

Avoidance of Blockages in Subsea Production Control and Chemical Injection Systems

API TECHNICAL REPORT 17TR5
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 (CIF) 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.

While there are universally accepted standards for the design of a SPS and its sub-systems, none of these standards specifically address the subject of blockages and the measures necessary to minimize the risk of such occurrences. The intent of the BASICS JIP is to produce a recommended practice document for global industry use to address the issue using a holistic system approach.

This document is intended to be used as a reference guide by designers and operators of SPSs and also by control and production chemical fluid (PCF) manufacturers. It is also intended to be used as a reference document to enable audits to be undertaken to ensure that blockages avoidance has been properly considered as part of SPS design and operations reviews.

Additionally, the document has been designed to be educational such that persons new to the industry, or, less experienced persons within the industry, can understand the extent and complexity of SPSs and more readily assimilate the blockage avoidance content contained herein.

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Avoidance of Blockages in Subsea Production Control and Chemical Injection Systems

1 Scope

This document addresses the avoidance of blockages in subsea production control and chemical injection systems (CISs). It includes requirements and gives recommendations for the design and operation of subsea production systems (SPSs) with the aim of preventing blockages in control and production chemical fluid (PCF) conduits and associated connectors/fittings.

In the context of design, this covers not only installed subsea hardware (trees, manifolds, etc.), the connecting linkages (jumper arrangements, umbilical systems, etc.), but the fluids to be conveyed, initially from the fluid manufacturers' facilities through to bunkering at the host facility and, ultimately, injection or usage at remote subsea locations.

The guidelines set out the framework within which more detailed specifications and procedures should be developed to address the particular features of specific projects and specific installations in respect of design through to production operations and, ultimately, decommissioning. They also indicate what needs to be taken into account and approaches that can be considered, or may be taken, in order that blockages do not occur during the installation, commissioning and operations of a SPS.

It should be noted, however, that the inclusion of a particular approach identified in the document does not imply it is the only approach. Other approaches may be more suitable; this depends on the nature of the SPS and knowledge and experience of the system and fluid designers.

While the aim of this document is to prevent blockages in a SPS, it also addresses the issues of topside equipment which provides the control and chemical injection (CI) services necessary for the operation and performance of a SPS. **The correct design of a SPS and the fluids to be utilized, and operation of the SPS including topside fluid bunkering, are critically important in avoiding blockages.**

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 Recommended Practice 17A/ISO 13628-1, *Design and Operation Of Subsea Production Systems—General Requirements And Recommendations*

API Specification 17D/ISO 13628-4, *Design and Operation of Subsea Production Systems—Subsea Wellhead And Tree Equipment*

API Specification 17E/ISO 13628-5, *Specification for Subsea Umbilicals*

API Specification 17F/ISO 13628-6, *Specification for Subsea Production Control Systems*

API Recommended Practice 17G/ISO 13628-7, *Recommended Practice for Completion/Workover Riser Systems*

API Recommended Practice 17N, *Recommended Practice—Subsea Production System—Reliability and Technical Risk Management*

API Technical Report 17TR6, *Attributes of Production Chemicals in Subsea Production Systems*

ISO 4407 ¹, *Hydraulic Fluid Power—Fluid Contamination—Determination of Particulate Contamination by the Counting Method Using an Optical Microscope*

ISO 20815, *Petroleum, Petrochemical and Natural Gas Industries—Production Assurance and Reliability Management*

ISO 11014, *Safety Data Sheet for Chemical Products-Part 1: Content and Order of Sections*

SAE AS 4059 (2001) ², *Aerospace Fluid Power—Cleanliness Classification for Hydraulic Fluids*

3 Terms, Definitions, and Abbreviations

It should be noted that in the design, manufacture, installation/commissioning and de-commissioning of a SPS, a wide range of disciplines are involved (project engineers, production chemists, equipment designers, etc.). In some instances, different terminology is used depending on the discipline involved. The general approach to terminology in this document has been to adopt the term considered to have the greater area of usage with cross reference to alternative terminology used by other disciplines.

3.1 Terms and Definitions

The following terms and definitions apply to this document.

3.1.1

blockage

Total or partial loss of flow in a control or chemical injection fluid (CIF) circuit forming part of a SPS.

3.1.2

'brownfield' development

Addition, extension, or re-development of an existing SPS.

3.1.3

bunkering

Process of transferring control/PCFs from their shipping containers into the host facility storage tanks and the subsequent storage in such tanks prior to, or during pumping into the SPS.

3.1.4

chemical injection fluid

See **production chemical fluid**.

3.1.5

chemical injection system

Whole of the chemical injection (CI) arrangement ranging from the host facility equipment through to, and including, the injection equipment at the points of injection; that includes all fluid conduits necessary to transport the PCFs and any intermediate equipment that may be used to distribute PCFs.

3.1.6

completion fluid

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

NOTE Such fluid may have been in the annulus when the well completion (tubulars, screens, packers, etc.) was performed or was circulated into the annulus after well completion. May also be known as **workover fluid**.

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

² Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001, www.sae.org

3.1.7

control fluid

Sometimes referred to as **hydraulic fluid**.

Fluid in a SPS used to transmit both hydraulic signals and power from one location in the system to another location.

NOTE 1 Such fluids may be either oil or water based and contain inhibitors to prevent corrosion, biological growth and to tolerate a degree of seawater ingress without having a significant effect on performance and characteristics.

NOTE 2 Control fluid may be expected to remain in some parts of a SPS for the productive life of the field, thus long term stability is very important.

3.1.8

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.

3.1.9

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 specified service fluid following installation of the equipment.

3.1.10

design

Documentation required to enable production of a product or execution of a service.

NOTE This documentation, or parts thereof, should enable a design or service review to be performed.

3.1.11

design review

Formal, documented comprehensive and systematic examination of a design to evaluate the design and the capability of the design to meet these requirements and to identify problems and proposed solutions.

3.1.12

downhole

Part of a well bore below the mud line.

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 control and PCFs used in a SPS. Also includes fluid conduits used for the conveyance of hydrocarbons as part of annulus bleed or gas lift requirements.

3.1.14

fluid change-out

The replacement of a SPS service fluid by another service fluid, including replacement of delivery fluid by service fluid.

3.1.15

fluid stability

Quality of a fluid being stable whereby the characteristics (chemical, physical, micro-biological) remain unchanged with time, after a disturbance or subject to environmental exposure, (UV, elevated temperature, etc.).

3.1.16**'go/no go' test**

Test involving the use of upper and lower specified limits.

NOTE For measurements/observations above the upper limit and below the lower limit, the test results identify non-compliance with specification requirements. For measurements/observations between the upper and lower limits the results identify compliance.

3.1.17**hydraulic fluid**

See **control fluid**.

3.1.18**host facility**

Offshore platform, floating facility, land based control station to which a SPS is tied-back.

3.1.19**jumper arrangement**

Jumper bundle, jumper assembly, 'flying lead', manipulated tube, etc., used to make short jumper connections in the fluid circuitry, e.g. between an umbilical subsea termination and a tree or manifold.

3.1.20**Key Performance Indicator**

Critical measurement (quantitative or qualitative) of the performance of essential tasks, operations, or processes, for comparison against established norms that allows performance to be assessed.

3.1.21**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.

3.1.22**may**

Indicates a possible course of action.

3.1.23**normative reference**

Details (title, reference number, revision number, etc.) identifying a specific document that provides rules, guidelines or characteristics, for activities or their results.

NOTE The term 'normative reference' is a generic term that covers the references of such documents as standards, technical specifications, codes of practice, and regulations.

3.1.24**process chemical**

See **production chemical**

3.1.25**produced fluid**

Fluid emanating from a well bore or well head arrangement during production operations of a SPS.

3.1.26**production chemical**

The active chemical(s) in a PCF which provides functionality when injected in produced fluid flow-streams.

3.1.27**production chemical fluid**

Fluid transported within SPS CIF conduits providing functionality (corrosion inhibition, asphaltene inhibition, etc.) when injected into produced fluid flow-streams.

NOTE This may also be referred to as **process chemical** or **chemical injection fluid**.

3.1.28**service fluid**

Fluid conveyed by the SPS fluid conduits during operational service.

NOTE 1 Such fluids include CI, control, and gas lift service. May also include produced fluid service where an annulus bleed arrangement forms part of the SPS.

NOTE 2 Service fluid conduits may be exposed to other fluids during well completion, testing, unblocking, fluid change-out (spacer arrangement), and backflow of produced fluid.

3.1.29**shelf life**

Time period in which a fluid remains stable and useable when stored in accordance with the manufacturers storage and handling procedure(s). Also applies to SPS materials of construction, e.g. elastomeric seals.

NOTE Long residence times in SPSs host facilities and onshore bunkering containers need to be considered as part of the shelf life period.

3.1.30**should**

Indicates a preferred course of action or is recommended as good practice.

3.1.31**shut-down**

Short term production cessation from a SPS that arises from such events as planned maintenance, additions to a SPS, emergency actions, etc.

3.1.32**spacer fluid**

Barrier (gas, liquid, gel, foam, etc.) that provides physical separation between two incompatible fluids used during fluid change-out in a fluid circuit.

NOTE This may also be known as **barrier fluid**.

3.1.33**Statutory Instrument**

A form of delegated secondary legislation invoked by Government organizations making detailed provisions in respect of primary legislation.

3.1.34**suspension**

Cessation of production from a SPS for an extended period of time. e.g. FPSO is de-coupled from a SPS to undergo modifications.

3.1.35**test fluid**

A fluid used for test purposes which may not necessarily be the service fluid.

3.1.36**will**

Indicates an intent.

3.2 Abbreviations

The following abbreviated terms apply to this document.

API	American Petroleum Institute
BASICS	Blockage Avoidance in Subsea Injection and Control Systems
CAPEX	capital expenditure
CIF	chemical injection fluid
CI	chemical injection
CIS	chemical injection system
Cv	flow coefficient
CRA	corrosion resistant alloy
DCIV	directional control isolation valve
DV	design verification
FEED	front end engineering design
FMECA	Failure Modes, Effects, and Criticality Analysis
HSE	health, safety, and environment
IBC	intermediate bulk container
ISO	International Organization of Standardization
KPI	Key Performance Indicator
LDHI	low dosage hydrate inhibitor
MSDS	Materials Safety Data Sheet
O&M	operations and maintenance
OPEX	operational expenditure
PCF	production chemical fluid
PPE	personal protective equipment
ppmv	parts per million by volume
PSD	planned shut down
PTFE	polytetrafluoroethylene
ROV	remotely operated vehicle
RP	recommended practice
RV	relief valve
SI	Statutory Instrument
SPS	subsea production system
SCSSV	surface controlled subsea safety valve
SUTU	subsea umbilical termination unit
SUDU	subsea umbilical distribution unit
UNS	unified numbering system
UV	ultra-violet

4 Overview

Blockages in SPS control and CI lines can be the result of many causes, or combinations of causes, ranging from poor design of SPSs/service fluids to bad operational practices. They can occur at any stage in the life of a SPS, including commissioning following installation of the SPS.

SPSs and service fluids used in SPSs are diverse and frequently complex in nature and, once installed, are difficult to access to undertake remedial works. Consequently, design issues need to be addressed during the conceptual/front end engineering design (FEED) stages of projects. Additionally, operational practices need to be addressed at both the design stage and throughout life of the field with awareness training and operational discipline being of paramount importance.

In planning a project, sufficient time needs to be allocated at the start of a subsea development to review and challenge design issues associated with control and CIS. The selection of PCFs with wide ranging design and operational implications is, invariably, far more complicated than the selection of the control fluid for a particular field development. This results from PCFs frequently being field-specific formulations and/or subject to change throughout life of the field.

Remedial work, in an attempt to unblock a fluid line, can be very costly especially if vessel mobilizations are involved. Additional spare fluid lines and jumper arrangements should, therefore, be a consideration as part of the design review process.

While not applicable to the avoidance of blockages in a SPS, the subject matter of de-commissioning has been included. This is to highlight the potential safety issues associated with de-commissioning blocked elements of a SPS.

Additionally, the subject of overcoming blockages is also covered, outlining the limited methods available and the issues to take into account. The potential for blockages when a SPS is temporarily inoperative is also addressed.

In attempting to minimize the risk of blockage occurrence and mitigate against the impact of such blockages, it is recommended that the design, manufacture, installation and operations are subject to a life cycle approach. This will almost certainly have an impact on project capital expenditure (CAPEX), but with a consequent operational expenditure (OPEX) reduction. In not taking this approach, Offshore Operators should be aware of the increased risk of blockages and the not insignificant consequences associated with this risk.

5 Subsea Production System

5.1 Introduction

SPSs allow hydrocarbons to be produced from subsea located wells ultimately tied to, and controlled from, host facilities. Such facilities can range from being located relatively close to an SPS (<5 km) to very great distance (>100 km). Host facilities typically operate in topside temperatures ranging from -20°C to $+40^{\circ}\text{C}$ (depending on latitude, location and exposure to sunlight) whereas the underwater parts of a SPS typically operate in temperatures ranging from -1°C to $+20^{\circ}\text{C}$. In addition to being exposed to these temperatures, fluids used in SPSs may be exposed to elevated temperatures of up to 70°C where the umbilical is installed adjacent to flowline risers in confined environments (e.g. turret, sea-bed trench). For downhole applications, control and PCFs may be exposed to temperatures in excess of 150°C .

Temperature changes can be a major factor in the cause of blockages in a SPS and it is important that temperatures and durations at temperature that can potentially lead to blockages are assessed on a case by case basis.

SPSs may be controlled and serviced by a fixed platform, a floating facility or a land based control center. They can range in complexity from a single well with a simple tie-back arrangement to multi-well arrangements in a daisy-chain

tie-back configuration to a host facility. Increasing complexity of the SPS brings increased risk of blockages in fluid conduits because of the greater number of connectors, the greater number of connections to be made subsea, more fluids to be stored and conveyed, longer residence times, etc.

5.2 Description of Subsea Production System

A SPS typically comprises combinations of the following major items of equipment:

- host facility,
- control system,
- subsea isolation valve(s),
- flowline(s),
- umbilical system(s),
- manifold(s),
- jumper arrangements,
- christmas tree(s),
- well head(s),
- subsea well(s),
- downhole safety valve(s),
- intelligent well systems.

With the majority of these being interconnected or tied back to the host facility by means of fluid conduits to provide operability of the SPS. The arrangement and interconnection of such components is illustrated typically in Annex A. The operation of such a system involves the transfer of control and PCFs from manufacturing facilities to the host facility for bunkering and then onward transmission through small bore fluid conduits generally for use at remote locations.

During field life, a work-over control system will invariably interface with the SPS during well work-over operations involving disconnection and re-connection operations to the SPS.

Fluid conduits typically range in size from $\frac{3}{8}$ in. to 1 in. (9.5 mm to 25.4 mm) in internal diameter with connectors substantially reducing the cross sectional area. Such transmission distances and residence times can be considerable, especially if a closed loop control system is in operation with fluid returning to the host facility. Thus, to minimize the risk of blockages occurring, the fluids must be of low viscosity and free of solids.

Nothing in a SPS, including the reservoir remains constant as a result of such factors as reservoir depletion, field expansion, intervention activities, etc. All control and PCFs must remain robust and unforgiving in the face of changing production conditions. This robustness includes performance, solubility and stability. PCFs which have narrow physical limits or performance ranges are unlikely to be suitable for use in a SPS.

Thus, there is the very high potential for blockages in a SPS should fluid and system design or operational handling and delivery be flawed.

5.3 Fluid Service

5.3.1 General

In considering the subject of blockages in SPSs, it is worth highlighting the purpose of such fluids in such systems.

5.3.2 Control Fluids

Control fluids in a SPS serve to transmit hydraulic power to operate subsea and downhole located actuators or pilot valves and may be water or hydrocarbon based.

5.3.3 Production Chemical Fluids

PCFs serve to provide solutions to a variety of oil and gas field problems such as solids deposition, fluid emulsification and internal corrosion, all of which pose a threat to flow assurance with produced fluids. Such PCFs may also be water or hydrocarbon based but with much wider chemical and physical properties compared with control fluids.

They are very diverse in nature and formulation and are frequently developed as a project-specific product to suit produced fluid formulation at start up and early field life. During the course of the field life, such fluids and their formulations may be subject to change as the nature of the produced fluid changes.

Production chemicals are typically required to be either continuously or intermittently injected into produced fluid flow streams at the well bore, the subsea tree, or a manifold if part of the SPS. The correct and reliable delivery of a production chemical in the form of a PCF is the primary function of the CIS.

The majority of a CIS is located subsea. Hence, subsea environmental data, in particular, subsea operational temperatures and flow regimes may have a significant influence on the physical properties of the PCF and overall system performance.

Downhole CI can be more complex and problematic than conventional subsea injection, primarily as the system is subjected to differential densities between the PCF and produced fluid over potentially long vertical distances. There is also the issue of significant resistance to flow associated with long small bore downhole tubing. For these reasons, it is essential that all downhole CI parameters (pressure, temperature, etc.) are fully and correctly specified early in a project.

5.4 Potential Areas for Blockages Occurrence

Blockages may occur in all parts of a fluid circuit ranging from the point of transmission at the host facility through to the point of use or injection within the SPS.

5.5 Potential Causes of Blockages

Blockages in fluid conduits may arise from errors in one or more of the following:

- system design (e.g. non-corrosion resistant materials of construction);
- fluid design (e.g. chemical reaction between active constituent components of a PCF or between an active constituent component and its solvent base);
- mixing of incompatible fluids during equipment build, flushing, and functional testing phases;
- SPS installation (e.g. seawater ingress, purging of delivery fluid, flushing with an incompatible fluid, improper tube fitting);
- fluid handling (e.g. contaminated transfer pumps/connector assemblies);