# "Produced Water Monitoring: Performance Improvements"

By: Gary Bartman, Turner Designs Hydrocarbon Instruments, Fresno, CA

**24th Annual Produced Water Society Seminar**
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# Produced Water Society 2014 Seminar

"Produced Water Monitoring:  Performance Improvements"

**Abstract:** Continuous on-line monitoring of oil concentration in produced water for discharge and process improvement has proven to be of great value if the monitors can be maintained. Without exception, maintenance is the biggest hurdle to successful continuous on-line produced water monitoring. There are plenty of schemes on the market – some work, some do not, but none have proven to be universally successful. This paper explores the rediscovery of simple proven solutions for improved performance and lower maintenance using standard industry practices. The inspiration for this paper came from a number of people who have broad experience with cleaning systems in heavy industry and others who have specific experience with simple cleaning methods for the maintenance of our monitors.

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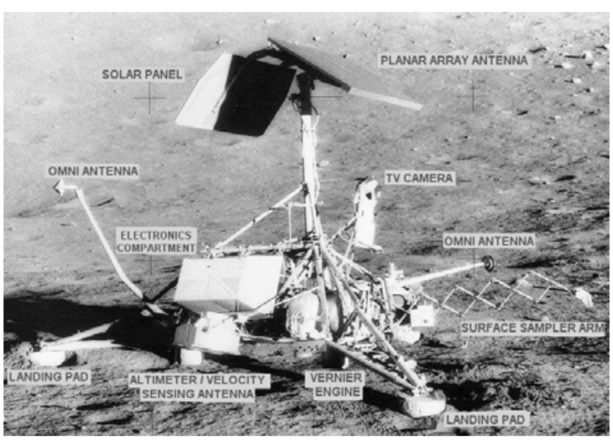
I was inspired to write this paper by a number of people who have broad experience with cleaning systems in heavy industry and others who have specific experience with simple cleaning devices to maintain our monitors such as I will describe below. There are people in this industry and in this forum who have employed similar clean in place systems for their instruments in these and other tough applications. In fact, clean in place systems are everywhere. Why not use them?

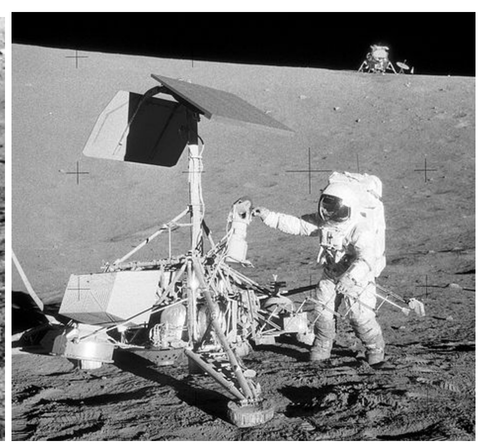
If you ask any user of continuous oil in water monitors they will tell you the biggest problem is maintenance. This paper will explore the reasons for those maintenance problems along with the evolution of cleaning systems. But know this: There is no magic pill that will keep every system clean. The challenge is to find the combination of tools.

First, it is important to explore the reasons for oil in water monitor reliability complaints. Is the problem related to actual instrument electronic or mechanical failure? Or, is the problem that the instrument will not make the measurement? Or, is it that the instrument works as specified, makes the measurement, but cannot be kept clean?

**Electronic Failure:**

In today's world, there is no excuse or reason that an electronic device should fail prematurely if designed properly for the environment and application. There are plenty of manufacturers that have been supplying ruggedized designs and components for all levels of electronics for several generations. We put soft landers on the Moon 47 years ago in 1966 – 1968 with only two failures out of 7 systems. My Dad was a Program Manager for Hughes Aircraft at the time.



Hughes Moon Surveyor 1966 Pete Conrad Apollo 12 visits Surveyor 1969

Electronic reliability should be standard. Examples: We have just completed the second servicing of generation one monitors stationed along the Danube River in Austria. Those instruments were installed in 1994 and operate 24/7 with only minor maintenance such as lamp changes twice a year. A customer in the Gulf of Mexico reports zero electronic failures with any of our instruments including installations as early as 1999.

Quote from operator in the Gulf of Mexico: "Just remember that this monitor was purchased in 1999, moved and re-installed 3 times and is still working with no failures other than the fouling of the sample line which has been corrected. That's reliability, to me."

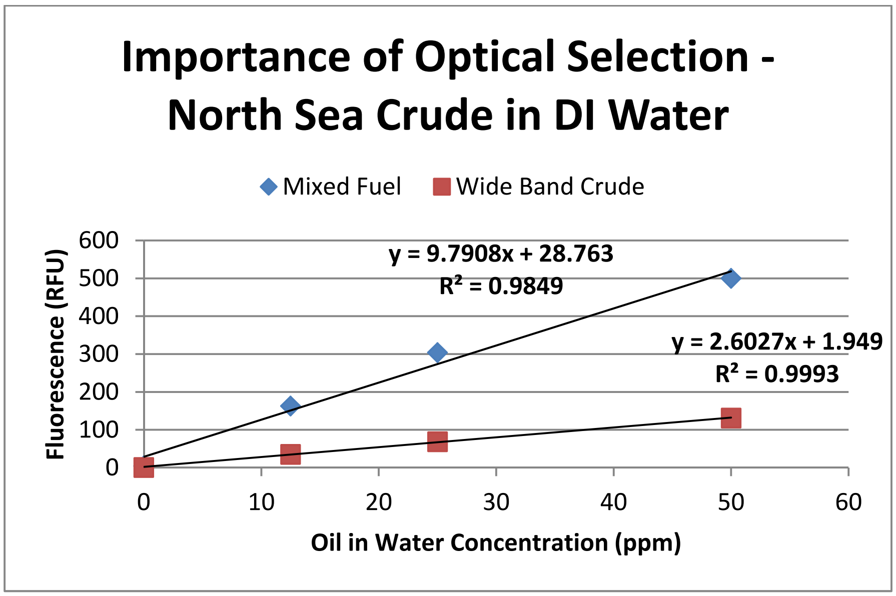
In local oilfields in California there are two important installations with a total of 10 instruments with only 3 minor electronic component failures since they began installation over seven years ago. That is a total of 64 operating years with only three failures and none during the first 12 month warranty period.

**Failure to make the measurement**

With the many technical papers we have published about the capabilities of fluorescence and the large body of science on fluorescence measurement of hydrocarbons, there should be no reason that a properly set up fluorometer would not make the measurement in produced water applications provided that the target substance can be measured with fluorescence. Usually, the problem is not the electronics of the instrument or the failure to make the measurement. Usually, the problem is in the maintenance of the sample delivery system and the components in contact with the water.

On a side note, if the instrument is not properly set up for the target oil(s) the data may lead to the wrong conclusion. For instance, several years ago, in Norway, a produced water operation was having trouble getting good results with a certain type of fluorescence analyzer. It was thought that the instrument was not sensitive enough to changes in concentration for the process. After some experimenting, ultrasonic homogenization was tried with better results. It was thought that the oil in larger droplet form was not providing enough signal to the analyzer. With much smaller droplets as would be generated via ultrasonic homogenizing, the analyzer showed much higher sensitivity to changes in concentration. This technique had been in practice since the '70's with light scatter instruments as a way to equalize the droplet size to get more accurate readings in bilge water analyzers. This technique is still used today on the US Navy's ET 35N bilge alarm system and others. However, it is our experience that homogenization is only important when measuring very low concentrations of heavy oil or where the signal from the oil is low compared to the natural background signal from water soluble organics in the water. The same result can be accomplished using mild surfactant injection. However, it is our opinion that the real problem in the Norwegian test was an incorrect optical system. The homogenization conclusions derived from the experiment were correct for the specific optical system installed but an optimized optical system may have given better results and negated the need for homogenization.

As an example, the data below shows the relative response of two different optical systems with oil in water from the Brage platform in Norway. The two plots show the difference in slope from two commonly used optical filter kits. Lower slope means less response to change in concentration. As you can see, the best choice for maximum sensitivity is the upper slope.




## Failure to keep optics clean

### Full optical surface in contact with oily water:

In the beginning, (and yes, I was there) the main contender in the market was light scatter and there was some experimenting with fluorescence for oil in water measurement. Portable instruments normally used for dye tracing were also used for detecting hydrocarbons in drill cuttings (Texaco QFT Method). Light scatter instruments were used for ships' bilge water monitoring and some companies stretched their use to more dirty water industrial and produced water applications.  These simple devices used the same light scatter principle as turbidity monitors.  The theory is that particles of oil larger than about 5 microns scatter the light in a way that can be measured by optical sensors.  In order to get steady readings, the water was contained in a glass tube (flow cell) where the measurement was made.  The glass tube was in constant contact with the dirty water and the biggest complaint was the inability to keep them clean.  Attempts to keep them clean included wiper type devices such as a simple plunger.  I have been on ships where it was the duty of several individuals to hit the manual plunger each time they walked by the monitor.  The users of these systems were not so much concerned about making the measurement, just going through the motions of keeping them clean.

Plunger for light scatter cell cleaning on bilge monitor.

When we first started in the business 20 years ago at the original Turner, we decided that the only way to be successful in the oil in water / dirty water measurement business was to have a non-contact falling stream flow cell.  Once we convinced the market to use fluorescence, our success in the early years was specific to our ability to convince people that the non-contact falling stream was a better way.  We designed a few prototypes and combined it with our experience with fluorescence and the TD-4100 with falling stream flow cell (photo of first units in production) was born.

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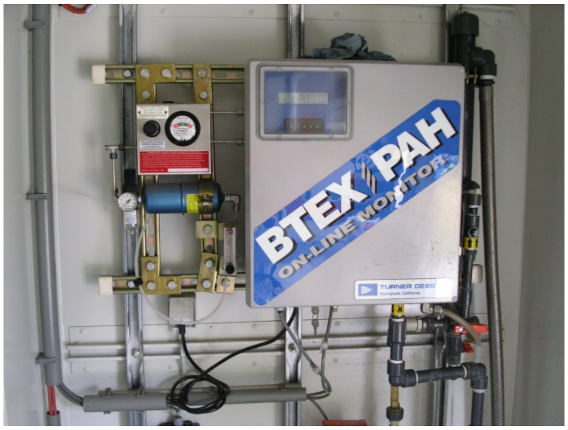
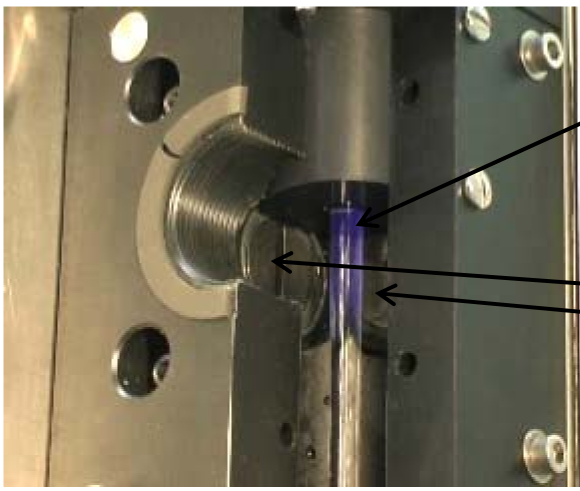



First production run of TD-4100's with falling stream flow cell installed in 1994 in Austria



First Generation Falling Stream Flow Cell. Water flows via gravity.

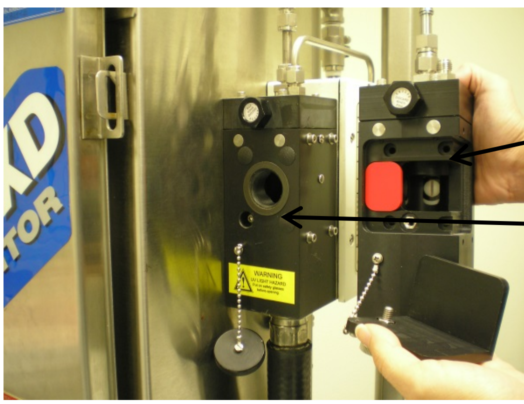
Optical Windows ½" back

The first Turner continuous on-line monitors carried the same circuitry as the original Model 10-Au Fluorometer which became the QFT mud logging portable fluorometer we made for Texaco (still manufactured today).

QFT Mud Logging Fluorometer courtesy of Turner Designs Inc.

Of course, the TD-4100 was housed in an industrial IP 65 enclosure that could be purged for hazardous areas. Now, despite what others in business have said, we did not steal the falling stream design. In fact, over the years, there have been many falling stream designs for various measurement purposes. The oldest that I know of was a fluorescence falling stream developed 40 years ago in 1974 – 1976 by Baird Atomic under contract with the US Navy in an attempt to improve the bilge water monitoring systems that were traditionally light scatter technology.  As far as we know, there were two systems built for the Navy and later the technology was sold to a company who is no longer in business.

The design of the falling stream flow cell requires the optical windows be a safe distance back from the falling water to help prevent splashing but not so far back that sensitivity is lost.  Our latest EZ Access Flow cell optical windows are about ½” back from the falling stream of water.



EZ Access Flow Cell with falling stream.

Original Flow Cell with falling stream

Falling stream flow cells require a constant pressure head above the flow nozzle to keep the sample stream a consistent shape and the nozzle must be kept clean and clear of obstructions.  Further, entrained gas must evolve out before it exits the nozzle or splashing will contact the windows.  However, if the head is constant and the nozzle is kept clean and with a de-gassed sample, they will perform perfectly for years without maintenance even with high vibration and the pitch and roll of shipboard operations.  In our early designs we found that a simple air stream over the windows kept the optical glass from fogging with high temperature sample water.  We called it an “air curtain” and we still use it today in our EZ Access falling stream flow cells.

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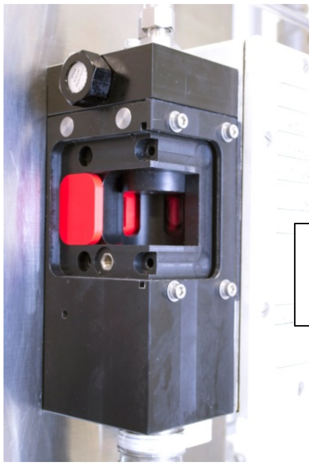
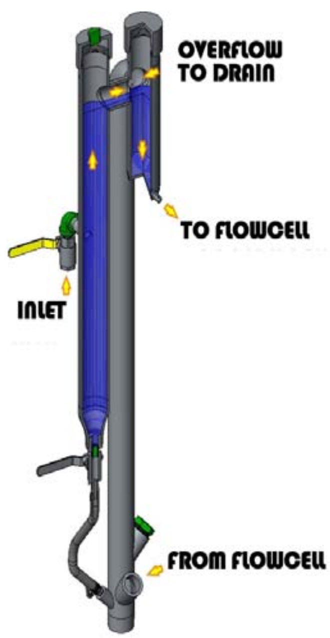


EZ Access flow cell installed with cover removed

In the early years, we experimented with constant head tanks that were placed above the flow cell to provide both constant head pressure and a method to degas the sample at atmospheric pressure. A valve was employed between the constant head tank and the flow cell to prevent the head tank from draining down unexpectedly from stopped or reduced flow to the head tank. If the tank drained down, the reduced head pressure (driving force) would cause irregular flow in the flow cell and potential splashing on the optical windows.




Bubbletrap provides constant head to flow cell for falling stream applications.

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Our operational procedures dictated that the operator shut off the flow to the flow cell before shutting off the main flow to the head tank but rarely, if ever, did they do that. We then designed in an Auto-Valve (valve actuator) that automatically shut off the flow to the flow cell when the sample pressure to the sample system dropped below 5 psig. The Auto-Valve reduced the maintenance considerably but there still remained the issue of keeping the sample lines and sample system clean. The constant head tank we now use is called a "bubbletrap" and consists of a constant overflow weir to provide the constant head of about 12" of water with a flow rate of about 1 lpm. Note that there are other falling stream flow cell systems on the market that have been deployed without the benefit of the constant head tank and Auto Valve. And, in some competitive events, projects have been won by offering a lower price without the benefit of a constant head / bubbletrap hardware.


Original bubbletrap with manual valve

Same bubbletrap with Auto-Valve helps prevent splashing on the optical windows

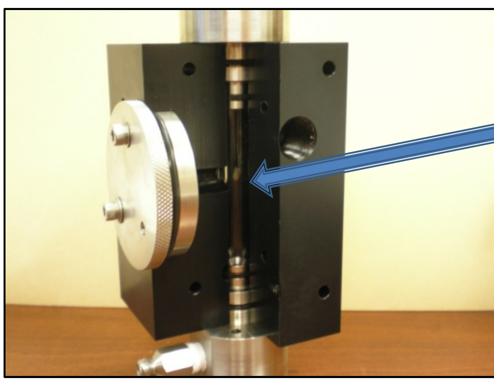
**Field Validation**

All operators and those who specify on-line monitoring instruments for produced water should insist on a way to validate instruments in the field. All of our continuous on-line monitors as well as our bench top and hand held monitors use a device called the "CheckPOINT" to validate the stability and operation of the device. The CheckPOINT provides a simple and adjustable fluorescing element which when introduced to the light path provides instant confirmation / validation of the operation of the monitor.

In spite of the Bubble-Trap Constant Head System and Auto-Valve, operators still had problems keeping the systems clean. A better way had to be employed.

**Closed Flow Cell:**

In 2005 after more than 11 years of selling against closed constant contact flow cells, we developed our "C" type closed flow cell due to market demands for monitoring high quality steam condensate where oxygen introduction could not be tolerated. There were additional benefits to the closed cell because the flow rate was considerably less and the sample could be returned to the process under pressure without pumping. However, we were determined that we would not introduce a C type flow cell without a system to monitor the condition of the light path meaning the condition of the glass flow cell. Therefore, our C type flow cells all have Cell Condition Monitors installed that alert the operator when the cell needs cleaning.



"C" type closed flow cell with quartz tube

Next, we determined that, like our other products, we needed a way to validate the condition of the monitor at any time while in service. We then added in a liquid injection port that allows the operator to inject a water soluble dye into the port to provide a standard and repeatable signal to the detector. This check standard is called a CheckPOINT and is used the same way our solid CheckPOINT standards are used in the rest of our products. We also decided we would not sell the constant contact C type flow cell for dirty water applications without a means to keep it clean. Our first big contract for the C type flow cell included several units for steam condensate. Despite our best efforts, the EPC contractor insisted on the C flow cell for the produced water applications to eliminate H2S exposure and to maintain commonality between monitors. We pressed the EPC contractor to specify and purchase on board cleaning systems for the produced water applications but to date (>6 years), they have not been used. (They did not want to pay extra for an automated system). Further, the cleaning system only cleaned the sample lines and valves on the monitor skid and did not address the sample line coming from the process.


Manual valves not user friendly do not get used!!

Continuous on-line oil in water monitor with self - cleaning system did not address the inlet sample line.

Turner Designs Hydrocarbon Instruments' Ultrasonic Cleaning System

After several years of experiments, along came ultrasonic cleaning as the "end-all" for keeping flow cells clean. As stated above, ultrasonic systems for homogenizing the sample had been used for many years in light scatter instruments to provide uniform oil drop size for more consistent bilge water monitoring (US Navy ET 35N bilge alarm).

By now, most users of ultrasonic cleaning systems have discovered that ultrasonic cleaning is not the final answer and they can be very expensive to repair / replace especially in hazardous areas. High energy ultrasonic systems in direct contact with the optical surfaces can cause erosion and mechanical damage. Plus, keeping the flow cell clean is only half the battle. The rest of the battle is in keeping clean the sample lines and any sample conditioning system attached to it. There are plenty of monitors with ultrasonic cleaning installed that are reading nothing due to plugged sample lines. And, yes, we have our own ultrasonic cleaning system so we can answer bid requests from EPC contractors but we know it is not the ultimate answer for continuous monitoring.

**To review the sequence of events:**

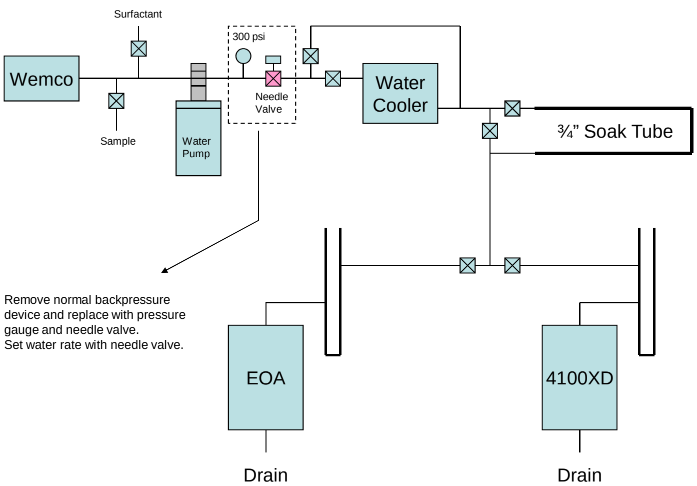
- Constant contact optical flow cells had the market with light scatter oil in water monitors,
- Falling stream non-contact flow cells became popular and took over the job of monitoring from the constant contact closed cells,
- Customers discovered the falling stream works continuously if the lines are kept clean but because of plugging of the sample lines, perfectly good monitors went dormant and became orphans.
- Then, constant contact optical systems came back on the market with the great hope that mechanical cleaning systems like ultrasonics would win the business with the promise of no maintenance.
- We now have an ultrasonic cleaning solution but we know from more than 3 years of experiments with ultrasonic cleaning that it is a tricky business and does not provide a universal solution.

**Early Alternate: Chemical Injection into the Sample Line**

A direct chemical injection into the sample line can prove valuable in keeping lines and sample systems clean. However, keep in mind that continuous chemical into the overboard line may not be allowed, even in low concentrations and volumes.

In other applications onshore a simple surfactant drip into the sample line at the sample take off point has provided little or no maintenance to our first generation closed cell type instruments for more than 7 years. The original concept was developed by Dr. Dale Brost while at Texaco. He used a cocktail of surfactant and acetic acid in constant dose rate into the sample line to provide enhanced signal to the Texaco EOA fluorometer, which he also developed. He discovered that with very heavy crude, the requirement to measure very low concentrations of oil in the produced water (1 - 2 ppm), and with a high background signal from water soluble organics, a small dose of surfactant would emulsify the heavy oil droplets into smaller particles. The smaller particles enhance the fluorescence signal of the oil over the WSO's. The added benefit was that the sample system stayed clean. (See photo below).

As mentioned above, in similar applications with inorganic fouling, a constant low dose of acid in the sample line keeps it clean.  Again, the choice of chemical is dependent on the chemistry requirements for the type of fouling.




Early surfactant system in California enhances oil signal, maintained clean sample lines.

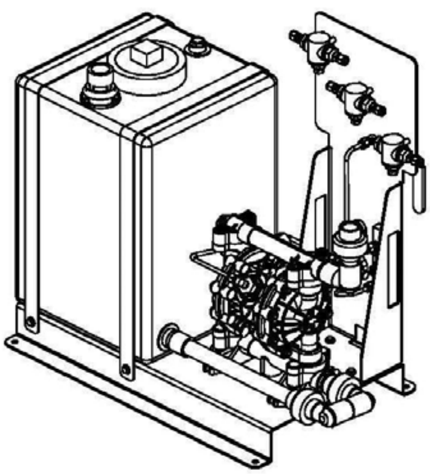
Clean tubing after several months of running. 12˚API in produced water.

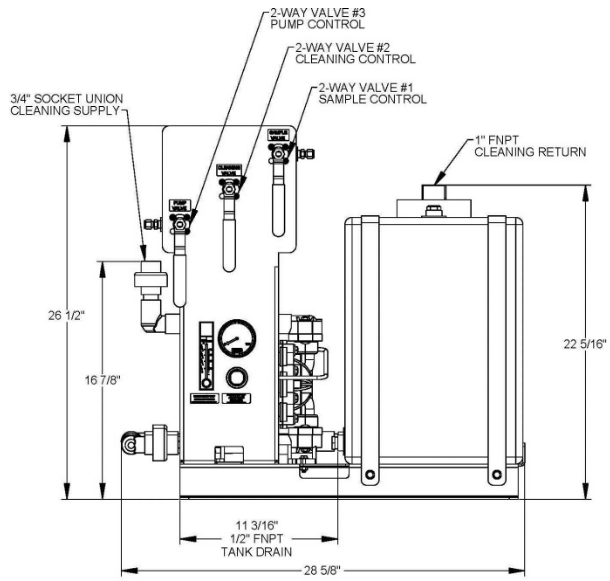
**Development of the Clean in Place System (CIP)**

CIP is used universally for pipe and process cleaning in pharmaceuticals, dairy and all sorts of food processing industries and for cleaning heat exchangers in refineries and offshore facilities.  Many of the facilities represented by the people in this room may have used CIP.  The CIP is a simple system which uses chemicals in a closed loop to flush out and dissolve deposits in the tubing and fittings.  The chemicals used and the frequency of cleaning are specific to the application.  The chemicals can range from plain water to simple surfactants to biocides, acids and other aggressive cleaning chemicals.  The type of chemical and its strength will depend on the character of the water and the type of foulants.  Assistance in choosing the correct chemical can come from the facility chemical representative who is probably already using the needed chemical in other places on the site.  In most systems the cleaning chemical is circulated in a closed loop and back to the supply tank without discharge to the environment. The cleaning chemical can be reused over and over until it becomes ineffective.

A system such as this has been successfully deployed on a platform in the Gulf of Mexico using a small 10 gal tank, pump, valves and fittings and with a once per week flush of the system, there has been no other maintenance on the monitor since March 2013.

We recommend the CIP be used for the entire sample system from the sample take off through the instrument and flow cell measurement cell.






FRONT

Simple CIP with diaphragm pump, pneumatic remote actuated valves, very easy to automate.

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CIP in service in GOM offshore

The example above is of a simple CIP system employed offshore in the Gulf of Mexico on a platform that has an iron sulfide fouling problem. Iron sulfide in the sample lines, bubble trap and flow cell caused extra maintenance including removing parts and fittings and cleaning with acid. In a similar situation, hydrochloric acid was employed on a constant drip basis but the operators wanted to avoid the potential for unwanted chemicals in the discharge line. The CIP system was installed in March 2013 with the chemical tank filled to the 50% point with Apex Engineeing's Rydlyme® biodegradable de-scaler http://www.apexengineeringproducts.com/ Apex and others make biodegradable cleaning chemicals for CIP systems. For specific application details and assistance in choosing the correct chemicals, contact Apex or your chemical representative.

In the cleaning process, the sample system is first, drained down to the main sample drain, then the valves shift position and the pump starts pumping the Rydlyme around the system for a period of about 10 minutes with the waste returning to the supply tank so that no chemicals enter the overboard line. The time required is dependent on the type of foulants. Then, the residual cleaning chemical is drained back into the chemical tank for reuse. In the months since installation in March, the operators report as follows: "Unit is used once per week for 10 minutes and as of December 17th the Rydlyme has yet to be refreshed. And, very little maintenance is required on the monitor except to check the optical windows".

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There are many CIP systems on the market. Apex also makes portable and fixed clean in place systems and there are others such as Goodway and major players such as Alfa Laval and GEA.


Goodway portable CIP

Rydlyme portable CIP

GEA CIP Unit

Alfa Laval CIP 20 and Alfa Laval CIP 40

**Cleaning in Place unit for heat exchangers**

A problem frequently encountered in almost all applications is the build-up of deposits on heat transfer surfaces. Alfa Laval supplies a wide range of cleaning agents suitable for removing most of these troublesome deposits and restoring performance to optimal levels. The time-consuming work of opening plate heat exchangers can thus often be avoided by using an Alfa Laval Cleaning in Place (CIP) unit.

Alfa Laval CIP units are available in a wide range of standard sizes, with optional extras that include reversible flow and explosion-proof capabilities. Alfa Laval CIP units can be used for all types of heat exchangers, including spiral heat exchangers, shell-and-tube heat exchangers and gasketed, welded and brazed plate heat exchangers.

Alfa Laval portable CIP for heat exchangers

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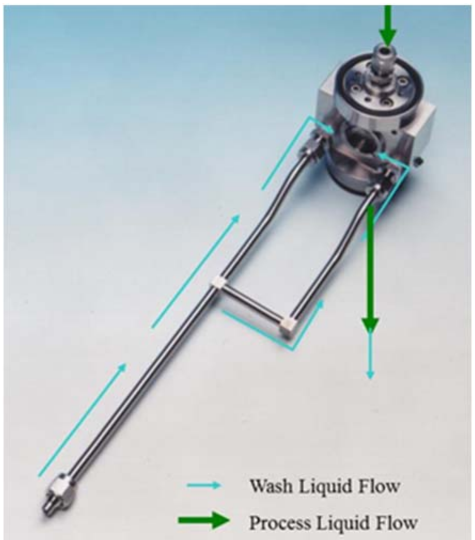
Jorin also have a compact Non-Destructive clean in place system for their particle analyzers and they can provide you with data showing the effectiveness of their CIP system recovering from pure oil contamination to completely clean and back in service in a matter of minutes.

Good advice from Jorin – “complete system cleaning is particularly useful to undertake immediately before shutting down the analyzer for any length of time”.




Non-Destructive Clean in Place system for particle analyzer also can clean entire sample system.

Photo courtesy of Jorin, Limited.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**Conclusions:**

1. If oil in water monitoring is important, we must find a way to keep the monitors and sample system clean. No matter what flow cell is used to make measurements in produced water, cleaning is the major maintenance complaint.
2. There is no universal cleaning method that assures no maintenance.
3. In most cases, the entire system can be cleaned from sample take off through the monitor and the only known way to clean the entire system is with chemicals.
4. There are very low cost and practical ways to keep continuous on-line monitors clean by using standard industry Clean In Place (CIP) designs.
5. CIP uses biodegradable chemicals that do more than adequate cleaning and last several months before disposal.
6. Ultrasonic cleaning is not the ultimate answer to successful on-line monitoring. In some cases both ultrasonic and chemical cleaning may be necessary if neither can do it alone.

**Advice:** CIP can be used to revisit orphaned monitors and put them back in service.

**Refererences:**

Alfa Laval Clean in Place Systems
http://www.alfalaval.com/service-and-support/service-solutions/cleaning-and-chemicals/cleaning-in-place-pays-for-itself/Pages/cleaning-in-place-pays-for-itself.aspx

GEA Clean in Place Systems
http://www.geap.be/gpbe/cmsdoc.nsf/webdoc/webb7nzb9k

Tranter Recommended Practice for Heat Exchangers
http://tranter.com/literature/products/joe-bell-maintenance-article.pdf

Rydlyme – Apex Engineered Products
http://www.apexengineeringproducts.com/

Goodway Portable CIP
www.goodway.com

Jorin
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