

Attributes of Production Chemicals in Subsea Production Systems

API TECHNICAL REPORT 17TR6
FIRST EDITION, MARCH 2012



AMERICAN PETROLEUM INSTITUTE

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Upstream Segment

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Foreword

This document was generated, by means of the BASICS Joint Industry Project (JIP) in response to the continuing problem of blockages occurring in control and chemical injection fluid conduits incorporated in subsea production systems (SPSs). The JIP committee comprised a representative cross section of experienced industry personnel from engineering, manufacturing and operational organizations.

Shall: As used in a standard, “shall” denotes a minimum requirement in order to conform to the specification.

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Introduction

Production chemicals delivered to a subsea production system (SPS) via a chemical injection system can be complex formulations that have a wide range of chemical and physical properties. In service, the production chemicals can come into contact with other fluids, metallic and polymeric materials, and a range of physical conditions in respect of temperature and pressure. Inadequate specification can therefore result in failure to deliver a production chemical to the required production system location.

The intent of the BASICS JIP is to produce a Specification (Spec) standard for global industry use to address this problem. This document has been developed with the objective of minimizing the risk of a production chemical not being delivered at the required volumetric rate, due to inadequate specification of the production chemical delivery system, or formation of restrictions or blockages in that system.

To do this, the document specifies parameters that address manufacture, storage and transportation of the production chemical, as well as its deployment using the SPS chemical injection system. The document provides for two approaches, requiring that parameters be either:

- 1) measured and reconciled with SPS design and operation; or
- 2) meet or exceed acceptance criteria specified, either in this document or by manufacturers of production chemicals or equipment used to deliver production chemicals.

Attention is drawn to the fact that in addition to the assessment and testing specified in this document, project specific assessments and tests may be required, and these should be agreed between the purchaser and the production chemical supplier or equipment manufacturer, as appropriate.

This document takes into account, many aspects of conventional SPS design and operation and also some common aspects of SPS failure that can impact on the application of a production chemical in an SPS. It should be noted however that any SPS can have specific features that in the event of failure may result in a blockage or restriction. Such system specific features and failures are not addressed by this document.

This document is intended to be applicable to all subsea developments, irrespective of whether the development is in shallow or deep water. However, it should be recognized that the significance of a blockage or restriction can be significantly different for a deepwater development relative to a shallow water development. Consequently, more rigorous application of the verification program could be appropriate for a deepwater development.

Attributes of Production Chemicals in Subsea Production Systems

1 Scope

This document identifies and specifies the essential attributes of production chemicals intended to be introduced to subsea oil and gas production systems.

The document is intended for use by chemical suppliers to facilitate the provision of chemicals compatible with existing and intended subsea production systems (SPS) although it is envisaged that use of the document for specification purposes by the operators of such processes, will assist in ensuring the completeness of requests to supply.

The application of the document requires acceptance of the principle that it is the supplier's responsibility to ensure that the chemicals supplied are fit for purpose and safe to use, although it is acknowledged that this responsibility can only be fulfilled if specification of requirements is complete. To this end the document identifies essential information that only SPS designers and operators can provide but without knowledge of which, suppliers should not supply. In the requirements of this document, responsibility for obtaining these items of critical information is placed upon the supplier, in the expectation that designers and operators will respond with their ready provision.

The functional performance of production chemicals is outside the scope of this document.

The assessments and tests specified in this document are not intended to qualify materials for use in an SPS in respect of pressure containment, mechanical load, cyclic mechanical load, or other design parameters.

The chemical-chemical compatibility of production chemicals at their respective application concentrations is also outside the scope of this document as is the effect of any incompatibility on their respective functional performance.

Finally, this document does not consider the health, safety, or environmental (HS&E) implications of deploying a production chemical in an SPS.

NOTE Attention is drawn to the fact that the tests specified in this document can generate data and information about the effect of a chemical/material incompatibility on the integrity of a material used in a SPS, that could necessitate additional testing, outside the scope of this document. Such additional testing should however be undertaken in order to ensure that all possible mechanisms that could threaten the integrity of a production, transportation, or chemical injection system are fully evaluated.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Specification 17D/ISO 13628-4, *Subsea Wellhead and Christmas Tree Equipment*

ASTM D471¹, *Standard Test Method for Rubber Property Effect of Liquids*

ASTM D543, *Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents*

ASTM D638, *Standard Test Method for Tensile Properties of Plastics*

ASTM D664, *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration*

¹ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM D1141, *Standard Practice for the Preparation of Substitute Ocean Water*

ASTM D1298, *Standard Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method*

ASTM D4289, *Standard Test Method for Elastomer Compatibility of Lubricating Greases and Fluids*

ASTM G1, *Standard Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens*

ASTM G31, *Standard Practice for Laboratory Immersion Corrosion Testing of Metals*

ASTM G46, *Standard Guide for Examination and Evaluation of Pitting Corrosion*

ISO 3771 ², *Petroleum products—Determination of base number—Perchloric acid potentiometric titration method*

ISO 6073, *Petroleum products—Prediction of the bulk moduli of petroleum fluids used in hydraulic fluid power systems*

ISO 10523, *Water quality—Determination of pH*

ISO 13628-5, *Petroleum and natural gas industries—Design and operation of subsea production systems—Part 5: Subsea umbilicals*

IP 160 ³, *Crude petroleum and liquid petroleum products - Laboratory determination of density - Hydrometer method*

SAE AS4059 (2005) ⁴, *Aerospace fluid power—Cleanliness classification for hydraulic fluids*

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1.1

attribute

Feature of a subsea production system that is fixed and inherent to the existence of the SPS.

NOTE Examples of SPS attributes are a material of construction or the volume of a vessel.

3.1.2

bacteriostat

Biological or chemical agent that prevents bacterial reproduction without killing or otherwise harming the bacteria.

3.1.3

barrier

Element forming part of a pressure-containing envelope which is designed to prevent unintentional flow of produced/injected fluids, particularly to the external environment.

² International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

³ Energy Institute, 61 New Cavendish Street, London W1G 7AR, UK. www.energyinst.org

⁴ Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001, www.sae.org.

3.1.4**barrier arrangement**

Provision of physical separation between two fluids during fluid change out in a fluid circuit, using a barrier element, e.g. a gel.

3.1.5**barrier fluid (spacer)**

Fluid introduced to the SPS as an intermediary to provide physical separation between an existing fluid and the fluid intended to replace it during the change-out process.

3.1.6**biofilm**

Viscous or gelatinous coating deposited on SPS components as a result of microbiological growth.

3.1.7**bunkering**

Transfer of production chemical from transport container to host facility storage facility.

3.1.8**chemical reaction**

Change of the chemical state of a substance, which may involve a change of oxidation state or molecular structure.

3.1.9**chemical injection system**

Facilities that inject a production chemical into produced or injected fluids.

3.1.10**completion fluid**

Fluid in the "A" annulus of a well between the production tubing and well casing.

NOTE 1 The fluid may have been in the well when the well completion (tubulars, screens, packer, etc.) were run into the well, or was circulated into the well after the well completion was run.

NOTE 2 Completion fluid can also be known as a "workover fluid".

3.1.11**dead spot**

Localized region in a fluid circuit whereby fluid in a flowing circuit is stationary or flows at a much lower velocity than the bulk fluid, e.g. step change in bore diameter.

3.1.12**delivery fluid**

Fluid that is in the fluid conduits at the time of delivery of the SPS equipment.

NOTE This fluid may be the service fluid, or where not the service fluid, will be changed out with the service fluid following installation of the equipment.

3.1.13**fluid conduit**

Steel tube or thermoplastic hose used in an umbilical, jumper bundle/assembly, rigid pipe-work, etc., for the transmission of fluids used in, or produced by a SPS.

3.1.14**fluid change-out**

Replacement of a SPS service fluid by another fluid.

3.1.15**fluid stability**

Condition of a fluid in which it is not liable to undergo chemical decomposition i.e. in which the characteristics of the fluid (chemical, physical, micro-biological) remain unchanged over time, after a disturbance, or having been subject to environmental exposure (UV, elevated temperature, etc.).

3.1.16**host facility**

Offshore platform, floating facility or onshore facility to which the SPS is tied back.

3.1.17**hydrate**

Compound in which water molecules form a solid ice like structure with methane, i.e. Type I or Type II methane hydrate.

3.1.18**hydraulic analysis**

Detailed examination of SPS performance on the basis of calculating the variation of pressure in the chemical injection system as a function of production chemical injection rate, relative to system design pressure, in order to assess whether system performance in the various modes of operation is safe and operationally acceptable.

3.1.19**hydrocarbons**

Produced hydrocarbons, which may be gas, condensate, oil and combinations of all three.

3.1.20**mapping**

Process of making diagrammatic representations of aspects/issues relating to the design, manufacture, load-out and installation of the components that comprise the SPS, e.g. materials of construction, damage/potential damage locations.

3.1.21**operational envelope**

Set of parameters that define the intended operational range of a SPS.

3.1.22**parameter**

Feature of a subsea production system that is variable, measurable or quantifiable and fundamental to the nature and operation of the system.

NOTE Examples of SPS parameters are temperature; pressure; dose rate of a production chemical or oil production rate.

3.1.23**production chemical**

Chemical, or mixture of chemicals, that are applied to produced or injected fluids in order to enable the production or injection process to take place, e.g. prevention of corrosion that could be caused by the produced or injected fluids; prevention of hydrate formation; prevention of mineral scale or wax deposition; H₂S scavenging; demulsification; friction reduction.

NOTE A production chemical may also be referred to as "process chemical" or "chemical".

3.1.24**produced fluid**

The expected output of the SPS.

NOTE This is a collective term that includes oil, condensate, water, and gas.

3.1.25**shelf life**

The time period in which a fluid remains stable and useable when stored in accordance with the manufacturer's storage and handling procedure.

3.1.26**solvent**

Chemical that can dissolve or disperse another chemical so that the resulting liquid is either a solution or suspension of the other chemical.

NOTE The scientific definition is, "A liquid that dissolves a solid, liquid, or gaseous solute, resulting in a solution."

3.1.27**uptime requirement**

Unit of time during which production chemicals are required to be injected.

3.1.28**yellow metal**

Metal or metal alloy containing copper.

3.2 Abbreviated Terms

For the purposes of this document, the following abbreviated terms apply.

AS	Aerospace
CI	corrosion inhibitor or chemical injection
CITHP	closed in tubing head pressure
CRA	corrosion resistant alloy
FEED	front end engineering design
HPHT	high pressure high temperature, e.g. >10,000 psi and 150 °C
HP	high pressure, e.g. >10,000 psi
HS&E	Health, Safety, and Environment
HT	high temperature, e.g. >150 °C
IBC	intermediate bulk container
IMS	industrial methylated spirit
IRCD	injection rate control device
ISO	International Organization for Standardization
LDHI	low dosage hydrate inhibitor, e.g. kinetic hydrate inhibitor or anti-agglomerant hydrate inhibitor
MAWP	maximum allowable working pressure
NRV	non-return valve
OIW	oil-in-water
SAE	Society of Automotive Engineers

SI	scale inhibitor
SDU	subsea distribution unit
SPS	subsea production system
TAN	total acid number
TBN	total base number
UV	ultraviolet

4 Overview

Injection of a production chemical into produced fluids at a subsea location can be impeded by many incidents, events or combinations of these. Such causes can be related to SPS and chemical injection system design, production chemical specification, system commissioning, system maintenance, chemical change-out operation, fluid ingress, material degradation, etc. The consequences of being unable to inject production chemicals at the required rate and location can have significant economic impact. When restrictions or blockages occur, remediation may not be practicable or possible, therefore a significant cost may be incurred for replacement facilities. Alternatively, if remediation of restrictions or blockages is achievable, significant cost may still be involved due to the complexity of intervention where vessel mobilization is required.

Chemical vendors supply a wide range of production chemicals that may be applied in subsea systems. Production chemicals are often complex formulations that can change due to safety, performance, economic and environmental, requirements. They can be water based, hydrocarbon based, or an intermediate formulation and in addition, specific project functional requirements can necessitate formulation of new and unique products.

The production chemical requirement of a subsea development is dictated by the type of produced fluids. The produced fluids can consist of varying combinations of different types of oil, condensate, gas, and water ranging from condensed water that does not contain salts to formation water that contains salts close to salt saturation limits. Typical production chemicals include the following:

- scale inhibitors;
- corrosion inhibitors;
- methanol (hydrate inhibitor);
- ethylene glycol/monoethylene glycol/MEG (hydrate inhibitor);
- industrial methylated spirits/ethanol (hydrate inhibitor);
- wax inhibitors/pour point depressants;
- low dosage hydrate inhibitors (LDHIs);
- asphaltene inhibitors and dispersants;
- flow improvers;
- biocides;
- H₂S scavengers;
- demulsifiers;
- combined products, i.e. products that have dual function.

As a consequence of this background, it is necessary that project planning for SPS recognizes the wide range of criteria that should be considered when verifying a production chemical for deployment in a SPS and make provision for the time required for rigorous verification.

It is recommended that only production chemicals that have been verified to this specification and which fully meet the specified acceptance criteria, be deployed in an SPS. In addition, fluids used for installation, commissioning and production chemical change-out operations should be subject to verification as specified in this document.

It is also recommended that the responsibility of organizations associated, or directly involved, in data generation or verification processes, required by this document and their liability in the event of default, be specifically confirmed.

5 SPS Production Chemicals—Application Data

5.1 Supplier Responsibility

Before committing to supply a production chemical, the supplier shall be in possession of the values of the parameters that define the operational envelope within which that production chemical will be required to function. This shall include the parameters listed in Table 1, as a minimum.

NOTE This identifies the nature of the required application data, which should be part of the basis of system design and will include data required for specifying calculations, interpretation of reference data (e.g. materials compatibility data) and specifying laboratory test conditions.

Table 1—Parameters of the SPS Operational Envelope

SPS Parameters	Comments
Maximum and minimum application rates (volumetric rate) *	Required for verification that the chemical injection system can deliver the production chemical at the required volumetric rate, and estimation of the production chemical residence time.
Continuous or intermittent operation	Used to define duration of temperature stability tests.
Uptime requirement	Fraction or percentage of time when production chemical shall be injected.
Flow regime: laminar or turbulent flow	The majority of applications involve laminar flow, which will result in settling of solids that may cause blockage or restriction.
Temperature and pressure	The temperature and pressure data incorporating the known ranges and combinations for different locations in the production system, e.g. host, subsea, wellhead, bottom hole, as well as steady state versus transient operation.
Injection system design features	Any features that may be used to define required assessments or laboratory tests, for example: <ul style="list-style-type: none"> — common injection port used for more than one production chemical, which necessitates compatibility testing of the undiluted “as supplied” production chemicals; — component with a specified solids tolerance specification that requires testing of the production chemical compliance; — components for which a failure in service would result in mixing of a potentially incompatible production chemicals.
SPS chemical injection system materials map (materials wetted by production chemical)	Required for definition of chemical-material compatibility evaluation and testing.
* Determined by functional testing of the production chemical, which is outside the scope of this document.	

5.2 Parameter Verification

The range of attributes addressed in this document relate to the installation, commissioning and operation of the SPS and is divided into those for which measurement shall be taken and reconciled against the SPS operational envelope and those for which acceptance criteria can be provided.

The attributes and related parameters addressed in clause 6 constitute the minimum requirement and shall be verified for every instance of production chemical supply.

Annex A sets out requirements relating to other attributes that may be relevant to some SPSs. For SPSs and associated production chemicals to which such attributes apply, the requirements of this annex shall be met.

6 SPS Production Chemicals—Common Parameters

6.1 General Application

The verification data provided in relation to a production chemical submitted for introduction to an SPS, shall include the parameters identified in 6.2 through 6.13, as a minimum.

6.2 Viscosity

6.2.1 Requirement

Viscosity measurements at a range of temperature/pressure combinations corresponding to host facility, subsea and well conditions, shall be taken to determine whether a production chemical can be injected at the required volumetric rate. The SPS operational envelope shall define the range of conditions selected for measurement of viscosity.

NOTE 1 Viscosity data are essential to determine whether or not a production chemical injection system can deliver at the required volumetric rate, or whether a production chemical has a viscosity that will permit its use in an existing injection system. The viscosity of a production chemical will vary as a function of temperature and pressure.

NOTE 2 The viscosity of hydrocarbon based production chemicals tends to exhibit the greatest pressure dependence. However, water/glycol based production chemicals can also exhibit a significant dependence. In addition, some production chemicals exhibit non-Newtonian behavior where viscosity varies as a function of shear rate.

6.2.2 Procedure

6.2.2.1 Measurement

Viscosity measurements shall be made using a method of the chemical providers own choosing, in accordance with a published standard. Reporting of the results of viscosity measurement shall always include identification of the method employed and corresponding standard. Should the SPS Operator not be satisfied with the results reported, the viscosity of the chemical shall be checked using one of the following methods:

- capillary viscometer;
- flow cup;
- rotational viscometer;
- rolling ball viscometer; and
- drawing ball viscometer.

6.2.2.2 Measurement at Elevated Temperature

Related viscosity measurement at elevated pressure shall be made using a method that is based on the principles of an atmospheric pressure measurement standard. Reporting of the results of viscosity measurement shall always include identification of the method employed and corresponding standard that is the basis of the method.

NOTE 1 OECD Guideline for testing of chemicals 114 "Viscosity of liquids" provides extensive details of available standards.

NOTE 2 Elevated pressures: Standards specifically for elevated pressure are not published. However, general specifications presented in standards can be applicable and should be considered when making measurements.

NOTE 3 It is recommended that at least two determinations should be made at each set of conditions.

6.2.3 Interpretation of Results

The measured viscosities shall be reconciled with the requirements of the SPS operational envelope to demonstrate that any specific production chemical can be injected at the required volumetric rate(s).

6.3 Density

6.3.1 Requirement

Density data are essential to the undertaking of an accurate hydraulic analysis of the production chemical injection system. Density measurement at a range of temperature/pressure combinations corresponding to the SPS operational envelope, shall be taken to determine whether a production chemical can be injected at the required volumetric rate.

6.3.2 Procedure

Density measurements shall be made using a method specified in a published standard and reference to the standard method used shall always be included in a report of results.

Where other specific standards are not selected for use and reference, either IP160 or ASTM D1298 shall be used as the default standard for the measurement of production chemical density.

6.3.3 Interpretation of Results

The measured densities shall be reconciled with the SPS operational envelope to demonstrate that any specific production chemical can be injected at the required volumetric rate(s).

6.4 Solvent Type

6.4.1 Requirement

Classification of solvent type shall be used as the basis for selection of compatible candidate flushing fluids and the assessment of the implications of mixing with the solvents used for installation, commissioning and flushing fluids, e.g. assessment of the likelihood of emulsion formation. For the purposes of this document, solvent type shall be classified as follows.

- **Water based:** Base solvent is fully miscible in water.
- **Hydrocarbon based (fully miscible):** Base solvent is fully miscible in hydrocarbon liquids such as diesel or kerosene.

- **Hydrocarbon based (partially miscible):** Base solvent is fully miscible with a limited number of hydrocarbon liquids such as diesel or kerosene.
- **Intermediate:** Base solvent fully or partial miscibility in both water and hydrocarbon liquids such as diesel or kerosene.

NOTE The above classification does not consider the potential for precipitation or separation of components that are part of the production chemical formulation. The potential precipitation or separation should be assessed using the procedures presented in 6.8 and 6.9.

6.4.2 Procedure

6.4.2.1 Determination of pH for Water Based Production Chemicals

The pH of a production chemical can be used to indicate possible chemical-chemical and chemical-material compatibility issues. Where determination of pH is required, the following method shall be used.

6.4.2.1.1 Equipment

Use a pH Meter, with glass electrode, having a measuring range from 0 to 14 pH units, graduated in 0.05 pH units.

6.4.2.1.2 Method

The principles and methods specified in ISO 10523, *Water quality—Determination of pH*, shall be used. Where required, dilution of the production chemical to increase the speed of the pH electrode response, is permissible.

NOTE “Definitions of pH scales, standard reference values, measurement of pH, and related terminology,” *Pure Appl. Chem.* (1985), 57, pp 531–542., should also be consulted.

6.4.2.2 Hydrocarbon Based Production Chemicals

Where production chemicals are formulated with solvents other than water, pH measurement are unlikely to be appropriate. Hydrocarbon based production chemicals can contain acidic or basic components. TAN and TBN represent the amount of acidic and basic components, respectively.

6.4.2.2.1 TAN

TAN shall be determined in accordance with ASTM D664, *Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration*.

6.4.2.2.2 TBN

TBN shall be determined in accordance with ISO 3771, *Determination of base number—Perchloric acid potentiometric titration method*.

6.4.3 Interpretation of Results

6.4.3.1 The pH at temperatures corresponding to those experienced in the SPS operational envelope shall be recorded and reported.

The pH data can be used to assess possible chemical-material compatibility issues and chemical-chemical compatibility issues, e.g. reactive hazard potential, emulsion stability, etc.

6.4.3.2 The TAN or TBN data derived from production chemicals shall be compared to data derived from the SPS operational envelope to assess possible chemical-material and/or chemical-chemical compatibility issues, e.g. reactive hazard potential, emulsion stability.

6.5 Particulates

6.5.1 Requirement

Production chemicals will contain variable amounts of particulates which will have the potential to cause blockages and/or restrictions in a SPS. Particulate content shall be determined and reported in respect of any production chemical supplied.

6.5.2 Procedure

Determination of particulate content of a production chemical shall be undertaken in accordance with SAE AS4059.

Where a production chemical has been manufactured to have a specific particulate content, the same procedure shall be used to verify the manufacturing process.

6.5.3 Interpretation of Results

The contamination code derived from SAE AS4059 for the production chemical shall be reconciled with the SPS operational envelope to ensure the production chemical will not cause a blockage or restriction.

6.6 Temperature Stability

6.6.1 Requirements

The stability of a production chemical shall be evaluated over the range of temperatures corresponding to those experienced in the SPS operational envelope.

The evaluated temperatures shall correspond to those associated with:

- transportation;
- day/night fluctuation;
- geographical location;
- storage;
- subsea application;
- downhole well injection.

The evaluated temperatures shall also take into account the likely duration of exposure to particular temperature associated with normal operational conditions and SPS shutdown.

6.6.2 Procedures

6.6.2.1 General

6.6.2.1.1 The Test Vessel

The preferred test vessel shall adhere to the following.

- a) Be of glass and fitted with a screw cap but in all cases shall be confirmed as being inert in respect of the production chemical.

NOTE Where the production chemical is shown to react in contact with glass, a vessel of alternative material inert in the presence of the production chemical is used.

- b) Be sized such that when the sample volume of production chemical is inserted, the headspace in the test vessel shall be not less than 10 % and not more than 20 % of the test vessel volume, so as to minimize the effect of solvent evaporation.
- c) In all cases, allow visual observation of the production chemical during the test.
- d) Have its internal surface swabbed with a cotton bud to test for evidence of residue or deposit on completion of the test.

NOTE The swabbing shall be performed immediately when the bottle or vessel is emptied so that any residue does not significantly change temperature.

6.6.2.1.2 The Test Sample

Test sample volumes shall be not less than 100 ml and not greater than 300 ml.

6.6.2.1.3 Evaluation Conditions

The following conditions apply when performing sample evaluations.

- a) A strong light shall be used when visually examining a test sample.
- b) The test sample shall be compared to a reference sample of the production chemical.
- c) Visual observations shall be made and recorded at the start and at the end of the test, and where practical periodically during the test.

NOTE It is recommended that photographs be used to record the condition of the test sample.

- d) Samples of separated phases, deposits, and precipitates shall be separated and stored for further characterization.

NOTE Such samples may be used to ascertain suitable solvents that might be used to clean an SPS chemical injection system, or to characterize the cause of any production chemical instability.

6.6.2.2 Low and Moderate Temperature Tests

The following apply when performing low and moderate temperature tests.

- a) Bottles should be used for low to moderate temperature tests. The suitability of the bottle for the test temperature should be verified with the manufacturer.
- b) Test durations of not less than three months shall be applied to allow for the potentially slow chemical reaction kinetics at low temperature.

NOTE It is recommended that test periods of even longer duration be applied, if the specific operating conditions of a SPS suggest this to be appropriate.

- c) The low end test temperature of the range tested shall be not less than 3 °C lower than the lowest recorded or estimated, operating temperature of the SPS.

6.6.2.3 High Temperature Tests

The high end test temperature of the range tested shall be not less than 10 °C higher than the highest recorded or estimated, operating temperature of the SPS.

6.6.2.4 Temperature Change Tests

The effect on production chemicals of temperature changes within the SPS shall be evaluated, e.g. any increase from ambient seabed temperature to the temperature at the injection port in a wellhead tree, immediately prior to injection into the produced fluids.

The evaluation shall simulate the rate of temperature increase specific to the application.

6.6.2.5 Temperature Cycling Tests

Production chemicals can experience temperature variations during transportation and storage that may go beyond the range of the temperature variation experienced in the SPS. Where records or estimation show this to be the case, tests simulating the transportation and storage conditions shall be performed. The temperature variations applied shall include frequent cycling where transport and storage conditions are shown to include such conditions.

6.6.3 Interpretation of Results

A production chemical shall be considered stable when:

- precipitates/sludge are not formed;
- bulk phase separation does not occur;
- solidification does not occur;
- adherent deposits or residues are not formed on the test vessel;
- viscosity and density is unchanged relative to a reference sample;
- pH or TAN/TBN are unchanged relative to a reference sample;

- any suspended or dispersed material present in the production chemical before testing, e.g. micro-emulsion, shall not have separated or settled.

If a particulate specification has been defined, the procedure presented in 6.6 shall be applied to determine if the test sample complies with the specification.

Test results consistent with the above acceptance criteria shall be recorded.

NOTE A production chemical found to be unstable under transportation conditions can be considered acceptable for subsea application provided that the instability is reversible and does not occur at the application conditions.

6.7 Hydrate Stability

6.7.1 Requirements

Production chemicals shall not form a hydrate under the conditions to be experienced in the operational envelope of the SPS. This shall be assessed/tested by one of the procedures provided in 6.7.2 of which that in 6.7.2.3 is preferred.

NOTE 1 The significance of 6.8.1 is that production chemicals containing water can potentially form methane hydrates when mixed with produced hydrocarbons, e.g. due to an NRV not being “gas tight” and allowing gas to enter the chemical injection system. The resulting hydrate can block and/or restrict chemical injection systems

NOTE 2 Attention is drawn to the fact that NRVs in subsea chemical injection systems are by design not “gas tight”.

NOTE 3 Hydrates can potentially form in subsea chemical injection systems due to backflow of water saturated hydrocarbon gas, e.g. due to passing an NRV. This mechanism of hydrate formation is not dependent on the formulation of the production chemical. However, the production chemical may prevent hydrate formation due to being formulated with a thermodynamic hydrate inhibitor, assuming effective mixing can be achieved.

NOTE 4 It should be noted that hydrocarbon-based production chemical formulations are unlikely to contain components that act as thermodynamic hydrate inhibitors.

6.7.2 Procedure

6.7.2.1 General

Derivation of a hydrate dissociation curve for assessment of the potential for hydrate formation in a chemical injection system shall be based on the full range of operating conditions to be experienced in the intended SPS (see Note 1, Note 2, and Note 3).

A detailed composition of the produced hydrocarbon, i.e. N_2 , CO_2 , CH_4 , C_2H_6 , C_3H_8 , $n-C_4H_{10}$, $i-C_4H_{10}$, etc., shall also be determined.

NOTE 1 The potential for a production chemical to form a hydrate is primarily a function of temperature and pressure, and the composition of the different fluids in the system, e.g. production chemical and hydrocarbon composition.

NOTE 2 The minimum temperature is usually the ambient seabed temperature. However, the potential for Joule-Thomson cooling below ambient seabed temperature during operation should be assessed.

NOTE 3 The maximum system pressure is normally the CITHP. Alternatively, the subsea chemical injection system relief pressure, or MAWP, may be appropriate for definition of the maximum system operating pressure.

6.7.2.2 Theoretical Evaluation

6.7.2.2.1 Introduction

Simulation tools that allow calculation of hydrate dissociation curves are commercially available. In addition, simple spreadsheet models can be developed based on published methods and correlations. A simulation tool can be used in various ways to assess the potential for hydrate formation, which may involve making assumptions due to limitations of the tool or absence of data describing the system of interest.

Several methods for assessing hydrate formation potential using simulation tools are presented below but, in all cases, the user shall determine the accuracy of the chosen tool.

6.7.2.2.2 Simple Theoretical Assessment

This procedure, which requires the following assumptions:

- the components of the production chemical formulation do not act as either a hydrate inhibitor or hydrate promoter;
- the simulation tool can explicitly simulate the hydrate inhibitor to be added to the production chemical formulation.

shall be undertaken as follows.

a) Establish:

- 1) pressure and temperature range of the chemical injection system;
- 2) composition of the produced hydrocarbon;
- 3) water content of the production chemical to be applied;
- 4) hydrate inhibitor to be added to production chemical formulation, e.g. ethylene glycol, 2-butoxyethanol, salt, etc.

b) Calculate the following using a simulation tool:

- 1) the hydrate dissociation curve for a pure water; and
- 2) the hydrate dissociation curve for pure water plus increasing fractions of the hydrate inhibitor.

c) Determine the required fraction of hydrate inhibitor to be added to the production chemical formulation to prevent hydrate formation over the full operating range of temperature and pressure.

6.7.2.2.3 Tuned Assessment Based on Freezing Point Suppression

This method which relies on the assumption that the profile of the hydrate dissociation curve over the operating pressure and temperature range is independent of the type of hydrate inhibitor added to the formulation, shall be undertaken by measuring the freezing point of a production chemical formulation in accordance with the following procedure:

a) Establish:

- 1) pressure and temperature range of the chemical injection system;

2) composition of the produced hydrocarbon;

3) freezing point of the production chemical.

NOTE Increasing the proportion of hydrate inhibitor, e.g. ethylene glycol, 2-butoxyethanol, salt, etc., will decrease the solution freezing point.

b) Define a composition that matches the measured freezing point, using a simulation tool, ensuring a match with the freezing point suppression due to the hydrate inhibitor.

NOTE For example, the composition used in the simulation can be a simple water and ethylene glycol, or water and sodium chloride composition. The hydrate inhibitor that will be used in the actual production chemical formulation does not have to be used in the simulation composition. The important requirement is to match the freezing point suppression due to the hydrate inhibitor.

c) Use the simulation tool to calculate hydrate dissociation curve for the composition in the presence of the produced hydrocarbon. Based on the hydrate dissociation curve, establish if the production chemical formulation will form a hydrate at any of the combinations of temperature and pressure of the SPS operating envelope.

d) Repeat the procedure for different production chemical formulations to establish a formulation that does not form a hydrate at the operating conditions.

NOTE 1 Typically, suppression of freezing point by 10 °C will result in hydrate dissociation suppression of ~6.25 °C.

NOTE 2 Freezing point suppression can be dependent on the system pressure due to the dissolution of gas into liquid phase. This can be significant for HP systems.

NOTE 3 See bibliography for further methods.

6.7.2.2.4 Tuned Assessment Based on Single Point Hydrate Dissociation Measurement

This method which relies on the assumption that the profile of the hydrate dissociation curve over the operating pressure and temperature range is independent of the type of hydrate inhibitor added to the formulation, shall be undertaken by measuring a hydrate dissociation point (temperature and pressure) for the production chemical in accordance with the following procedure.

a) Establish:

1) Pressure and temperature range of the chemical injection system.

2) Composition of the produced hydrocarbon.

3) Hydrate dissociation point of the production chemical—see 6.8.3 for description of laboratory method. The measurement should be made at temperature and pressure conditions in the region of the SPS operating envelope.

b) Use a simulation tool to define a composition that matches the measured hydrate dissociation point, e.g. the composition used in the simulation can be a simple water and ethylene glycol, or water and sodium chloride composition. The hydrate inhibitor that will be used in the actual production chemical formulation does not have to be used in the simulation composition. The important requirement is to match the hydrate dissociation point.

c) Use the simulation tool to calculate hydrate dissociation curve for the composition in the presence of the produced hydrocarbon. Based on the hydrate dissociation curve, establish if the production chemical formulation will form a hydrate at the full operating range of temperature and pressure of the SPS.

d) Repeat the procedure for different production chemical formulations to establish a formulation that does not form a hydrate at the operating conditions.

6.7.2.3 Hydrate Dissociation Curve Measurement

6.7.2.3.1 Introduction

Standards for measurement of hydrate dissociation points are not published. However, many laboratory service providers have methods for measurement of hydrate dissociation points. Numerous authors have published details and discussion of the methods.

Methods include the classical thermodynamic method, where hydrate dissociation temperatures vs. pressure curves are determined using pressure vs. temperature measurements in a constant volume cell (PVT). Calorimetric methods such as high pressure differential scanning calorimetry (DSC) can also be used.

6.7.2.3.2 Requirements

General requirements for measurement of hydrate dissociation points shall be as follows.

- a) The capability of a laboratory service provider to accurately measure hydrate dissociation points shall be verified, e.g. measurement of a known hydrate dissociation point.
- b) Hydrate dissociation points shall be measured, as opposed to hydrate formation points. This allows for the sometimes significant degree of subcooling below the hydrate thermodynamic equilibrium that can occur before a hydrate forms.
- c) Replicate measurements shall be made for each dissociation point. At least three dissociation points over the SPS operating range shall be measured.

6.7.3 Interpretation of Results

The production chemical shall not form a hydrate for any of the pressure and temperature combinations that define the operating envelope of the chemical injection system.

6.8 Chemical-Chemical Compatibility

6.8.1 Requirements

Qualification of a production chemical shall be based on determination of its potential for mixing in the conditions to be experienced in the SPS and on evaluation of the compatibility of the mixture components.

NOTE 1 During operation of an SPS, a production chemical in the “as supplied” form can mix with other production chemicals, flushing, installation and commissioning fluids, produced hydrocarbons and sea water. The mixing may be due to system design, a specific operation, human error, or failure of a component of the SPS. Mixing may result in phase separation and formation of solids, deposits and gels that may restrict or block the chemical injection system.

NOTE 2 A compatibility assessment can use existing data, or can be based on a specific laboratory evaluation. Many production chemicals are complex proprietary formulations that can only be reliably assessed for compatibility by laboratory testing. However, published data can be used to screen production chemical formulations for possible compatibility issues.

6.8.2 Procedure

6.8.2.1 Compatibility Assessment Using Existing Data

A compatibility assessment shall take into account the following aspects of a chemical injection system, with respect to the potential for mixing and definition of appropriate assessment and laboratory testing:

- design and normal operation, e.g. injection ports where “as supplied” chemical can mix with other chemicals and produced fluids;

- installation and commissioning, e.g. mixing with installation fluids;
- flushing or change-out operations, e.g. mixing flushing fluid with incumbent fluid due to fluid flow characteristics;
- SPS dead legs and tees;
- injection system component failure, e.g. NRV failure that results in backflow of produced fluids, or other production chemicals into the chemical injection system;
- maintenance, e.g. mixing of “as supplied” chemical with seawater due to hose disconnection during diver operations;

A compatibility matrix across the entire array of chemicals to be used in the intended SPS shall be prepared (see Figure 1). The content of the matrix can be based on existing data, or specific laboratory test data. Example of the range of chemicals that may need to be considered is given in Table 2.

NOTE It is recommended that an assessment of the potential for mixing and consequences include consultation with the responsible subsea engineer, maintenance engineer, equipment vendor, and operations team.

It shall be recognized that static compatibility tests will not definitively determine if a blockage will occur due to incompatibility. The characteristics of an incompatibility shall be used to assess the likelihood of blockage based on the specific characteristics of the production chemical injection system, e.g. connector type restrictions, potential for settling, and accumulation.

	Chemical 1	Chemical 2	Chemical 3	Chemical 4	Chemical 5
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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 (ref 1)		
Chemical 5	Gel on side of test bottle	2 immiscible layers	Large amount of coarse solid		

Key:

	Compatible	Phase separation	Solid precipitation	Gel formation	Emulsion formation
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Figure 1—Example of a Compatibility Matrix

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Key:

Compatible	Phase separation	Solid precipitation	Gel formation	Emulsion formation
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