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Well testing, clean-up and flowback systems

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Foreword

NORSOK D-007:2021 was adopted as NORSOK Standard 2021-03-09 and published 2021-03-26.

NORSOK D-007:2021 supersedes NORSOK D-007 Rev. 2, September 2013.

NORSOK is an acronym for the competitive position of the Norwegian continental shelf and comprise petroleum industry standards in Norway. The collaboration initiative in 1993 between the authorities and the petroleum industry initiated the development of NORSOK standards.

Reducing the project execution time and developing and operating cost for petroleum installations on the Norwegian shelf was the target.

The intention for the Petroleum industry is to develop and use standards providing good technical and cost effective solutions to ensure that the petroleum resources are exploited and managed in the best possible way by the industry and the authorities. The industry will actively contribute to the development and use of international standards in the global market.

The NORSOK standards shall:

- bridge the gap based on experiences from the Norwegian continental shelf where the international standards are unsatisfactorily;
- replace oil company specifications where possible;
- be available as references for the authorities' regulations;
- be cost effective; and
- promote the Norwegian sector as an attractive area for investments and activities.

Developing new NORSOK standards and regular maintenance of existing standards shall contribute to maintain the competitiveness both nationally and internationally for the Norwegian petroleum industry.

The NORSOK standards are developed by experts from the Norwegian petroleum industry and approved according to the consensus principles as laid down by the guidelines given in [NORSOK A-001N](#) directive.

The NORSOK standards are owned by [the Norwegian Oil and Gas Association](#), [the Federation of Norwegian Industries](#) and [the Norwegian Shipowners' Association](#). The standards are managed and published by [Standards Norway](#).

Annex A through F are normative.

The document title was changed to reflect the extended scope of the document; now also covering clean-up and flow-back operations. The other main changes to this edition are:

- requirements related to “locked to bottom” operations;
- requirements related to flexible flow line;
- requirements related to flexible kill line;
- related to the recognition that the surface test tree and the kill hoses have dual well control functions.

Introduction

The objective of this document is to describe the equipment required to ensure a capable temporary installed well completion and surface well testing system including considerations related to permanent systems used for these types of operations.

This document is valid for both fixed platforms, and mobile drilling and workover units.

The bibliography lists standards, norms, laws, regulations, and other literature that may be relevant to the use of this document.

The use of recognized standards is described in the Framework Regulations, established by the Petroleum Safety Authority Norway, section 24 on the use of recognized norms and associated guidance.

The bibliography lists important regulations that is relevant to this document

Normative text contains the requirements of the standard. Informative text is only guidance to the reader. All text in foreword, introduction and notes is informative text. Note to entries in section 3 and annexes to the document may be either normative or informative.

Well testing, clean-up and flowback systems

1 Scope

This document describes the technical, functional, and operational requirements for temporary well testing, production clean-up and bleed-off equipment and systems. The equipment and systems are used for hydrocarbon flow from exploration or development wells on both mobile units and fixed platforms.

2 Normative references

The following referenced documents contain text which fully or in part is part of the requirements in the document. For dated references, only the edition cited applies. For undated references, the latest edition of the cited document applies (including amendments).

[NORSOK D-001](#), *Drilling facilities*

[NORSOK D-010](#), *Well integrity in drilling and well operations*

[NORSOK P-002](#), *Process system design*

[NORSOK S-001](#), *Technical safety*

[NORSOK S-002](#), *Working environment*

[NORSOK U-001](#), *Subsea production systems*

[NORSOK Z-015](#), *Temporary equipment*

[API Std 521](#), *Pressure-relieving and depressurizing systems*

[API RP 5C1](#), *Recommended practice for care and use of casing and tubing*

[API Spec 5CT](#), *Casing and tubing*

[API RP 14C](#), *Recommended practice for analysis, design, installation, and testing of basic surface safety systems on offshore production platforms*

[API RP 14E](#), *Recommended Practice for Design and Installation of Offshore Products Platform Piping Systems*

[API Spec 16C](#), *Specification for kill and choke system*

[API Spec 16D](#), *Control systems for drilling well control equipment and control systems for diverter equipment*

[DNVGL-RP-A203](#), *Qualification of new technology*

[NOG GL 070](#), *Application of IEC 61508 and IEC 61511 in the Norwegian Petroleum industry (Recommended SIL requirements)*

3 Terms and definitions

In this document, the following terms and definitions apply.

3.1 **shall (requirement)**

expression in the content of a document conveying objectively verifiable criteria to be fulfilled and from which no deviation is permitted if compliance with the document is to be claimed

Note 1 to entry: Requirements are expressed using the verbal forms specified in ISO/IEC Directives, Part 2 clause 7.2 Table 3.

3.2 **should (recommendation)**

expression in the content of a document conveying a suggested possible choice or course of action deemed to be particularly suitable without necessarily mentioning or excluding others

Note 1 to entry: Recommendations are expressed using the verbal forms specified in ISO/IEC Directives, Part 2 clause 7.3 Table 4.

Note 2 to entry: In the negative form, a recommendation is the expression that a suggested possible choice or course of action is not preferred but it is not prohibited.

3.3 **may (permission)**

expression in the content of a document conveying consent or liberty (or opportunity) to do something

Note 1 to entry: Permissions are expressed using the verbal forms specified in ISO/IEC Directives Part 2 clause 7.4 Table 5.

3.4 **can (possibility and capability)**

1: expression in the content of a document conveying expected or conceivable material, physical or causal outcome.

2: expression in the content of a document conveying the ability, fitness, or quality necessary to do or achieve a specified thing

Note 1 to entry: Possibility and capability is expressed using the verbal forms specified in in ISO/IEC Directives, Part 2 clause 7.5 Table 6.

3.5 **bypass**

alternative fluid flow conduit

3.6 **clean-up**

operation conducted on MODU and fixed platforms as a standalone service, or in support of platform permanent process equipment, emptying the well bore and formation of drilling fluids, mud filtrate and other impurities

3.7 **dead-man system**

automatic safety function for subsea wells, activated by loss of electrical or hydraulic control

3.8 **process shutdown system**

PSD

1: system that shuts the hydrocarbon production by stopping the flow from the well on surface.

2: system that can depressurize the well test or production clean-up system in case of a fire or gas situation

3.9

emergency shutdown system

ESD

system that shuts down all main drilling systems

Note 1 to entry: See [NORSOK S-001:2020](#) Clause 11.

3.10

large bore subsea equipment

subsea equipment with internal diameter larger than 5" used for well test operations

3.11

well operation control system

WOCS

combined shutdown and control system for subsea production clean-up and workovers jobs

3.12

zone 0

area in which an explosive gas atmosphere is present continuously or for long periods

3.13

zone 1

area in which an explosive gas atmosphere is likely to occur in normal operation

3.14

zone 2

area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it occurs, will only exist for a short time

3.15

locked to bottom

operational phase when the work string is locked in place, for example the test string locked in by closed pipe rams

3.16

isolate

process control action to enable maintenance operation or emergency repairs

Note 1 to entry: See [NORSOK P-002](#).

3.17

top side flow and processing control equipment

equipment used on the platform or rig down stream the surface tree for managing the well stream

3.18

well control equipment

systems and sub-systems (components, parts, or assemblies) that are used to control pressure within the wellbore

Note 1 to entry: See [API Std 53 \[8\]](#).

3.19

well test tool

tool used downhole and on surface to enable well testing operations

3.20

temporary equipment

equipment for time-limited use onboard platform and requires connection hook-up and/or constitutes a possible ignition source

Note 1 to entry: See [NORSOK Z-015](#).

4 Symbols and abbreviations

For this document, the following symbols and abbreviations apply.

API	American Petroleum Institute
BOP	blowout preventer
ESP	electrical submersible pump
FEMA	failure element mode analyses
HP	high pressure
HPHT	high pressure high temperature
H ₂ S	hydrogen sulphide (gas)
LP	low pressure
MODU	mobile offshore drilling unit
PSV	process shutdown valve
WHP	well head pressure
WSOG	well specific operating guidelines
WTDR	well test design report

5 General principles

Any well test system design shall include barrier descriptions and schematics, in accordance with the requirements of [NORSOK D-010:2021](#) Clause 5 and Clause 7 with associated barrier element acceptance tables in [Annex C](#).

This document is written based on a piping & instrumentation diagram (PID) basis. Thus, a device may be physically positioned on a different unit than as prescribed. For instance, a back-pressure valve is required between two units, but the valve may be included in the description in one or the other unit.

Large bore subsea equipment used for well intervention and well completion operations shall comply with [NORSOK D-001](#) and [NORSOK U-001](#).

6 Functional requirements

6.1 General

SI units or imperial units may be used. The chosen unit shall be clearly identified and consistently used.

6.2 Equipment, tools, and services

6.2.1 General

The well testing equipment is grouped into five categories as detailed below. Equipment selection shall be suitable for the service conditions as provided for in the WTDR (see [6.9](#)).

6.2.2 Downhole well test tools

The downhole equipment shall control the production of reservoir fluids into the test tubing, or the injection of fluids from the tubing into the formation. The downhole equipment shall provide a means of establishing communication between tubing and annulus for well control purposes.

Downhole test tools shall have diameters that are consistent with standard API drifts, including tolerance according to [API Std 5CT](#).

6.2.3 Landing string equipment

The landing string equipment shall enable shutting in the well and allowing a controlled disconnect at BOP level, as required. The landing string equipment shall also provide means for lubricating working tools into the test string. The landing string shall include a shearable handling sub to provide a suitable place for emergency cutting using the BOP shear ram. For jack-up rigs and permanent installations using a surface mounted BOP the same applies, but the controlled disconnect function is not required.

For jack-up rigs and permanent installations using a seabed mounted BOP a hydraulic operated tubing shut-off valve shall be used. The controlled disconnect function is optional, depending on the BOP and marine riser set-up. For jack-up rigs and fixed installations using a nipped up production tree, the same assessments as for completed development wells shall be applied.

For jack-up rigs and fixed installations using a nipped up production tree, safety valves similar to a completed development well shall be applied.

6.2.4 Surface equipment

The surface equipment shall be designed and equipped to:

- 1) assure a high level of phase separation;
- 2) assure accurate measurement of individual phase flows;
- 3) provide for the safe disposal of produced water and hydrocarbons without spill to sea; and
- 4) provide for the safe disposal or preparation for transport of collected solids.

No repair or maintenance shall be performed on surface equipment that breaks containment while the well is flowing. The well shall be shut in and the plant pressure bled down to zero, and a double barrier established vs. the well before any work involving break of containment takes place.

6.2.5 Data acquisition and fluid sampling

The equipment shall accurately acquire, store and handle data and fluid samples such as:

- reservoir pressure and temperature;
- seabed pressure and temperature;
- surface pressure and temperature and flowrates;
- bottom-hole fluid samples;

- surface fluid samples;
- wellsite chemical analysis.

6.2.6 Test tubing

The test tubing shall provide a gastight conduit to surface.

6.3 Performance and output

The engineered service solution provided shall be mobilized, installed, commissioned, operated, maintained, and demobilized according to the WTDR, see [6.9](#).

6.4 Performance level

The complete system (well test-, well clean-up- or well bleed-of package) shall be designed for repeated operations. This shall be one of the objectives and requirements for the spare parts and design strategy. The equipment shall be operated/maintained in such a way that it can fulfil the required operation for the entire planned period.

6.5 Process and ambient conditions

[Table 1](#) describes the performance envelopes for the various operational categories.

Table 1 — Performance envelopes for upstream equipment, including choke manifold

	Normal condition	HPHT conditions ^c	Ultra HPHT conditions
Maximum expected surface pressure	690 bar	1035 bar	Above 1035 bar
Maximum annulus surface pressure	690 bar	1035 bar	Above 1035 bar
Maximum downhole temperature	< 150 °C	> 150 °C	> 175 °C
Maximum expected surface flowing temperature	100 °C	130 °C ^a	Above 130 °C ^a
Minimum design temperature	-20 °C	-20 °C	-20 °C
H ₂ S Service ^b	Yes	Yes	Yes
CO ₂ Service ^b	Yes	Yes	Yes
NOTE			
a) For operations using a production type surface test tree in combination with rigid piping with hub connectors, the limit is 175 °C.			
b) Valid for work on platforms where reservoir properties are well known and when risk of flow back organically formed H ₂ S from annulus/reservoir is evaluated in a risk assessment or hazid.			
c) HPHT: Well with expected shut-in pressure exceeding 690 bar (10 000 psi), and a static bottom hole temperature higher than 150 °C. HP: Well with expected shut-in pressure exceeding 690 bar (10 000 psi). HT: Well with expected static bottom hole temperature higher than 150 °C.			

The above table covers normal ambient conditions. Other conditions such as “Arctic” can necessitate modifications to the above ambient requirements.

All process equipment shall be designed for an offshore marine environment with corrosive and salt containing atmosphere, 100 % relative humidity and ambient temperatures ranging from -20 °C to +30 °C.

6.6 Operational requirements

6.6.1 General

6.6.1.1 Shipping

The equipment shall comply with requirements in [NORSOK Z-015](#).

6.6.1.2 General commissioning requirements

An acceptance test checklist shall be made and completed. The acceptance test checklist shall include sequence for initial and pre-job leak and function testing, including the PSD system.

6.6.2 Well test tools

6.6.2.1 General

All downhole tools shall be drifted with a standard API drift according to [API Spec 5CT](#).

6.6.2.2 Operation of downhole test tools

The downhole test tools shall be operated by either annulus or tubing pressure or by telemetry.

The supplier shall have established procedures that include testing to verify the functionality and pressure integrity of the tool string.

It shall not be possible to unintentionally unseat or pull out of packers regardless of planned well or operational conditions.

The well test string shall be designed such that the well can be killed if the tester valve fails in closed position. Load case verifications shall be performed to determine a safe working envelope.

6.6.2.3 Handling

All test string components shall be designed such that handling on deck and drill floor can be performed safely and efficiently using remotely operated pipe handling system as far as possible.

Wherever pressure can be trapped there shall be means to safely verify such trapped pressure and to safely bleed it off. The risk and the procedure for mitigation shall be included in the well test program.

6.6.3 Landing string equipment

Landing string valves below the drill floor shall allow for well kill operations. To mitigate the effect of heave-compensator lock up during locked to bottom operations, the following shall be in place:

- 1) If the drill string compensator has a lock open feature to avoid lock-up, this shall be activated. Activation shall be included in the pre-operation check list.
- 2) If the rig WSOG (Well Specific Operating Guidelines), with supporting well test string fatigue analysis, rig motion assessments and risk analysis conclude the need for a weak-link system, such shall be in use. The type of system selected shall mitigate the identified risk and shall be described in the WSOG document.
- 3) Maximum allowable heave movement shall be determined, based on maximum allowable landing string elongation and compression and the weak link travel. This information shall be included in the WSOG and posted at the driller's position.

- 4) When reviewing a MODU's heave compensator system vs. locked-to-bottom operations, one shall have a clear assessment of the risks and the appropriate mitigations.
- 5) Technical requirements shall be according to [NORSOK D-001](#). For semisubmersible rigs there shall be a remote readout pressure sensor detecting sudden pressure drop in the tubing string upstream of the flow wing valve, in case of parting of the landing string below the flow-head. The sensor shall trigger automatic closure of the subsea test tree. The sensor is not part of the well test PSD system and is a stand-alone unit shutdown function. In addition, there shall be a manual closing function.

6.6.4 Surface equipment

6.6.4.1 Relief system

The discharge from a pressure relief device shall be routed to and terminated in a safe area, typically 3 m below lower deck level, as defined by a valid gas dispersion study or to the burner boom. The following requirements apply for the relief system:

- 1) A dedicated piping system shall be installed.
- 2) The piping system shall be routed such that there is no chance of a fluid accumulation between any PSV and the system termination point.
- 3) Where the system is routed to the burner booms, the valve(s) diverting flow to the separate burner booms shall be interlocked such that one line to the active burner boom is always open.

For atmospheric tanks:

- 4) vent systems shall be installed; and
- 5) flame arrestor devices shall be installed to prevent air influx

Pressure relief systems shall be designed according to [API Std 521](#).

Pressure relief systems shall be designed to handle the effects of any discharge through the system.

A valid gas dispersion study provided by the rig and covering the design criteria shall be present (see [6.9](#)).

Rupture discs may be used as pressure relief devices, provided they are fitted with rupture indicator and remote read-out. If used, they should be mounted in series with, and downstream of, a PSV.

6.6.4.2 Piping

All temporary piping shall be properly anchored and supported.

All piping not rated to maximum WHP shall be protected from overpressure according to [API RP 14C](#).

Flanged or hub metal to metal seals shall be used for HP connections, and for all permanent piping upstream of the choke manifold.

All piping shall be covered with grating or scaffolding as necessary to ensure unobstructed access and safe working environment according to [NORSOK S-001](#) and [NORSOK S-002](#).

If hoses are used as part of a plant, static electric ignition source assessment should be part of the design considerations.

6.6.4.3 Separator level control

When level systems are responding too slowly for adequate use of level switches, continuous manual monitoring of separator level during operations may be implemented as a replacement for level switches,