PRODUCED WATER POLISHING: FILTRATION AND FILTER MONITORING SYSTEM PROMOTES COMPLIANCE DURING CONVENTIONAL TREATMENT UPSETS

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ABSTRACT

Conventional solids filtration followed by vessels containing oil-adsorbent media has proven an economical and operational viable method of maintaining compliance with Produced Water discharges. A patented, proprietary blend of media based on resin, polymer and clay technologies has been developed for this purpose. The adsorbent media "CrudeSorb®" is packaged in radial flow non-ferrous canisters which allow for quick media changeouts. A "Smart Canister®" has also been developed to continually monitor media absorption capacity and alert platform operators when the media is nearly spent. A "Smart Canister®" contains a unique embedded probe that electrically measures the rate of media adsorption and sends that information to a nearby alarm panel. When a predetermined probe signal is analyzed and confirmed by the alarm panel, an alarm notifies an operator that media replacement will soon be required. Typically, conventional produced water treatment systems installed offshore produce effluent with "free" oil and grease within permitted concentrations. However, system upsets caused by surges in production or mechanical / process failures can cause incidents of non-compliance.

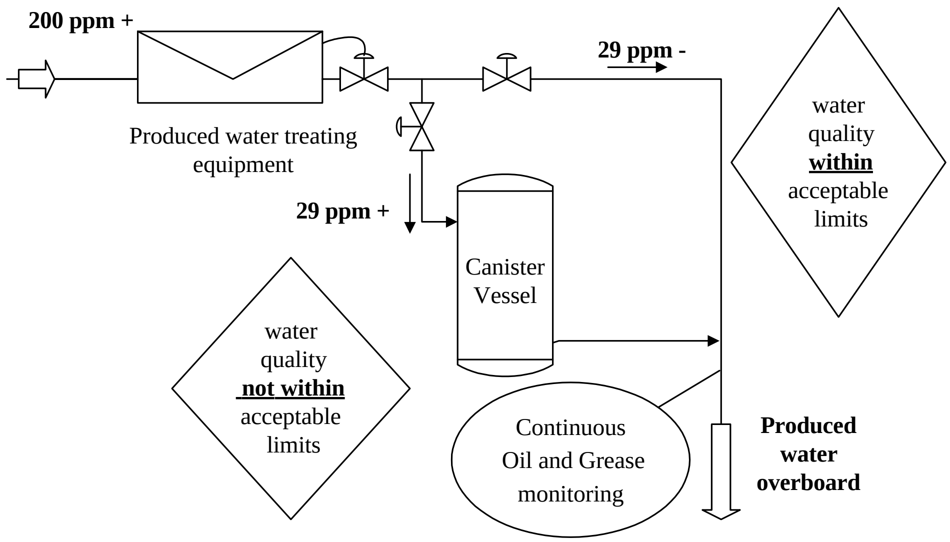
Whenever this condition occurs, the "Smart Canister®" polishing system will become operational, via manual or automatic interface, and prevent pollution and incidents of non-compliance.

Water Polishing Technology, a New Concept

Hydrocyclones, Induced Gas Flotation units, Sparging Columns and Skim Vessels normally produce effluent water quality that is within regulatory (oil, grease and toxicity) standards. However, surges in production, chemical upsets or equipment failure can create episodes where regulatory mandated effluent oil and grease levels will exceed permitted guidelines.

"Produced Water Polishing" is a new concept, applying a secondary treatment process to produced waters prior to final discharge overboard. Offshore operators monitor the effluent quality of their platforms primary treatment systems and intervene, either manually or automatically, before an incident of non-compliance occurs. Therefore, water polishing can be an intermittent process employed only as needed during upsets to prevent pollution.

The following schematic illustrates the process:

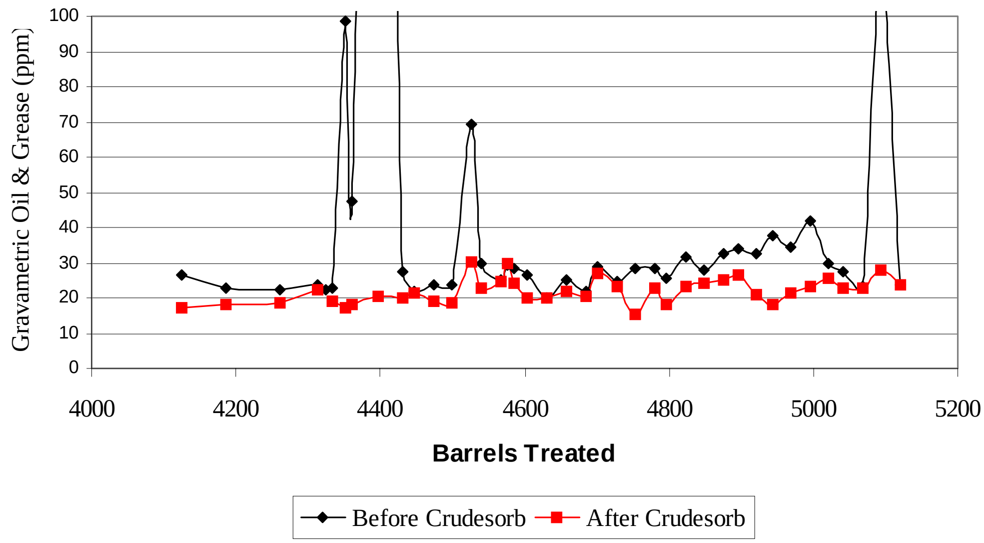


At Chevron’s Vermillion (VR) 214C structure, a continuous online oil and grease monitor determines when the effluent from the structures two sparging columns require polishing. Two 66 inch polishing vessels each containing ninety-two CrudeSorb® canisters provides capacity to polish 12,000 bpd of produced water.

On the Genesis Spar, also operated by Chevron, platform operators determine when effluent from the Spar’s sparging columns need to be polished. When required valves are manually switched to direct fluid into the Spar’s “Smart Canister®” polishing system which has the capacity to process 17,000 bpd of produced water.

When free oil and grease droplets are not the contaminants, but Water Soluble Organics (WSO) are the problem, continuous polishing may be required. Continuous Crudesorb® polishing removes the soluble organics that conventional treatment systems will not remove. On one offshore platform, a continuous polishing system removed WSO's typically down to the 10 ppm range. At this location, two 48 inch Crudesorb® vessels connected in series provided the capacity to polish up to 4300 bpd of produced water. The data in Graph 1, showing the results from four months of monitoring a Crudesorb® polishing system, clearly illustrates how effective this process can be in keeping platforms compliant.

Influent / effluent oil and grease data (acidified IR) are illustrated.



Graph 1.

The data shows that the Crudesorb® polishing system significantly reduced the concentration of oil and grease in the effluent. The three surges above 40 ppm shown in the polishing system influent (platform primary system effluent) were prominently adsorbed by the Crudesorb® media, thus keeping the platform discharge continually within full compliance

Polishing as treatment during maintenance or the commissioning of "new water treatment equipment" is also a very promising endeavor. This allows the platform to continue production while repairs or installations are completed. The highly adsorbent CrudeSorb® media, that is canisterized to facilitate easy handling, has proven to be very useful as a short-term treatment tool. For weeks or even months at a time, the CrudeSorb® polishing process was the only water treatment equipment used at Chevrons ST 52C, ST 151-Prod, ST 177E, and Shell platforms at EI 158C, URSA, and Tahoe. CrudeSorb® canisters provided the produced water treatment capacity during maintenance or when the structures water treatment system was in-operative or being commissioned.

Obviously, CrudeSorb® media will become fully adsorbed more quickly when used in this way, and will require more frequent changeouts, but few options exist when environmental compliance and continuing production is the objective.

The specially designed polishing vessel skids have a minimal footprint, can easily be deployed and can accommodate (when required), rapid replacements of the expendable Crudesorb® canisters.

Vessel Mechanics

The adsorption process is optimized through several design features incorporated into polishing vessels.

- Long term exposure to hot produced waters (150°F) generates minimal creep in canisters rated for much higher temperatures. In typical carbon canisters, creep has been shown to cause canister bypass. This occurrence has been virtually eliminated in the CrudeSorb® canisters by utilizing spring loaded sealing caps that apply a continuous load to the stack of canisters assembled over centralizing rods. Zero leakage of oil and grease has been achieved even at differential pressure values of up to 50 psi.

- Gravity separation is encouraged in polishing vessels; coalescence begins as oil droplets grow on each canisters exterior filter cloth. A large accumulation area at the top of each vessel serves to collect the coalesced oil droplets. The accumulated oil is purged from the vessel by a programmed or manual cycle. Entrained gases, which separate from the aqueous phase in the polishing vessels, also accumulate in this area but will be removed during the purge cycle.

- Radial headers (patent pending), which can be easily removed, serve as the foundation for all canister centralizing rods. These headers optimize vessel capacity and streamline vessel maintenance.

Solids Filtration and Chemical Treatment

Before produced waters make contact with the canisterized adsorption media, solids filtration becomes a key process component. Each platform varies as to the type and amount of solids mixed with produced water. Solids such as scale, sand, silt, clay and chemical flocculents must be removed by conventional mechanical filtration.

Chemical treatment to prevent paraffin build-up or scale deposits from coating mechanical filtration equipment, Crudesorb® canisters or polishing vessel internals must be employed.

"Smart Canister®" Technology

A "Smart Canister®" has also been developed to continually monitor media adsorption capacity and alert platform operators when the media is nearly spent. A "Smart Canister®" contains an embedded unique probe that electrically measures the media adsorption and sends that information to a nearby alarm panel. When a predetermined probe signal is analyzed and confirmed by the alarm panel, an alarm notifies an operator that a media change-out will soon be required. The "real time" predictive nature of this instrumentation allows an operator enough time to make the necessary decisions.

Typically, conventional produced water treatment systems installed offshore produce effluent with "free" oil and grease within permitted concentrations. System upsets caused by surges in production or mechanical / process failures can cause incidents of non-compliance. Whenever this occurs, the polishing system will become operational, either manually or automatically, to prevent pollution and incidents of non-compliance.

The Need for Instrumentation

Polished Water Systems (PWS) containing Crudesorb® canisters are usually placed on manned production platforms. Occasionally, it is necessary to install PWSs on unmanned platforms. In either case periodic manual effluent measurement, e.g. infrared or gravimetric extraction to determine oil and grease compliance is labor intensive and is "after the fact" data. On stream oil ppm analyzers are a suitable alternative option, especially suited for installations on unmanned platforms, but has economical drawbacks. Automation/supervisory control and data acquisition systems (SCADA) are now prevalent on many production platforms since these systems are very reliable and affordable. Remote monitoring of equipment operation such as status, alarms or data trending is universally accepted as the norm.

All of the aforementioned motivated an approval for a research and development program aimed at finding a feasible, economical method to instrument an expendable Crude- sorb® canister. The key feature of the program was to target a changing physical parameter, during the filtration process, that could be monitored by a transducer. The information from the transducer should be reasonably accurate and be able to interface to a monitor panel. The monitor panel would display status and alarm an operator that the media is nearly spent and the effluent oil ppm is close to noncompliance (currently at 29 ppm).

Research and Development Testing

Initial laboratory examination of the physical characteristics of the Crudesorb® media when exposed to flowing oily salt water resulted in the following:

- Measurement parameters such as mechanical particle compression or weight change would be difficult to implement and the resulting data probably would be very inaccurate.
- Electrical measurement of media conductance or resistance would be easy to implement, cost effective and should be relatively accurate.

Physical Characteristics

The patented Crudesorb® media is best described as small granules very similar to "cat litter". The Crudesorb® media initially is water binding or hydrophilic. However, when exposed to oil molecules, the chemically modified media characteristically changes to a hydrophobic state. When oily salt water (the oil may be dispersed or "free" or partially soluble or both) flows through the media, the oil molecules become adsorbed on the surfaces of the chemically modified media granules. As the oil molecules begin coating the surfaces of the media granules, the surrounding water molecules are displaced. During this process, the hydrophobic characteristic of the media is significantly increased. The electrically conductive bound water is literally squeezed out of the surface path of the media granules by oil molecules. Some physical swelling of the media also results from the adsorptive process. Ionic surface bonding and Van Der Waal forces hold the oil molecules to the media granules.

Ultimately, if the process continues, there is an adsorptive saturation point where the media undergoes a "change of state". The internal structures of the media granules begin collapsing and the collapsed granules bind one another into a nonporous oily saturated powder. At this point, the electrical conductivity is extremely low. However, Crudesorb® will never get to that stage during normal filtering applications because non-compliance oil ppm effluent levels would have been detected much earlier during the adsorptive process.

If a fixed voltage were applied to two small metal plates at a given distance apart in a known volume of Crudesorb® media during a hydrocarbon adsorptive process, the results would clearly demonstrate an increasing resistance proportional to adsorbed Crudesorb® media. Hypothetically, there should also be a strong correlation to oil PPM effluent.

Small canisters of Crudesorb® were constructed with embedded electrical probes for laboratory testing. Synthetic seas water(2-3% salinity) and in some cases actual produced water was thoroughly mixed with samples of crude oil. The oily water mixture was allowed to flow through the small Crudesorb® canisters. Steady state and bipolar voltages at various frequencies were applied to the test probes and monitored. Data analysis indicated a predictive characteristic curve of current and voltage versus Crudesorb® impedance. During this test phase no chemical oil ppm effluent data was taken. The hypothetical correlation between impedance, adsorption percentage and *oil ppm effluent* could soon be confirmed by further testing (see Fig. 1).

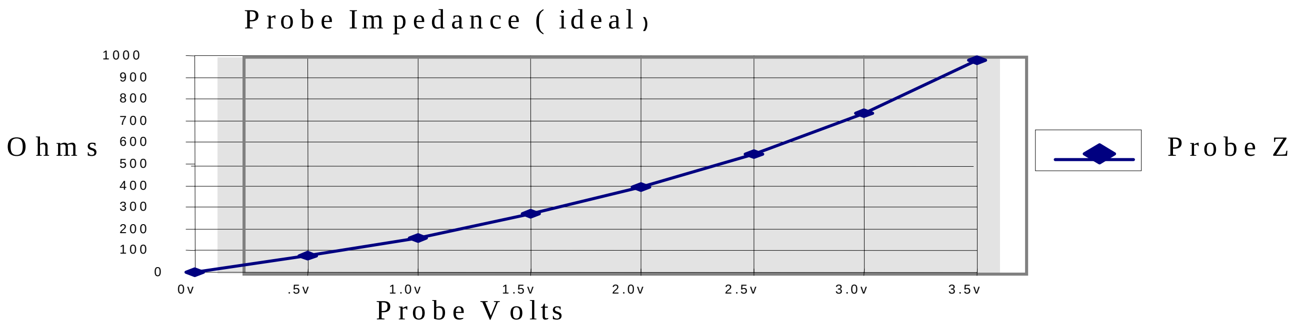


Fig. 1

To better understand the oil migration and adsorption density patterns of Crudesorb® media, after each test the small spent canisters were cut open and exposed to ultraviolet rays to observe the fluorescent oil patterns. The oil migration patterns indicated that the “small volume of adsorbed media sensed by the test probe” was a reflection of the adsorbed status of the total media volume in terms of radial location. This information would be valuable later in determining the physical probe location in the Crudesorb® canister.

A watertight, non-corrosive prototype probe was developed that would with stand temperatures up to 200°F. Long watertight-jacketed signal wires were affixed to the test probe. A large vessel was designed and fabricated to accommodate two production type 11 X 11-inch Crudesorb® canisters. One canister would have a probe and the other would be a dummy canister. The signal wires from the probe canister extended from the vessel and connected to laboratory test and measurement equipment. A test signal voltage was applied to the probe and then monitored. Oily water-same type and mixture used in the small laboratory canister tests was pumped into the vessel. The effluent would be chemically sampled at given periods for ppm oil. This test, which took a few days to complete, had comparable results to the laboratory small canister tests. At a point where the probe voltage indicated that the Crudesorb® should be adequately spent, an oil ppm measurement was extracted and indicated 18 ppm of oil. A second test with similar results was performed. The test results strengthened the correlation between media impedance and oil ppm effluent.

Each canister was cut open after testing and subjected to a fluorescent investigation. Oil migration patterns around and near the probe area were basically the same as the aforementioned small canisters. Field-testing would be the next validation phase for the "Smart Canister®".

Field Testing

Field-testing coordinated with Chevron USA. The Fourchon Chevron PipeLine Base was chosen as the test site. A two-canister vessel was fabricated. One Crudesorb® canister would be a dummy the other, a "Smart Canister®". The probe wires were connected to test equipment for signal generation and monitoring. Produced water was piped into the vessel. Effluent oil ppm measurements were periodically taken. Testing took several days. The results were as predicted for the voltage and media impedance data. Effluent oil ppm data showed a definite relationship to measurements of probe voltage (Fig. 2 and 3). Further field testing is now in progress.

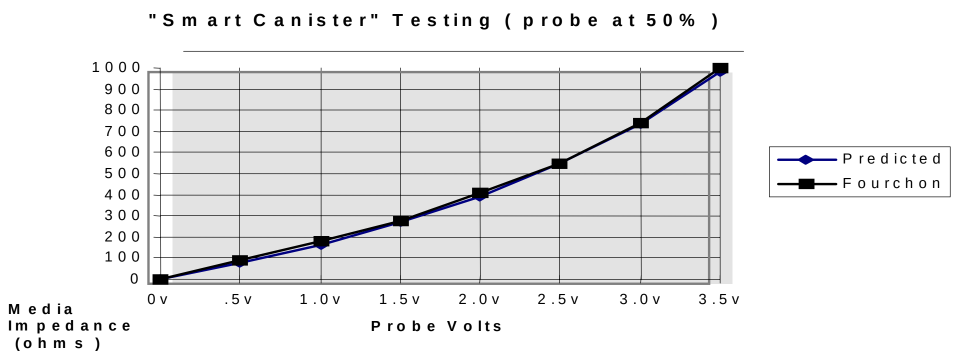


Fig. 2

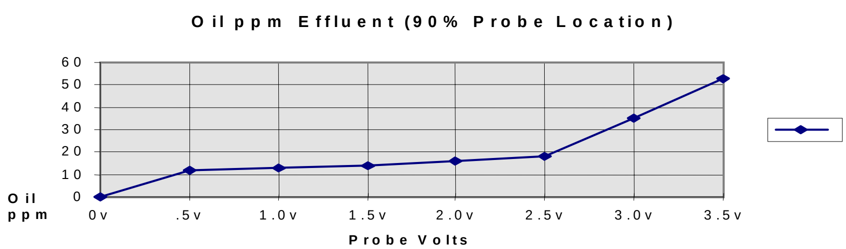
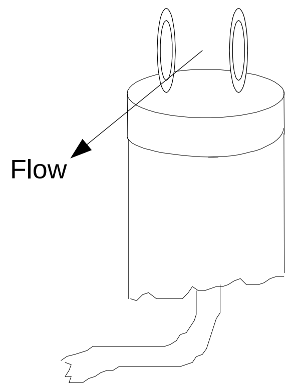


Fig.3

Probe and Alarm Panel Design

The expendable probe has three major parts, the body, probe tips and signal wire. The body is made from a durable, high temperature, chemically impervious, injection molded plastic compound. Probe tips are high-grade non-corrosive stainless steel and geometrically configured to optimize sensing when embedded in the Crudesorb® media. The flexible signal wires are encased in a high temperature, watertight PVC jacket. The interior probe body and exiting signal wire is sealed with a waterproof-potting compound. The probe body also has a seating adapter affixed for secure placement in the bottom of the "Smart Canister®".

Probe



The Alarm Panel

The alarm panel is a solid state design that provides the probe signal, signal conditioning, and probe signal evaluation and status/alarm indications. The current design will support two "Smart Canisters®". The alarm panel will normally be mounted on the polishing vessel skid. The input power is nominally 12VDC. The panel may be battery operated or adapted for solar power. Remote signal capability is available in the form of a dry contact closure or analog output (4-20ma). Short haul wireless transmission is another strong possibility. No electrical connection would be necessary if the alarm panel used battery/solar power and wireless transmission. The panel is designed to meet electrical intrinsic safety standards, but has not yet been submitted for agency approval (e.g., Underwriters Laboratory). The Alarm Panel will meet the electrical requirements of Class I, Division 2, Groups (A-D), since most locations where the panel will be operating are considered Class I, Division 2 hazardous locations. The second generation design of the alarm panel is called Guardian II.

Conclusions

After two years of laboratory and field-testing the "Smart Canister®", the following conclusions can be drawn:

- The Crudesorb® polishing system is a reliable, efficient method to assure regulator compliance.
- Use of the Crudesorb® media allows the platform operator to meet compliance and maintain production.
- There is a predictive relationship between Crudesorb® media impedance when adsorbed and probe voltage signal levels.
- That the correlation to probe signal voltage levels and effluent oil ppm exists and probably is predictable within a respectable accuracy range.
- Assuming that the radial flow mixture of oily water (free oil and/or partially soluble) is relatively uniform: that the ad sorbed media sensed by the probe, at a given location, will reflect the adsorbed status of the total media volume at the same radial location throughout the "Smart Canister®".
- A "Smart Canister®" installed in a polishing vessel with other Crudesorb® canisters can be used to alert an operator that the media is sufficiently adsorbed to a point that the effluent oil ppm level is close to non-compliance.

- That an alarm/monitor panel can be designed to interface with a “Smart-Canister®” to replace the laboratory test and measurement equipment.