GATEKEEPER
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Functionality Testing of Production Chemicals for Deepwater

Efficient production of oil and gas generally requires the use of specialty chemicals to ensure continuous and profitable system operability. The application of these chemicals help mitigate several flow assurance and integrity related challenges including asphaltene and wax deposition, scale build-up, hydrate blockage, corrosion, etc. In offshore applications, particularly in deepwater (DW), where many components of the production system are not easily accessible, it is critical to ensure safe and reliable chemical delivery to obtain maximum recovery without any lost production or asset integrity issues. It is of utmost importance that the selected chemical products have appropriate, standardized chemical functional requirements that each must pass – defined broadly as the physical and chemical characteristics essential for secure delivery through a subsea umbilical tube/capillary for use at the intended injection point.

This GATEKEEPER will discuss the key physical and chemical characteristics of each production chemical that must be evaluated prior to use in a subsea production system.

Cleanliness

The presence of particulates in the chemical increases the risk of umbilical, downhole line, pump, in-line filter, pipework, and check valve blockage which may be difficult to remediate economically. Therefore, it is important to quantify particulate contamination of production chemicals to ensure usability as per the project specification.

Currently, chemical cleanliness is most effectively evaluated per API 17TR6 (*Attributes of Production Chemicals in Subsea Production Systems*) recommended SAE aerospace standard (AS) 4059 (*Contamination Classification of Hydraulic Fluids*). The purpose of the standard is two-fold:

- Determine contamination class based on cumulative or differential particle count.
- Provide guidance on analytical method and data reporting.

The industry is currently gravitating towards using contamination level Class 6 standard or better to comply with AS4059 specifications (see Table 1). The operators can mandate stricter cleanliness levels beyond this, with the expected consequence of a more expensive product.

Compatibility

Production chemicals deployed within the subsea environment encounter a wide variety of fluids in addition to various components including umbilical tubing, pumps, seals, valves, flying leads, downhole tubing etc. Figure 1 lists various compatibility issues that must be considered while qualifying a product for application. Failure to ensure compatibility can result in an inaccessible blockage or restriction due to creation of precipitates, gels, emulsions, and/or deposits.

API 17TR6 clearly defines a base case for understanding a production chemical's compatibility profile. The following compatibilities must be assessed prior to application:

- **Chemical compatibility with other chemicals** – The process begins with defining and testing a production chemical compatibility matrix similar to Table 2 over nine defined ratios as per API 17TR6. Interaction types (e.g. compatible, phase separation etc.) are used as data output. The matrix should be constructed based on the potential for the production chemicals to mix/interact as a result of system design, standard operating procedure, human error, and component failure. The testing is usually conducted at various temperatures of interest to the system and in a static environment.

Particle Size (1) / Particle Size (2)	Particle Count
> 1 µm / > 4 µm	50,000
> 5 µm / > 6 µm	19,462
> 15 µm / > 14 µm	3,462
> 25 µm / > 21 µm	612
> 50 µm / > 38 µm	106
> 100 µm / > 70 µm	16

1. Size range, optical microscope based on longest dimension as measured per AS598 or ISO4407.
2. Size range, APC calibrated per ISO11171 or an optical microscope with image analysis software, based on projected area equivalent diameter.

Table 1: AS4059 Table for Cumulative Classification (Class 6)

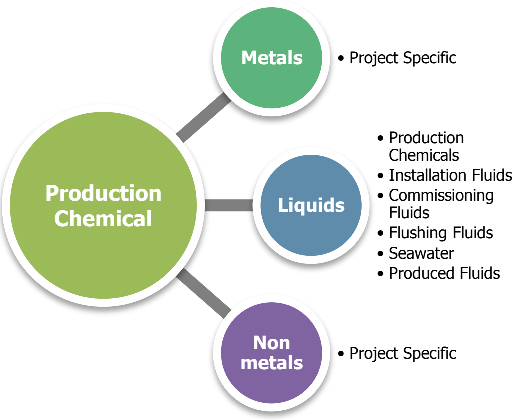

Figure 1: Compatibility Profile

	Chemical 1	Chemical 2	Chemical 3	Chemical 4	Chemical 5
Chemical 1					
Chemical 2	Stable tight emulsion at 50:50 mixture				
Chemical 3	Fine solid; exceeds AS4059 Class 8 B to F				
Chemical 4	Thin oil layer formed		Polymerises		
Chemical 5	Gel on side of test bottle	2 immiscible layers	Large amount of coarse solid		

Legend: Compatible; Phase Separation; Solid Precipitation; Gel Formation; Emulsion Formation

Table 2: API17TR6 Compatibility Matrix Table

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- **Chemical compatibility with produced fluids/seawater** – The testing is usually conducted at various temperatures of interest to the system and in a static environment. The effects of pressure and fluid movement are usually assumed negligible. Certain projects, with perceived risks, may elect to conduct dynamic flow loop testing which is explained in the API standard.
- **Chemical compatibility with materials of construction** – The final step in the compatibility process inspects the production chemical's interaction with the system's materials. Metals, thermo plastics, and elastomers are project specific and should be detailed in the wetted-materials map. API 17TR6 Annex C details how the compatibility testing should be conducted.

Stability/Reliability

Production chemicals in a DW environment must maintain physical and chemical stability under all application scenarios and field conditions. There are several scenarios that may challenge the chemical stability of a product, such as:

- **Injection** – Mechanical shearing and solvent flashing during injection can affect product stability. This can be particularly challenging when the injection point is at sub-hydrostatic pressure and chemical has a tendency to free-fall into the system.
- **Delivery** – The increasing length of umbilicals could result in chemicals being exposed to seabed temperature for weeks of months during steady-state operation. Additionally, cold and hot temperature cycling as the product traverses through the seabed to downhole injection location can stress product stability.
- **Shut-in** – Exposure to seabed and/or bottomhole temperatures and high pressure during shut-ins which can last for several months.

Much like the compatibility requirement, loss of stability can result from such exposures resulting in blockages and/or restrictions due to creation of precipitates, gels, emulsions, and deposits. In addition to ensuring physical stability, chemical degradation and polymerization are the two main chemical stability concerns which must be addressed. Both of these issues are usually due to long term/thermal storage effects.

All of the aforementioned scenarios need to be replicated as much as possible in the laboratory to mitigate the risk of instability. Pressures employed in the testing are often project specific, but temperatures of interest should include:

- Transport
- Storage conditions
- Seabed conditions
- Wellhead/reservoir conditions

Table 3 summarizes specific testing parameters used within the upstream community to ensure stability and reliability of DW production chemicals. It must be noted that each project is unique, which can necessitate deviation from typical testing. protocols

Deliverability

The two main areas of concern affecting production chemical deliverability are:

- Viscosity
- Hydrate tendency/stability

The viscosity of a production chemical varies with pressure and temperature. Generally, viscosity increases with increasing pressure and decreasing temperature. The greater the viscosity, the greater the pump pressure required for chemical delivery. Therefore, knowledge of a chemical's rheology in the production system operating envelope:

- Determines whether the product can be delivered at the required volumetric rate by planned injection pumps.
- Provides essential hydraulic information to determine if "free fall" of a chemical is a possibility.

Typical test parameters used to evaluate chemical rheology are listed in Table 4.

Additional informative testing such as pour point and high pressure density can be performed to aid project decisions and further ensure deliverability.

Leakage of water-saturated hydrocarbons from check valves can lead to hydrate blockage in umbilicals. Chemical suppliers usually determine the hydrate dissociation curve with industry available simulation tools. Essential inputs include:

1. Temperatures and pressures experienced in the operational envelope of a subsea production system.
2. Hydrocarbon/produced water compositions expected in the field

Projects may also insist upon empirical testing methods to provide visual observation capability (i.e. rocking cell testing). Any amount of hydrate formation is not acceptable.

Conclusions

Ensuring chemical performance under expected DW system conditions is only the first step in chemical selection. A systematic evaluation of various chemical properties including cleanliness, compatibility (metals, nonmetals, fluids, and chemicals), thermal stability and rheology must be performed to ensure safe, reliable, and uninterrupted production. The properties must be measured at all anticipated conditions in the subsea production system ,including worst-case scenarios.

Stability Type	Temp (°F)	Pressure (psi)	Time (days)	General Notes
Low Temperature	40	Ambient	1-7	Use Centrifuge to Aid Separation
High Temperature	BHT (a)	5k	1-7	Δ FTIR, Δ pH, Performance Test
Cyclic	140 «» 15	Ambient	1	Δ FTIR, Δ weight
Umbilical	40	8-15k	7 (b)	Δ Pressure, Simulate Shut-in
Capillary	BHT (a)	Project	7 (b)	Δ Pressure
Long-Term	Project	Project	>90	Project Storage Info. Critical

a. Bottom hole temperature or > 50°F highest recorded or estimated operating temperature.
b. Multiple cycles my be run.

Table 3: Typical Test Data Parameters for Stability Testing (Δ = Change in Variable)

Scenario Type	Temperature (°F)	Pressure (psi)
Seabed	40	0-20,000 (3-4 Points)
Mid-Range	120	0-20,000 (3-4 Points)
Down Hole	Project	0-20,000 (3-4 Points)

Table 4: Pressure/Temperature Values for Viscosity