to receive liquid hydrocarbons and to supply said hydrocarbons to said atomizer or to each said atomizer and to receive water and to supply said water to said water injection nozzles.

22. Apparatus in accordance with any of claims 8 to 21, further comprising means for providing a generally vertically directed water screen to provide a protection against the back radiation of the burning hydrocarbons.

23. Apparatus for use in burning away liquid hydrocarbons produced from an oil well during testing of the well, comprising: atomizer means adapted to receive liquid hydrocarbons from the well and having a

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5 plurality of openings to form a corresponding plurality of atomized sprays that are directed in diverging directions and burn away in an open air region in front of said atomizer means; and a plurality of water injection spray nozzles for injecting sprays of water droplets into the burning hydrocarbons in such a manner that the water droplets penetrate into the burning hydrocarbons but do not pass completely through them, to assure substantially smokeless combustion of the liquid hydrocarbons.

15 24. Apparatus according to claim 23, further including means for directing air towards the atomized sprays of liquid hydrocarbons to stabilize them, which air mixes with the atomized sprays of liquid hydrocarbons to promote combustion thereof.

20 25. Apparatus according to claim 24, wherein the air flow directing means comprises shroud means, in the form of ducting whose interior serves to direct said flow of stabilizing air, the water injection spray nozzles being mounted on piping means which is in turn mounted around the exterior of the ducting.

26. Apparatus according to any of claims 23 to 25, wherein said atomizer means and said water injection spray nozzles comprise an assembly, and further including boom means adapted to attach said assembly to the side of an oil well drilling platform.

30 27. Apparatus according to claim 26, further including means for mounting said assembly on said boom for rotation about a vertical axis to allow said assembly in use to be selectively pointed in a down-wind direction.

35 28. A method for burning liquid hydrocarbons produced from a well during testing of the well, the method being substantially as herein described.

40 29. Apparatus for use in burning away liquid hydrocarbons produced from an oil well during testing of the well, the apparatus being substantially as herein described with reference to the accompanying drawings.

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