

HYDROCARBON INDUSTRY SERVICING FLUID AND METHODS OF PERFORMING SERVICE OPERATIONS

FIELD OF THE INVENTION

5 The present invention relates to a hydrocarbon industry servicing fluid and methods of performing service operations. The invention also relates to an irradiation system and methods of treating fluids in hydrocarbon industry applications. In general, the invention relates to the use of irradiation, such as ultraviolet light, to disinfect fluids, including water. More particularly, the present invention relates to hydrocarbon industry applications where irradiation
10 may be used to disinfect fluids, instead of treating fluids with chemical biocides or using untreated fluids.

BACKGROUND

In hydrocarbon industry applications, such as offshore pipeline pre-commissioning procedures and well fracturing operations, servicing fluids including seawater and fresh water
15 may be left untreated or may be rendered biologically inert by treating the fluids using chemical biocides.

In offshore pipeline applications, a water-based servicing fluid may be used to flood the pipeline during installation or to flood and hydrostatically test the pipeline once installed. During installation, the pipeline is laid on the seabed and then flooded with seawater, or in the
20 case of alloy pipelines, fresh water. Once a pipeline is flooded, subsea connections can then be made. In particular, divers or remotely operated vehicles (ROVs) physically open the pipeline and connect it to a wellhead, subsea template, or riser system, for example. When making subsea connections to an alloy pipeline, it is undesirable for the seawater to contact the inner pipeline surfaces because seawater may corrode the pipeline. Therefore, the alloy pipeline is
25 flooded with fresh water that includes a slug of gelled water at each end. As such, when the

end of the pipeline is opened up for subsea connections to be made, the gel barrier prevents seawater from ingressing into the pipeline and mixing with the fresh water. After all subsea connections are made, additional water is pumped into the pipeline to hydrostatically test the structural integrity of the pipeline and any connected components. Once installation and testing
5 are complete, the water contained within the pipeline is displaced and, in some cases, disposed of to sea.

At any point where water is being introduced into the pipeline, whether in the flooding stage or in the hydrostatic test stage, this water is typically filtered and treated with a chemical biocide to disinfect the water. The purpose of such treatment is to prevent bacteria and
10 biological growth from causing damage to the pipeline internal surface. However, due to environmental laws and regulations, seawater used for hydrostatic testing in a number of locations, such as the Gulf of Mexico, cannot be disposed of to sea if it contains any chemical biocides. Therefore, untreated seawater is used, which permits organic growth in the pipeline, which may constrict and/or corrode the pipeline. This can have a detrimental effect on the
15 available flow rates of the pipeline once in service. Although discharge of water containing chemical biocides is still permitted in other parts of the world, many countries are beginning to follow the lead of the Gulf of Mexico by prohibiting the discharge of chemical biocide treated water to sea because such discharge may harm marine life. Therefore, a need exists for a fluid treatment method that complies with environmental requirements and is not harmful to marine
20 life if discharged to the ocean.

Chemical biocides are also used during pre-commissioning procedures for pipelines installed onshore. Disposal of water containing chemical biocides on land is also prohibited in some environmentally sensitive regions of the United States. In regions where no prohibitions exist, disposing of water containing chemical biocides is still undesirable in that it may harm

wildlife and contaminate underground water. Therefore, a need exists for an alternative, environmentally friendly method of disinfecting fluid.

Fluids treated with chemical biocides are also used in well bore servicing operations, such as fracturing a formation, for example. These operations are often conducted in remote locations where water is scarce and must be transported to the well site, which is costly. Typically, the water is filtered and treated with chemical biocides to prevent bacterial growth during transportation and/or storage. In a fracturing application, a gelling agent and other constituents are added to the water prior to injection into the well bore. However, gel may act as a food source for any bacteria present in the fluid. Thus, if bacteria is present in the base water, the bacteria will eventually destroy the gel and negatively impact the fracturing operation. Hence, the water is generally disinfected with chemical biocides before its use in the fracturing operation.

Once the fracturing operation is complete, flowback fluid recovered from the well bore may be stored in man-made tanks or lined pits, but it is not disposed of to land due to the chemical biocides. This flowback fluid containing chemical biocides is typically not remediated for re-use or disposal because such remediation of the fluid using chemical treatments, for example, is cost prohibitive. Instead, the flowback fluid is generally removed from the well site for proper treatment and disposal. Specifically, proper disposal of fluids containing biocides requires removal of the biocide before the fluid can be returned to the environment.

Due to the scarcity of water in many remote locations, and the cost associated with transporting water to and from these well sites, it would be beneficial if formation fluid produced from the well could be used, or flowback fluid could be reused following a service operation. However, treatment of formation fluid and flowback fluid to remove bacteria is

necessary for the success of many operations, such as fracturing. Hence, a need exists for a cost effective method of disinfecting produced fluid and flowback fluid for reuse in a well bore servicing operation, or for disposal to the environment.

SUMMARY OF THE INVENTION

5 In one aspect, the invention relates to a hydrocarbon industry servicing fluid comprising an irradiated fluid that is biologically inert. The irradiated fluid may be irradiated via exposure to ultraviolet light and may comprise a volume of fresh water, seawater, formation fluid, flowback fluid, or a combination thereof. The hydrocarbon industry servicing fluid may further comprise other constituents. In various embodiments, the hydrocarbon industry servicing fluid
10 comprises filling fluid, cleaning fluid, hydrostatic testing fluid, flooding fluid, flushing fluid, preservation fluid or fracturing fluid.

In another aspect, the invention relates to a method of performing a hydrocarbon industry service operation with an irradiated fluid that is biologically inert. In an embodiment, the fluid is irradiated with ultraviolet light. In various embodiments, the hydrocarbon industry
15 service operation comprises injecting the irradiated fluid into a well; fracturing a formation; flooding a pipeline, hydrostatically testing the pipeline, or both; or filling, cleaning, hydrostatically testing, flushing, preserving, or a combination thereof. The method may further comprise disposing of the irradiated fluid to the environment or capturing the irradiated fluid when the service operation is complete. In an embodiment, the method further comprises re-
20 irradiating the captured irradiated fluid to produce a remediated fluid, and performing a service operation with the remediated fluid.

In another aspect, the invention relates to a method of rendering a hydrocarbon industry servicing fluid biologically inert without using chemical biocides. In another aspect, the present disclosure relates to a method of rendering a hydrocarbon industry servicing fluid

biologically inert comprising irradiating at least one constituent of the hydrocarbon industry servicing fluid to produce an irradiated fluid. The irradiating may comprise exposure to ultraviolet light. In various embodiments, the at least one constituent comprises a volume of fresh water, seawater, formation fluid, flowback fluid, or a combination thereof. The method
5 may further comprise filtering at least one constituent either before or after irradiating, or injecting other constituents into the irradiated fluid. In an embodiment, the method further comprises performing a hydrocarbon industry service operation with the hydrocarbon industry servicing fluid. The hydrocarbon industry service operation may comprise filling, cleaning, hydrotesting, flushing, preserving, or a combination thereof; and may be conducted within a
10 pipeline; or within a hydrocarbon processing, storage or transport facility; or within a well bore. The method may further comprise disposing of the hydrocarbon industry servicing fluid to the environment by releasing or injecting the fluid.

In another aspect, the invention relates to a method of irradiating a used hydrocarbon industry servicing fluid to produce a remediated fluid that is biologically inert. In various
15 embodiments, the method may further comprise performing a hydrocarbon industry service operation with the remediated fluid; storing the remediated fluid; re-irradiating the remediated fluid; injecting other constituents into the remediated fluid; and/or disposing of the remediated fluid to the environment, which may be performed by releasing or injecting the fluid.

In another aspect, the invention relates to a fluid treatment system comprising an
20 irradiation apparatus, inlet piping directing an untreated fluid into the irradiation apparatus, outlet piping directing an irradiated fluid out of the irradiation apparatus, and a connection to a hydrocarbon industry application. In various embodiments, the fluid treatment system may be portable, the irradiation apparatus may comprise an ultraviolet light device, and a filter may be disposed along the inlet piping or the outlet piping. In various embodiments, the fluid

treatment system comprises at least one pump, at least one valve that directs the irradiated fluid into the hydrocarbon industry application or into a disposal line, and/or a re-treatment line that directs the irradiated fluid into the irradiation apparatus. In an embodiment, the hydrocarbon industry application comprises a pipeline, a processing facility component, a storage facility component, a transportation facility component, or a well. In another embodiment, a hydrocarbon industry application comprises the fluid treatment system.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more detailed description of the present invention, reference will now be made to the accompanying drawings, wherein:

Figure 1 is a flow schematic of a representative pipeline operation employing an irradiation system to disinfect seawater, fresh water or another fluid;

Figure 2 is a flow schematic of a representative well servicing operation employing an irradiation system to disinfect fluid to be used in a fracturing operation; and

Figure 3 is a flow schematic of a representative well servicing operation employing an irradiation system to remediate formation fluid or flowback fluid, either for re-use in another servicing operation or for disposal.

NOTATION AND NOMENCLATURE

Certain terms are used throughout the following description and claims to refer to particular assembly components. This document does not intend to distinguish between components that differ in name but not function. In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to ...".

As used herein, each of the terms "disinfect" and "remediate" mean to render biologically inert. Hence, to disinfect or remediate water, for example, means to render the water biologically inert by killing the micro-organisms in the water.

As used herein, the term "pipeline" includes any line in which fluid is moved, including
5 any onshore or offshore flow system, such as mainline systems, risers, flow lines used to transport untreated fluid between a wellhead and a processing facility, and flow lines used to transport treated fluids.

In the drawings, the arrows indicate the direction of fluid flow through the system in a sequential operation.

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DETAILED DESCRIPTION

Various embodiments of apparatus and methods for treating a fluid for use in hydrocarbon industry applications will now be described with reference to the accompanying drawings, wherein like reference numerals are used for like features throughout the several views. There are shown in the drawings, and herein will be described in detail, specific
15 embodiments of irradiation systems and methods of using such systems to disinfect fluid, with the understanding that this disclosure is representative only and is not intended to limit the invention to those embodiments illustrated and described herein. The embodiments of fluid treatment methods and irradiation systems disclosed herein may be utilized in any type of hydrocarbon industry application, operation, or process where it is desired to disinfect fluid,
20 including, but not limited to, pipeline operations; well servicing operations; upstream exploration and production applications; and downstream refining, processing, storage and transportation applications. It is to be fully recognized that the different teachings of the embodiments disclosed herein may be employed separately or in any suitable combination to produce desired results.

Figure 1 schematically depicts a representative pipeline operation 100 utilizing an irradiation system 110, such as an ultraviolet light treatment apparatus, to render the fluid 120 biologically inert. The fluid 120 may be seawater, fresh water, or another fluid, and preferably comes from a readily available source, such as a river or the ocean. In one embodiment, the pipeline operation 100 comprises a lift pump 150, an irradiation system 110, filters 130, a pipeline fill pump 160, and a pipeline 140. The filters 130 may comprise any type of filtering apparatus to remove particles from the fluid 120, such as a sock type filter where the fluid 120 flows through a filtering insert that collects particles or any other filter as described herein. The lift pump 150 and the pipeline fill pump 160 may be any type of pump suitable for moving the fluid 120 through the irradiation system 110, filters 130 and pipeline 140. The pipeline 140 may be constructed of carbon steel, an alloy, or any other material suitable for the pipeline pre-commissioning operation 100. The pumps 150, 160, the irradiation system 110, and the filters 130 may be containerized with other flow equipment and regulation instrumentation and mounted on a skid, thereby making the entire apparatus portable. In an embodiment, the skid mounted equipment is electrically powered and may be operated using generators in remote locations.

As represented by the flow arrows, the lift pump 150 transports the fluid 120 through the filters 130, into line 180, and then into the irradiation system 110, where the filtered fluid is disinfected. The purpose of disinfection is to kill micro-organisms in the fluid 120. In an embodiment, the irradiation system 110 comprises an ultraviolet light apparatus, such as a UV-disinfection system available from HOH Water Technology A/S of Denmark, for example. The irradiation system 110 causes the deactivation of micro-organisms, thereby effectively disinfecting the fluid 120. In an embodiment, the filters 130 remove a significant quantity of debris and biological material from the fluid 120 upstream of the irradiation system 110,

thereby enhancing the treatment process. In particular, the ultraviolet light source within the irradiation system 110 should penetrate through a filtered fluid more effectively than through a debris-laden fluid, and some removal of biological material upstream of the irradiation system 110 should enhance the efficiency of the irradiation treatment. In contrast to untreated fluids, such as water, irradiated fluids do not as readily corrode the wall of the pipeline 140. Further, as compared to using chemical biocides, disinfection by irradiation is more cost effective and also produces an environmentally safe fluid for disposal to the environment. After exiting the irradiation system 110, the irradiated and filtered fluid in line 185 is then transferred by the pipeline fill pump 160 through line 190 and into the pipeline 140 for use in pipeline operations, such as filling and testing procedures, for example. Once the pipeline operations are complete, the fluid exits the pipeline 140 through line 195 where the fluid may be disposed of to the environment 170 without harm thereto.

One of ordinary skill in the art will readily appreciate that the representative pipeline operation 100 of Figure 1 may be performed offshore or onshore, and may include different components than the ones shown in Figure 1. The pipeline operation 100 may involve pre-commissioning the pipeline 140, such as during installation and testing, or post-commissioning operations, such as a repair or replacement procedure. Although Figure 1 shows the fluid 120 passing first through the filters 130 and then through the irradiation system 110, the relative position of these treatment devices may be reversed. For example, the fluid 120 may be first irradiated and then filtered.

In another hydrocarbon industry application, the irradiation apparatus 110 may be used to remediate produced fluid, which includes formation fluid or flowback fluid produced during well fracturing or other servicing operations. Such remediated fluid may be reused as a well bore servicing fluid, or may be disposed of to the environment. While the following discussion

of Figure 2 and Figure 3 focuses on well fracturing, it should be understood that the present disclosure may be used to treat water for use in any well bore servicing fluid, or to treat such fluids themselves as needed to disinfect same.

Figure 2 schematically depicts a representative well bore servicing operation 200
5 utilizing the irradiation apparatus 110 to disinfect or remediate fluid supplied from a readily available source as an alternative to using trucked-in water treated with chemical biocides. The water 210 from a readily available source may be fresh water, seawater, or formation water. Formation water includes water produced from a well on site, which may be the same or different well from that being serviced. In an embodiment, this water 210 could even comprise
10 trucked-in water that has not been treated with chemical biocides. The well bore servicing operation 200 comprises a lift pump 150, filters 230, the irradiation apparatus 110, a valve 260, storage 290 for gel and other fracturing fluid components, an injection pump 295, a service pump 285, and a well bore 280 within which a servicing operation is being conducted, such as fracturing, for example.

15 The filters 230 may comprise a variety of different types of filters, depending upon the requirements of the operation, including sock type filters, boron removal filters, micron particle filters, activated charcoal filters, and/or another type of filter to make the fluid 120 suitable for a well fracturing operation. In one embodiment, the filters 230 comprise the filtering system depicted and described in U.S. Patent Application Serial Nos. 11/062,963 and 11/063,307, both
20 filed on February 22, 2005, and both entitled "Devices and Processes for Removal of Impurities from a Fluid Recovered from a Subterranean Environment", assigned to Halliburton Energy Services, Inc., also the assignee of the present application. Pumps 150, 285, and 295 may be any type of pump suitable for moving the fluid 210. Valve 260 may be any type that is operable to direct fluid flow and that is compatible with the fluids in the well bore servicing

operation 200. As in the pipeline operations 100 shown in Figure 1, the pumps 150, 285, 295; the filters 230; the irradiation apparatus 110; and the valve 260 may be containerized with the connecting piping and other flow regulation equipment and instrumentation and mounted on a skid, thereby making the entire apparatus portable. In an embodiment, the skid mounted
5 equipment is electrically powered and may be operated using generators in remote locations.

As depicted, the water 210 from a readily available source is conveyed through the filters 230 by the lift pump 150. The filtered water in line 240 then passes through the irradiation apparatus 110, where it is disinfected. The filtered and irradiated fluid in line 250 then passes through a valve 260 where it may be diverted into a re-treatment line 255 or
10 continue on through line 265 to the fracturing operation in the well bore 280. The filtered and irradiated fluid in line 265 is injected with gel and other fracturing fluid components from storage 290 via injection pump 295, resulting in a fracturing fluid entering line 270. The service pump 285 then injects the fracturing fluid from line 270 into the well bore 280 to conduct the fracturing operation. It should be understood that other servicing fluids can be
15 made in a like manner, and the additives injected via pump 295 may be selected accordingly.

Because water is often scarce at remote well site locations, it may also be desirable to re-use the flowback water produced by the well fracturing or other servicing operation. Figure 3 schematically depicts a representative remediation operation 300 utilizing the irradiation apparatus 110 to disinfect flowback fluid with the option to re-use the remediated fluid or
20 dispose of it. The remediation operation 300 comprises a lift pump 150, filters 230, an irradiation apparatus 110, a first valve 380, a storage tank 310, a second valve 330, an injection pump 295, storage 290 for gel and other fracturing fluid components, and a service pump 285.

The filters 230 may be of the same type, or a different type, as those used in the pipeline operation 100 or the well servicing operation 200 shown in Figures 1 and 2, respectively. The

storage tank 310 may be replaced by a lined pit or other fluid storage reservoir. Pumps 150, 285, and 295 may be of any type suitable for moving fluid and compatible with fluids in the remediation operation 300. Valves 330 and 380 may be any type of valve used to direct fluid flow and compatible with fluids in the remediation operation 300. Again, all or some of the components shown in Figure 3 may be containerized with other flow regulation equipment and instrumentation and mounted on a skid, thereby making the entire apparatus portable. In an embodiment, the skid mounted equipment is electrically powered, and may be operated using generators in remote locations.

When a fracturing operation is conducted in the well bore 280, flowback fluid 370 is produced comprising a mixture of formation fluid and fracturing fluid. The flowback fluid 370 is lifted out of the well bore 280 and conveyed through the filters 230 by the lift pump 150. Filtered fluid in line 240 then passes through the irradiation apparatus 110, where it is disinfected. The filtered and irradiated fluid in line 250 is then diverted by valve 380 to the storage tank 310 via line 390 or towards a second valve 330 via line 360. Fluid stored in the tank 310 may later be circulated through re-treatment line 320 and through the irradiation apparatus 110. The fluid diverted into line 360 is directed towards valve 330, where the filtered and irradiated fluid may be diverted through line 340 for disposal to the environment 350 or through return line 265 for re-use in the fracturing operation. Alternatively, instead of re-using the filtered and irradiated fluid at the same well site, this fluid may be hauled by truck or transported by another means for re-use at a remote well site. If diverted through line 340 for disposal, the filtered and irradiated fluid will be tested to ensure that it is environmentally safe before it is released to the environment 350, which may be a water source, *e.g.* river or lake; a land surface; or injected into a disposal well. If diverted through return line 265 for re-use, gel and other frac fluid components from storage 290 may be added to the irradiated and filtered

fluid in line 265 by the injection pump 295 to produce the frac fluid in line 270. The frac fluid is then injected by the service pump 285 to conduct the fracturing operation in the well bore 280.

Thus, where fluids treated with chemical biocides or untreated fluids previously may
5 have been used in a hydrocarbon industry application, such as pipeline pre-commissioning or well fracturing, for example, an irradiated servicing fluid may be used instead. Irradiation may be performed using a portable system comprising an irradiation apparatus 110. These portable systems may also be used at sites where fluids must be disinfected, but the use of fluids treated with chemical biocides is prohibited, either due to environmental concerns or cost or both.
10 Therefore, the irradiation apparatus may be sent to the location for any type of hydrocarbon industry application where it is desirable to disinfect fluid.

The foregoing descriptions of specific embodiments of hydrocarbon industry systems and applications utilizing an irradiation apparatus to disinfect fluids have been presented for purposes of illustration and description and are not intended to be exhaustive or to limit the
15 invention to the precise forms disclosed. Obviously many other modifications and variations of these hydrocarbon industry systems and applications are possible. In particular, the position of the irradiation system 110 could be varied. For example, the irradiation could be performed prior to the fluid entering the filtering stage, or the fluid may not require filtering at all. Also, the ultraviolet light treatment could be performed more than once, if necessary, with the use of
20 additional piping. The systems 100, 200, 300 could be arranged differently, and have more or less components.

Moreover, other hydrocarbon industry applications are possible. In particular, one of ordinary skill in the art will readily appreciate that the fluid treatment systems disclosed herein are equally suitable for disinfecting servicing fluids, or constituents thereof, for use in

applications such as refining and processing vessels, reactors and pipelines; production platform vessels and pipelines; storage applications, including land-based storage tanks and tanks provided on floating production storage and offloading facilities; and pipeline transportation stations and facilities, as well as other applications. Such disinfected servicing
5 fluids may be used for a wide variety of purposes, such as flushing out product and/or cleaning hydrocarbons from the walls of a vessel or pipeline, preserving a vessel or pipeline after cleaning, or filling a storage tank, for example.

While various embodiments of hydrocarbon industry applications utilizing irradiation to disinfect fluid, as a substitute for fluids treated with chemical biocides, or untreated fluids, have
10 been shown and described herein, modifications may be made by one skilled in the art without departing from the spirit and the teachings of the invention. The embodiments described herein are representative only, and are not intended to be limiting. Many variations and modifications of the invention disclosed herein are possible and are within the scope of the invention. Where numerical ranges or limitations are expressly stated, such express ranges or limitations should
15 be understood to include iterative ranges or limitations of like magnitude falling within the expressly stated ranges or limitations (e.g., from about 1 to about 10 includes, 2, 3, 4, etc.; greater than 0.10 includes 0.11, 0.12, 0.13, etc.). Use of the term "optionally" with respect to any element of a claim is intended to mean that the subject element is required, or alternatively, is not required. Both alternatives are intended to be within the scope of the claim. Use of
20 broader terms such as comprises, includes, having, etc. should be understood to provide support for narrower terms such as consisting of, consisting essentially of, comprised substantially of, etc.

Accordingly, the scope of protection is not limited by the description set out above but is only limited by the claims which follow, that scope including all equivalents of the subject

matter of the claims. Each and every claim is incorporated into the specification as an embodiment of the present invention. Thus, the claims are a further description and are an addition to the preferred embodiments of the present invention. The discussion of any reference in the Background section is not an admission that it is prior art to the present
5 invention, especially any reference that may have a publication date after the priority date of this application. The disclosures of all patents, patent applications, and publications cited herein are hereby incorporated by reference, to the extent that they provide representative, procedural or other details supplementary to those set forth herein.

CLAIMS

1. A method of rendering a hydrocarbon industry servicing fluid biologically inert comprising:

irradiating at least one constituent of the servicing fluid to produce an irradiated fluid,
and

injecting other constituents into the irradiated fluid.
2. The method of claim 1 wherein irradiating comprises exposure to ultraviolet light.
3. The method of claim 1 wherein the at least one constituent comprises a volume of fresh water, seawater, formation fluid, flowback fluid, or a combination thereof.
4. The method of claim 1 further comprising: filtering the at least one constituent either before or after irradiating.
5. A method of rendering a hydrocarbon industry servicing fluid biologically inert comprising:

irradiating at least one constituent of the servicing fluid to produce an irradiated fluid,
and

performing a service operation with the servicing fluid.
6. The method of claim 5 wherein the service operation comprises filling, cleaning, hydrotesting, flushing, preserving, or a combination thereof.
7. The method of claim 6 wherein the service operation is conducted within a pipeline.
8. The method of claim 6 wherein the service operation is conducted within a hydrocarbon processing, storage or transport facility.

9. The method of claim 5 wherein the service operation is conducted within a well bore.
10. The method of claim 5 further comprising: disposing of the servicing fluid to the environment.
11. The method of claim 10 wherein disposing comprises releasing or injecting the servicing fluid.
12. A method comprising: irradiating a used hydrocarbon industry servicing fluid to produce a remediated fluid that is biologically inert.
13. The method of claim 12 further comprising: performing a service operation with the remediated fluid.
14. The method of claim 12 further comprising: storing the remediated fluid; and re-irradiating the remediated fluid.
15. The method of claim 12 further comprising: injecting other constituents into the remediated fluid.
16. The method of claim 12 further comprising: disposing of the remediated fluid to the environment.
17. The method of claim 16 wherein disposing comprises releasing or injecting the remediated fluid.