



Glycol Fluid Cleanliness Monitoring in Subsea Oil Production Equipment

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ABSTRACT

Equipment installed in offshore or subsea petroleum production applications must be clean or free from particle-based contaminants before being installed on the ocean floor. Particle-based contaminants will lead to premature equipment wear, damage or failure. Offshore platform operators and owners require certification demonstrating equipment cleanliness.

Glycol-based hydraulic fluids are used to operate and clean offshore and subsea equipment. Several industry-recognized standards are used to guide testing and reporting of glycol fluid cleanliness. Microscopes are commonly used to analyze the cleanliness of glycol hydraulic fluids.

Laboratory particle counters have been widely used for many years to monitor the cleanliness of oil-based hydraulic fluids. Some customers have had great success with applying laboratory particle counters in glycol cleanliness monitoring. This paper will discuss best practices for successful application of particle counters in glycol fluid service and new advances in particle counter technology.

SITUATIONAL BACKGROUND

CUSTOMER DRIVERS

Oil production from subsea wells is technically challenging and exceedingly more expensive than surface production systems. Mechanical equipment is used to control the production process in both surface and subsea applications. This equipment is installed and operated on the ocean floor and must withstand extreme operating conditions, including high external and internal pressures as well as high produced oil temperatures. Similarly, produced oil can be both corrosive and erosive, and extending the life for this mechanical equipment is a priority and a difficult challenge.

Valve manifolds, hydraulic fluid accumulators and subsea control modules are installed on the ocean floor. These mechanical systems are used to manage production from oil fields at well locations several thousand feet below the ocean's surface. Most subsea valve networks or "Christmas trees" are hydraulically controlled. The subsea control modules are filled with hydraulic fluid to keep equipment housings from collapsing under the extreme pressures on the ocean floor. Umbilical cables transport electric power, control signals, and hydraulic fluid from the platform down to accumulator vessels and the subsea control module.

Costs for repairing or replacing subsea equipment are enormous. However, lost oil production is the most significant financial impact facing offshore producers. Consequently, offshore platform operators and owners demand that equipment be certified clean or free from particle-based contaminants that will lead to premature equipment wear, damage or failure. Likewise, the fluids used to operate this equipment must also be certified clean.

CURRENT PRACTICES

Offshore equipment users require that glycol fluids meet specific cleanliness classification codes that are spelled out in several industry-recognized cleanliness standards. These standards include NAS 1638, SAE AS4059 and ISO 4406. The codes define the particle count levels for various size classifications. Fluid samples are collected and analyzed per one or more of these standards.

Offshore or subsea equipment is tested several times for cleanliness before being installed subsea. Most end-users require that the equipment and the hydraulic fluid cleanliness be demonstrated at the point-of-use, i.e. the cleanliness must be demonstrated as the equipment is being readied for installation or when the fluid is being delivered. Equipment and fluids are cleaned and certified at the manufacturing location when factory acceptance testing (FAT) is performed. Oftentimes, the fluids and equipment will be evaluated for cleanliness again at a port or loading facility before being transported to the platform. Sometimes, final cleanliness testing takes place on the platform before the equipment is installed subsea.

Fluid and equipment cleaning are accomplished by flushing the equipment with hydraulic fluid, which is passed through a filtration system that is connected to the equipment. Fluid samples are drawn at regular intervals and analyzed for particulate contamination, typically with a microscope and/or laboratory liquid particle counter. Most flushing systems are manually operated. Flushing is complete when a collected fluid sample meets the cleanliness classification code that was specified by the customer. In some cases, fluids and equipment can become overly clean, i.e. fluid samples and testing was continued long after the fluid and equipment have reached the customer-specified cleanliness level.

Offshore petroleum producers prefer water/glycol hydraulic fluids versus oil-based fluids. The potential for negative environmental impacts from spilled hydraulic fluids has resulted in a dramatic decline in the use of oil-based fluids. Macdermid and Castrol are the two most widely recognized glycol fluid suppliers. See Table 1 for a listing of common glycol hydraulic fluids.

Glycol hydraulic fluids tend to foam under high flow rate and high shear conditions. As such, fluid producers often add silicon anti-foaming agents to facilitate faster filling of transport containers. Unfortunately, these anti-foaming agents can form solids at lower temperatures.

	Suppliers			
	Macdermid	Castrol	Petrofer Chemie	Niche Products
Common Glycol Fluids	Oceanic HW540	Transaqua HT	Ultra-Safe 620	Pelagic 100
	Oceanic HW443			

Table 1: Glycol Fluids & Suppliers

SUCCESSFUL GLYCOL ANALYSIS WITH LIQUID PARTICLE COUNTERS

Typically, microscopes and laboratory liquid particle counters are used to monitor hydraulic fluid cleanliness. Historically, microscopes have been the preferred analysis instrument, because the NAS 1638 standard was originally written for the microscope.

Laboratory liquid particle counters have delivered promising, but inconsistent performance in glycol fluid cleanliness testing. Recent liquid particle counter innovations by Hach Ultra, coupled with sample handling best practices are generating consistent glycol analyses results. These liquid particle counter developments provide greater reproducibility and confidence in the cleanliness test results. The amount of time and sample volumes needed for glycol fluid analyses have also been greatly reduced.

Liquid particle counters, utilizing light-blocking sensor technology, cannot distinguish between air bubbles and solid particles. Sample handling best practices are required to minimize or eliminate entrained gas from the fluid sample. This section will discuss these and other best practices.

BEST PRACTICES

Use Clean, Glass Sample Containers

Dirty sample containers will contaminate clean fluid samples. The sample container should be flushed two or three times with the fluid to be analyzed before collecting a sample. Glass sample containers are required. Visual sample inspection is easier with glass containers. Plastic sample containers can also introduce unwanted contaminants/solids or chemical compounds that cause foaming. Sample containers should be used for only one kind of hydraulic fluid, i.e. glycol- or oil-based fluids as well as one type of fluid (ex: Castrol Transaqua HT) to avoid cross contamination.

Minimize or Eliminate Entrained Gas and Bubbles

Entrained gas is a leading contributor to inconsistent liquid particle counter test results. Glycol fluid samples must be bubble-free to ensure accurate and reproducible particle counting results. Glycol fluids can foam and/or entrain gas when samples are taken from a filtration system at high flow rates. Taking samples too quickly will increase the probability of entrained air in the fluid.

Large gas bubbles can be easily removed by sonicating and/or by pulling a vacuum on the fluid sample. However, it is virtually impossible to remove small, non-visible bubbles once they are present in the fluid. Visual inspection of the sample can help to determine if entrained gas is present, but cannot be used to detect very small bubbles. There are several common indicators of visible entrained gas:

- The sample looks like a glass of sparkling water
- A layer of foam or bubbles is visible on the surface of the sample

Reducing the amount of shear on the sample is the most effective way to minimize the amount of entrained gas in the sample. Increased shear will cause small non-visible bubbles to be entrained in the fluid. Ball valves should be used at sample ports to reduce the amount of entrained gas in fluid samples. Gear pumps and needle valves should be avoided, as these will increase the likelihood for small non-visible bubbles in the sample.

Place Sample Ports in Strategic Locations

Samples should be taken in several key locations to gain the best fluids cleanliness results and to minimize the potential for entrained air. Fluid samples should be taken on the discharge side of the equipment being flushed. Samples should also be taken downstream from pumps.

Fluid Samples Should Be at Least Room Temperature

Some of the anti-foam agents added to glycol fluids can begin to solidify below room temperature (~75°F or 24 °C). Liquid particle counters will count these solids as particles. All samples should therefore be at least 75–80 °F (24 - 27 °C) before being analyzed.

Fluid Samples Should Be Analyzed Only Once

Clean instrument air and/or carbon dioxide can be used to pressurize the fluid sample and therefore deliver the force to move fluid through the liquid particle counter. These gases, especially carbon dioxide, are soluble in glycol fluids. The fluid sample will de-gas when the gas pressure is removed. The residual bubbles remaining in the glycol fluid are nearly impossible to remove from the fluid. These residual bubbles are often not visible, but can be counted as particles if the fluid sample is analyzed after being pressurized.

SOLUTIONS FOR GLYCOL CLEANLINESS MONITORING APPLICATIONS

Laboratory microscopes are the most common method for analyzing glycol fluid contamination. The NAS 1638 standard was written for microscope-based contamination analyses. This method is very subjective and labor intensive. A fluid sample is passed through a membrane disc filter then a laboratory technician views and counts particles on the filter media under the microscope. Analysis quality is completely dependent on the technician's experience and care in evaluating the particles present on the filter.

Offshore equipment manufacturers are also using other instruments that deliver NAS code outputs to monitor glycol fluids. Many of these instruments rely on a differential pressure measurement across a membrane to calculate NAS codes. These instruments require approximately two liters of sample and five minutes to complete a single analysis. The instrument is not a true liquid particle counter and does not provide particle size or count information. The membrane in these instruments is essentially a filter element and is susceptible to fouling if highly contaminated fluids are measured.

LIQUID PARTICLE COUNTING ADVANCES

Some offshore equipment suppliers have discontinued the use of microscopes and are now conducting fluid cleanliness testing exclusively with laboratory particle counters, such as the HIAC 8011. Particle counters deliver more reproducible analysis results, greater flexibility in selecting appropriate reporting protocols, and require less time to conduct testing. As a result, offshore equipment suppliers are achieving greater throughput in their filtration processes. While laboratory particle counters have delivered improvements over the traditional microscope method, they have not been used outside the laboratory. Additional process improvements for filtration systems will be realized as cleanliness monitoring instruments are taken to the point-of-use. Recent developments in liquid particle counter technology, like the HIAC GlyCount, are making point-of-use and on-line glycol cleanliness monitoring possible. The HIAC GlyCount delivers cleanliness test results faster than laboratory instruments (microscope or particle counter), thus providing vital feedback on the progress of the filtration process quicker.

CONCLUSION

Glycol fluid cleanliness is vital to trouble free offshore installations. Using the HIAC GlyCount coupled with best practices in sample collection and preparation can reduce the time required to conduct fluid contamination monitoring. These practices can also improve the reproducibility and confidence in the analysis results.

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