BS EN ISO 20815:2018

BSI Standards Publication

Petroleum, petrochemical and natural gas industries - Production assurance and reliability management

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National foreword

This British Standard is the UK implementation of EN ISO 20815:2018. It is identical to ISO 20815:2018. It supersedes BS EN ISO 20815:2010, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PSE/17, Materials and equipment for petroleum, petrochemical and natural gas industries.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Industries du pétrole, de la pétrochimie et du gaz naturel - Assurance de la production et management de la fiabilité (ISO 20815:2018)

Erdöl-, petrochemische und Erdgasindustrie - Betriebsoptimierung und Zuverlässigkeitsmanagement (ISO 20815:2018)

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European foreword

This document (EN ISO 20815:2018) has been prepared by Technical Committee ISO/TC 67 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries" in collaboration with Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries” the secretariat of which is held by NEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2019, and conflicting national standards shall be withdrawn at the latest by May 2019.

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*.

This second edition cancels and replaces the first edition (ISO 20815:2008), which has been technically revised. The main changes compared to the previous edition are as follows:

— Clause 3: several new terms, definitions and abbreviations;

— Clause 4: new 4.1 and new Figure 2;

— Annexes A, B, C and E: minor changes;

— Annex D: various new text and new figures;

— Annex F: new text in Clause F.3, new Clause F.4, and new figure;

— Annex G and H: some changes in Clauses G.2, G.3, H.1 and H.2;

— Annex I: various changes in Clauses I.7 to I.10, I.18 to I.22, and new Clauses I.23 to I.26.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The petroleum, petrochemical and natural gas industries involve large capital investment costs as well as operational expenditures. The profitability of these industries is dependent upon the reliability, availability and maintainability of the systems and components that are used. Therefore, for optimal production availability in the oil and gas business, a standardized, integrated reliability approach is required.

The concept of production assurance, introduced in this document, enables a common understanding with respect to use of reliability technology in the various life cycle phases and covers the activities implemented to achieve and maintain a performance level that is at its optimum in terms of the overall economy and, at the same time, consistent with applicable regulatory and framework conditions.

Annexes A to I are for information only.

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Petroleum, petrochemical and natural gas industries — Production assurance and reliability management

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document describes the concept of production assurance within the systems and operations associated with exploration drilling, exploitation, processing and transport of petroleum, petrochemical and natural gas resources. This document covers upstream (including subsea), midstream and downstream facilities, petrochemical and associated activities. It focuses on production assurance of oil and gas production, processing and associated activities and covers the analysis of reliability and maintenance of the components. This includes a variety of business categories and associated systems/equipment in the oil and gas value chain. Production assurance addresses not only hydrocarbon production, but also associated activities such as drilling, pipeline installation and subsea intervention.

This document provides processes and activities, requirements and guidelines for systematic management, effective planning, execution and use of production assurance and reliability technology. This is to achieve cost-effective solutions over the life cycle of an asset development project structured around the following main elements:

— production assurance management for optimum economy of the facility through all of its life cycle phases, while also considering constraints arising from health, safety, environment, and quality;

— planning, execution and implementation of reliability technology;

— application of reliability and maintenance data;

— reliability-based technology development, design and operational improvement.

The IEC 60300-3 series addresses equipment reliability and maintenance performance in general.

This document designates 12 processes, of which seven are defined as core production assurance processes and addressed in this document. The remaining five processes are denoted as interacting processes and are outside the scope of this document. The interaction of the core production assurance processes with these interacting processes, however, is within the scope of this document as the information flow to and from these latter processes is required to ensure that production assurance requirements can be fulfilled.

The only requirement mandated by this document is the establishment and execution of the production assurance programme (PAP). It is important to reflect the PAP in the overall project management in the project for which it applies.

This document recommends that the listed processes and activities be initiated only if they can be considered to add value.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

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ISO 14224:2016, *Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data for equipment*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
active repair time
effective time to achieve repair of an item

Note 1 to entry: The expectation of the effective time to repair is called MART (mean active repair time).

Note 2 to entry: ISO 14224:2016 distinguishes between the terms mean active repair time (MART), mean time to repair (MTTR), mean time to restoration (MTTRes), and mean overall repairing time (MRT). See ISO 14224:2016, 3.59, 3.63, 3.64 and 3.61 for further details.

Note 3 to entry: The mean active repair time (MART) is defined as "expected active repair time" in ISO/TR 12489:2013, 3.1.34. See also ISO/TR 12489:2013, Figures 5 and 6.

[SOURCE: ISO 14224:2016, 3.2, modified — Notes 1 to 2 to entry have been added.]

3.1.2
availability
ability to be in a state to perform as required

Note 1 to entry: For a binary item, the measure of the availability is the probability to be in up state (i.e. in a state belonging to the up state class), see 3.1.59.

Note 2 to entry: In 3.1.4, the figure shows the system is available at time t_1 and unavailable at time t_2.

Note 3 to entry: See ISO 14224:2016, Annex C for a more detailed description and interpretation of availability.

Note 4 to entry: Technical or operational availability (see ISO 14224:2016, C.2.3.2 and Table E.3) or system availability can be used as derived performance measures. Case specific definition of system availability is needed to reflect the system being addressed.

Note 5 to entry: Further terms are given in ISO/TR 12489:2013.

Note 6 to entry: See Figure G.1 for further information.

[SOURCE: IEC 60050-192:2015, 192-01-23, modified — Notes 1 to 6 to entry have been added.]

3.1.3
barrier
functional grouping of safeguards or controls selected to prevent a major accident or limit the consequences

[SOURCE: ISO 17776:2016, 3.1.1]

3.1.4
binary item
item with two classes of states

Note 1 to entry: The two classes can be 'up state' and 'down state'.

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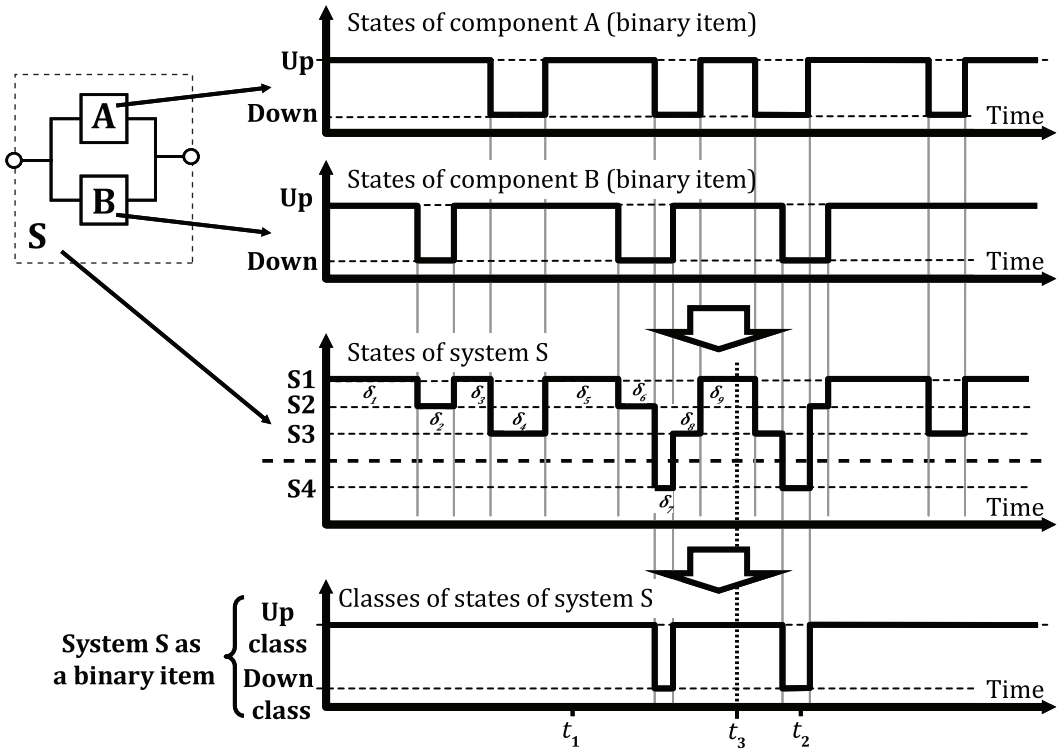
EXAMPLE 1 A usual item with an up state (3.1.59) and a down state (3.1.10) is a binary item. Components A and B in the figure below are binary items.

EXAMPLE 2 A system made up of two redundant binary items, A and B, has four states: S_1 (both A and B in up state), S_2 (A in up state and B in down state), S_3 (A in down state and B in up state), S_4 (both A and B in down state). If the system is able to operate as required in states S_1, S_2 and S_3 and not able in state S_4, it is a binary item with the up state class {S_1, S_2, S_3} and the down class {S_4}. This is illustrated in the Figure showing availability behaviour of an 1oo2 system.



3.1.5
common cause failure
failures of multiple items, which would otherwise be considered independent of one another, resulting from a single cause

Note 1 to entry: See also Notes to entry for common cause failures in ISO 14224:2016, 3.5.

[SOURCE: IEC 60050-192:2015, 192-03-18, modified — Note 1 to entry has been added.]

3.1.6
condition monitoring
obtaining information about physical state or operational parameters

Note 1 to entry: Condition monitoring is used to determine when preventive maintenance may be required.

Note 2 to entry: Condition monitoring may be conducted automatically during operation or at planned intervals.

Note 3 to entry: Condition monitoring is part of condition-based maintenance. See also ISO 14224:2016, Figure 6.

[SOURCE: IEC 60050-192:2015, 192-06-28, modified — Note 3 to entry has been added.]

3.1.7
corrective maintenance
maintenance carried out after fault detection to effect restoration

Note 1 to entry: See also ISO/TR 12489:2013, Figures 5 and 6, which illustrate terms used for quantifying corrective maintenance.

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[SOURCE: IEC 60050-192:2015, 192-06-06, modified — Note 1 to entry has been added.]

3.1.8
deliverability
ratio of deliveries to planned deliveries over a specified period of time, when the effect of compensating elements, such as substitution from other producers and downstream buffer storage, is included

Note 1 to entry: See Figure G.1 for further information.

3.1.9
design life
planned usage time for the total system

Note 1 to entry: to entry It is important not to confuse design life with the 'mean time to failure' (MTTF), which is comprised of several items that might be allowed to fail within the design life of the system as long as repair or replacement is feasible.

3.1.10
down state
unavailable state
internally disabled state
internal disabled state
<of an item> state of being unable to perform as required, due to internal fault, or preventive maintenance

Note 1 to entry: This concept is related to a binary item (3.1.4), which can have several down states forming the down state class of the item. All the states in the down state class are considered to be equivalent with regard to the unavailability of the considered item.

Note 2 to entry: See also Notes to entry for down state in ISO 14224:2016, 3.15.

EXAMPLE In the figure in 3.1.4, the down state class of the system S comprises only one state $\{S_4\}$ and the system S is in down state at time t_2.

[SOURCE: IEC 60050-192:2015, 192-02-20, modified — Notes 1 and 2 have been added.]

3.1.11
down time
time interval during which an item is in a down state

Note 1 to entry: The down time includes all the delays between the item failure and the restoration of its service. Down time can be either planned or unplanned (see ISO 14224:2016, Table 4).

Note 2 to entry: Down time can be equipment down time (see Figure 4 and Table 4 in ISO 14224:2016), production down time (see Figures I.1 and I.2) or down time for other operations (e.g. drilling). It is important to distinguish between the equipment down time itself and the down time of the plant to which the equipment belongs.

[SOURCE: IEC 60050-192:2015, 192-02-21, modified — Notes 1 and 2 have been added.]

3.1.12
downstream
business category most commonly used in the petroleum industry to describe post-production processes

Note 1 to entry: See ISO 14224:2016, A.1.4 for further details.

[SOURCE: ISO 14224:2016, 3.17]

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3.1.13
failure
<of an item> loss of ability to perform as required

Note 1 to entry: A failure of an item is an event that results in a fault (i.e. a state) of that item (see 3.1.18). This is illustrated in the figure in 3.1.50 for a binary system S comprising two redundant components A and B.

[SOURCE: IEC 60050-192:2015, 192-03-01, modified — Note 1 to entry has been added.]

3.1.14
failure cause
root cause
set of circumstances that leads to failure

Note 1 to entry: A failure cause can originate during specification, design, manufacture, installation, operation or maintenance of an item.

Note 2 to entry: See also ISO 14224:2016, B.2.3 and Table B.3, which define failure causes for all equipment classes.

[SOURCE: IEC 60050-192:2015, 192-03-11, modified — Note 2 to entry has been added.]

3.1.15
failure data
data characterizing the occurrence of a failure event

Note 1 to entry: See also ISO 14224:2016, Table 6.

[SOURCE: ISO 14224:2016, 3.25]

3.1.16
failure mode
manner in which failure occurs

Note 1 to entry: See also the tables in ISO 14224:2016, B.2.6, on the relevant failure modes, which define failure modes to be used for each equipment class.

[SOURCE: IEC 60050-192:2015, 192-03-17, modified — Note 1 to entry has been added.]

3.1.17
failure rate
conditional probability per unit of time that the item fails between t and $t + \mathrm{d}t$, provided that it has been working over $[0, t]$

[SOURCE: ISO/TR 12489:2013, modified — Notes 1 to 4 to entry have been added.]

Note 1 to entry: See ISO 14224:2016, C.3 for further explanation of the failure rate.

Note 2 to entry: This definition applies for the first failure of binary items (3.1.4).

Note 3 to entry: Under the assumptions that the failure rate is constant and that the item is as good as new after repairs the failure rate can be estimated as the number of failures relative to the corresponding accumulated up time divided by this accumulated up time. In this case this is the reciprocal of MTTF (3.1.34). In some cases, time can be replaced by units of use.

Note 4 to entry: The estimation of the failure rate can be based on operating time or calendar time.

3.1.18
fault
<of an item> inability to perform as required, due to an internal state

Note 1 to entry: A fault of an item results from a failure, either of the item itself, or from a deficiency in an earlier stage of the life cycle, such as specification, design, manufacture or maintenance. See latent fault (ISO 14224:2016, 3.44). The down states of items A, B and S in the figure in 3.1.46 are examples of faults.

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Note 2 to entry: An item made of several sub-items (e.g. a system) which continues to perform as required in presence of faults of one or several sub-items is called fault tolerant.

Note 3 to entry: See also ISO/TR 12489:2013, 3.2.2.

[SOURCE: IEC 60050-192:2015, 192-04-01, modified — Note 2 to entry has been added.]

3.1.19
fault tolerance
attribute of an item that makes it able to perform a required function in the presence of certain given sub-item faults

3.1.20
human error
discrepancy between the human action taken or omitted and that intended

EXAMPLE Performing an incorrect action; omitting a required action.

Note 1 to entry: Discrepancy with intention is considered essential in determining human error; see Reference[81].

Note 2 to entry: The term "human error" is often attributed in hindsight to a human decision, action or inaction considered to be an initiator or contributory cause of a negative outcome such as loss or harm.

Note 3 to entry: In human reliability assessment, human error is defined as any member of a set of human actions or activities that exceeds some limit of acceptability, this being an out of tolerance action or failure to act where the limits of performance are defined by the system (see Reference[78]).

Note 4 to entry: See also IEC 62508:2010 for further details.

Note 5 to entry: See also ISO/TR 12489:2013, 5.5.2.

[SOURCE: IEC 60050-192:2015, 192-03-14, modified — Notes 1 through 5 to entry have been added.]

3.1.21
instantaneous availability
$A(t)$
probability that an item is in a state to perform as required at a given instant

[SOURCE: IEC 60050-192:2015, 192-08-01]

3.1.22
integrity
ability of a barrier to function as required when needed

Note 1 to entry: See 3.1.2 in ISO/TR 12489:2013 for definition of safety integrity.

Note 2 to entry: There are different definitions of integrity: plant, asset, system, pipeline (see DNVGL-ST-F101: 2017), well (see ISO 16530-1:2017, 3.73), mechanical, safety (see ISO/TR 12489:2013, 3.1.2), structural (see ISO 19900:—, 3.47) and technical.

3.1.23
item
subject being considered

Note 1 to entry: The item can be an individual part, component, device, functional unit, equipment, subsystem, or system.

Note 2 to entry: The item may consist of hardware, software, people or any combination thereof.

Note 3 to entry: In this document, item can also be plant/unit and installation. See ISO 14224:2016, Figure 3.

[SOURCE: IEC 60050-192:2015, 192-01-01, modified — Note 3 to entry has been added.]

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3.1.24
logistic delay
delay, excluding administrative delay, incurred for the provision of resources needed for a maintenance action to proceed or continue

Note 1 to entry: Logistic delays can be due to, for example, travelling to unattended installations, pending arrival of spare parts, specialists, test equipment and information, and delays due to unsuitable environmental conditions (e.g. waiting on weather).

Note 2 to entry: See also ISO/TR 12489:2013, Figure 5.

[SOURCE: IEC 60050-192:2015, 192-07-13, modified — Notes 1 and 2 to entry have been added.]

3.1.25
lost revenue
total cost of lost or deferred production due to down time

3.1.26
maintainability
<of an item> ability to be retained in, or restored to a state to perform as required, under given conditions of use and maintenance

Note 1 to entry: Given conditions would include aspects that affect maintainability, such as: location for maintenance, accessibility, maintenance procedures and maintenance resources.

Note 2 to entry: Maintainability can be quantified using appropriate measures. See IEC 60050-192:2015, 192-07-Maintainability and maintenance support: measures.

Note 3 to entry: See Figure G.1 for further information.

[SOURCE: IEC 60050-192:2015, 192-01-27, modified — Note 3 to entry has been added.]

3.1.27
maintainable item
item that constitutes a part or an assembly of parts that is normally the lowest level in the equipment hierarchy during maintenance

[SOURCE: ISO 14224:2016, 3.48]

3.1.28
maintenance
combination of all technical and management actions intended to retain an item in, or restore it to, a state in which it can perform as required

[SOURCE: IEC 60050-192:2015, 192-06-01]

3.1.29
maintenance data
data characterizing the maintenance action planned or done

Note 1 to entry: See also ISO 14224:2016, Table 8.

[SOURCE: ISO 14224:2016, 3.51]

3.1.30
maintenance management
all activities of the management that determine the maintenance requirements, objectives, strategies, and responsibilities, and implementation of them by such means as maintenance planning, maintenance control and the improvement of maintenance activities and economics

[SOURCE: EN 13306:2017, 2.2]

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3.1.31
maintenance supportability
supportability
<of an item> ability to be supported to sustain the required availability with a defined operational profile and given logistic and maintenance resources

Note 1 to entry: Supportability of an item results from the inherent maintainability (3.1.26), combined with factors external to the item that affect the relative ease of providing the required maintenance and logistic support.

Note 2 to entry: See ISO 14224:2016, Annex C for further details regarding the interpretation of maintainability.

[SOURCE: IEC 60050-192:2015, 192-01-31, modified — Note 2 to entry has been added.]

3.1.32
major accident
hazardous event that results in multiple fatalities or severe injuries; or extensive damage to structure, installation or plant; or large-scale impact on the environment

Note 1 to entry: Examples of large-scale impact on the environment are persistent and severe environmental damage that can lead to loss of commercial or recreational use, loss of natural resources over a wide area or severe environmental damage that will require extensive measures to restore beneficial uses of the environment.

Note 2 to entry: In ISO 17776:2016, a major accident is the realization of a major accident hazard.

[SOURCE: ISO 17776:2016, 3.1.12]

3.1.33
mean availability
average availability
$A(t_1, t_2)$
average value of the instantaneous availability over a given time interval $[t_1, t_2]$

[SOURCE: IEC 60050-192:2015, 192-08-01, modified — Note 1 to entry has been added.]

Note 1 to entry: The average availability is the ratio between the accumulated time spent in up state and the length of the considered period of observation. For example, in 3.1.4 the figure shows the average availability of the system over the interval $[0, t_3]$ is equal to $(\delta_1 + \delta_2 + \delta_3 + \delta_4 + \delta_5 + \delta_6 + \delta_8 + \delta_9)/t_3$, i.e. $1-\delta_7/t_3$ where δ_7/t_3 is the average unavailability of the system. This formula is similar to the formula obtained for production availability calculations when only two levels, 100 % and 0 %, are considered.

3.1.34
mean time to failure
MTTF
expected time before the item fails

Note 1 to entry: See further details in ISO/TR 12489:2013, 3.1.29.

Note 2 to entry: IEC 60050-192:2015 defines MTTF as ”expectation of the operating time to failure”.

Note 3 to entry: See also ISO 14224:2016, Annex C.

[SOURCE: ISO/TR 12489:2013, 3.1.29, modified — Notes 1 through 3 to entry have been added.]

3.1.35
midstream
business category involving the processing, storage and transportation sectors of the petroleum industry

Note 1 to entry: See ISO 14224:2016, A.1.4 for further details.

[SOURCE: ISO 14224:2016, 3.65]

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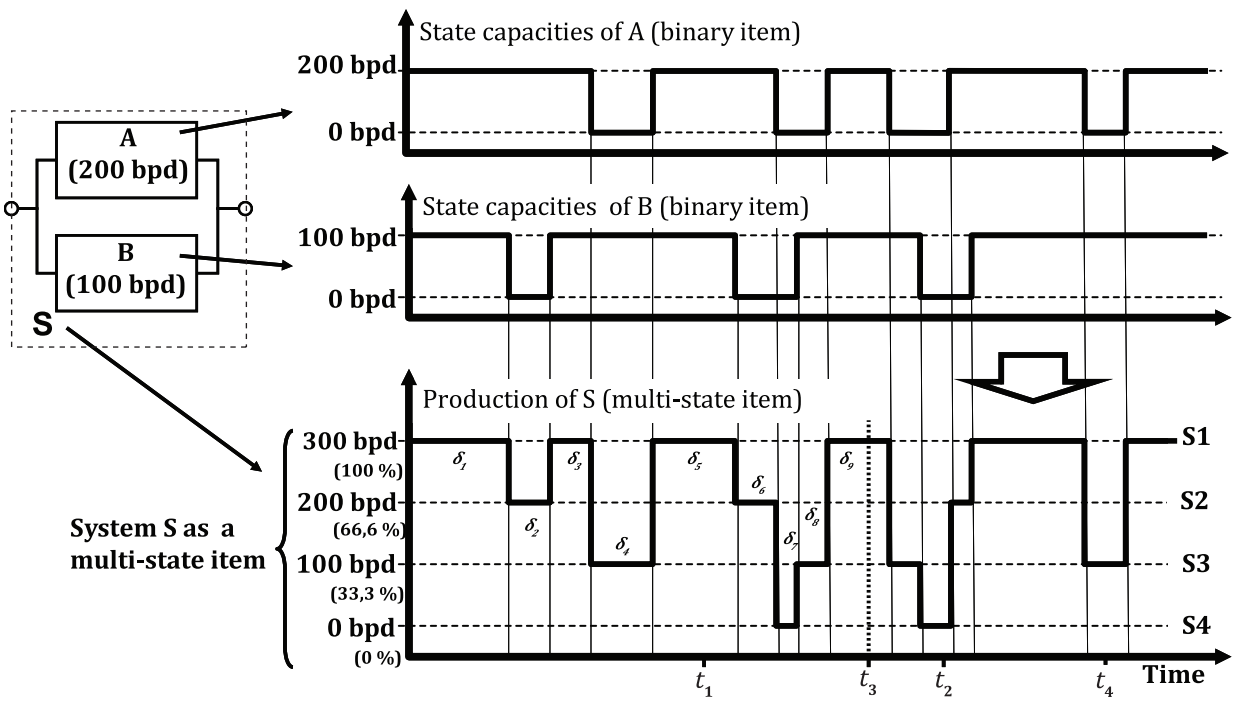
3.1.36
modification
combination of all technical and administrative actions intended to change an item

[SOURCE: ISO 14224:2016, 3.67]

3.1.37
multi-state item
item with more than two classes of states

Note 1 to entry: This is an extension of the binary items beyond the concepts of up and down states. This can characterize single items with degraded states or systems made up of several components.

EXAMPLE An oil production system comprising two wells, A and B, that can be considered as binary items (see 3.1.3) has four states: S_1 (both A and B in up state), S_2 (A in up state and B in down state), S_3 (A in down state and B in up state), S_4 (both A and B in down state). If, when they are in up state, A produces 200 bpd (barrels per day) and B produces 100 bpd, then the system has four classes of production 300 bpd, {S_1},200 bpd, {S_2}, 100 bpd, {S_3} and 0 bpd, {S_4}. With regards to oil production, it is a multi-state item. This is illustrated in the figure showing production availability behaviour of a multi-state system.



3.1.38
observation period
time period during which production performance and reliability data are recorded

3.1.39
operating state
<of an item> state of performing as required

Note 1 to entry: See also ISO 14224:2016, Table 4.

Note 2 to entry: In some applications, an item in an idle state is considered to be operating.

Note 3 to entry: The state capacities of a multi-state item characterize various levels of operation and consequently, the definition of the operating state of a multi-state item depends on the situation, for example, if:

— no other requirement is given, any state with a capacity greater than zero is an operating state;

— a minimum capacity is required, it provides the limit to split the states between up and down classes;

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— a given capacity is specified, then only the states with this capacity are operating states;

— no other requirement is given, any state with a capacity greater than zero is an operating state (300 bpd, 200 bpd and 100 bpd in the figure in 3.1.37);

— a minimum capacity is required, it provides the limit to split the states between up and down classes (300 bpd, 200 bpd in the figure in 3.1.37, if the minimum allowed production is 200 bpd);

— a given capacity is specified, then only the states with this capacity are operating states (200 bpd in the figure in 3.1.37 if and only if 200 bpd are required).

[SOURCE: IEC 60050-192:2015, 192-02-04, modified — Notes 1 and 3 to entry have been added.]

3.1.40
operating time
time interval during which an item is in an operating state

Note 1 to entry: The accumulated times of various disjunct operating times interrupted by e.g. unplanned or planned down time is also called operating time.

Note 2 to entry: Sometimes the term "running time" is used instead of "operating time". Often the running time describes the active part of the operating time, see Table 4 in ISO 14224:2016. Whether rundown or start-up period is included depends on equipment, but hot-standby time is not included even though some equipment functions can be active to minimize start-up time in e.g. redundant configuration ("hot standby").

Note 3 to entry: Running hours during testing is also called running hours, even though this is at test conditions.

[SOURCE: IEC 60050-192:2015, 192-02-05, modified — Notes 1 to 3 to entry have been added.]

3.1.41
performance objective
indicative level for the desired performance

Note 1 to entry: Objectives are expressed in qualitative or quantitative terms. Objectives are not absolute requirements and may be modified based on cost or technical constraints. See further details in Annex F.

3.1.42
performance requirement
required minimum level for the performance of a system

Note 1 to entry: Requirements are normally quantitative, but may also be qualitative.

3.1.43
petrochemical
business category producing the chemicals derived from petroleum and used as feedstock for the manufacture of a variety of plastics and other related products

Note 1 to entry: See ISO 14224:2016, A.1.4 for further details.

[SOURCE: ISO 14224:2016, 3.75]

3.1.44
preventive maintenance
maintenance carried out to mitigate degradation and reduce the probability of failure

Note 1 to entry: See also condition-based maintenance, and planned (scheduled) maintenance.

[SOURCE: IEC 60050-192:2015, 192-06-05]

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3.1.45
production assurance
activities implemented to achieve and maintain a performance that is at its optimum in terms of the overall economy and at the same time consistent with applicable framework conditions

Note 1 to entry: Production assurance in this document is not only limited to cover production of oil and gas, but can also be other activities such as drilling operations, downhole well intervention, subsea intervention, offshore loading operations, for which production assurance activities and reliability management are needed.

Note 2 to entry: Production assurance activities relate closely to the integrity management of the installations. See definition of integrity in 3.1.22.

3.1.46
production availability
ratio of production to planned production, or any other reference level, over a specified period of time

Note 1 to entry: Production availability is an extension of the mean availability (3.1.33) to deal with multi-state items. It is the ratio between the accumulated production delivered over a given interval of time and a reference production level defined for this interval. For example, in 3.1.4, the figure shows the production availability of the system over the interval $[0, t_3]$ is equal to $[300 \cdot (\delta 1 + \delta_3 + \delta_5 + \delta_9) + 200 \cdot (\delta_2 + \delta_6) + 100 \cdot (\delta_4 + \delta_8)] / (300 \cdot t_3)$ provided the reference production level is 300 bpd at any time. By dividing by 300, this formula can also be written $[(\delta_1 + \delta_3 + \delta_5 + \delta_9) + 66{,}6\ \% \cdot (\delta_2 + \delta_6) + 33{,}3\ \% \cdot (\delta_4 + \delta_8)] / t_3$.

Note 2 to entry: This measure is used in conjunction with analysis of delimited systems without compensating elements such as substitution from other producers and downstream buffer storage. Battery limits need to be defined in each case.

Note 3 to entry: See G.1 and Figure G.1 for further information. Examples of production loss categories (or time loss categories) are shown in Tables G.1 to G.6.

Note 4 to entry: Production efficiency (PE) is a term often used by operators for historic production availability in the operating phase and is a reported measure, but is in principle the same measure as predicted production availability that is a modelled measure. This document uses the term production availability.

Note 5 to entry: For offshore and onshore loading systems, some special performance measures exist when undertaking loading performance analyses, see further details of such metrics in I.26.

3.1.47
production performance
capacity of a system to meet demand for deliveries or performance

Note 1 to entry: Production availability, deliverability or other appropriate measures can be used to express production performance.

Note 2 to entry: The use of production performance terms should specify whether it represents a predicted or historic production performance.

3.1.48
production performance analysis
systematic evaluations and calculations carried out to assess the production performance of a system

Note 1 to entry: The term should be used primarily for analysis of whole systems, but may also be used for analysis of production unavailability of sub-systems. Annex D provides guidance for planning and reporting such analysis, and parts of Annex D can also be useful for loading performance analysis.

Note 2 to entry: Loading performance analysis is a particular type of production performance analysis focussing on offshore and onshore loading operations, which e.g. use metocean data to analyse weather impact on such operations (see I.25 and I.26).

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3.1.49
redundancy
existence of more than one means for performing a required function of an item

Note 1 to entry: See ISO 14224:2016, C.1.2 for further details, where passive (cold), active (hot) standby and mixed redundancy are described.

Note 2 to entry: Redundancy in IEC 61508-1:2016 is called "fault tolerance".

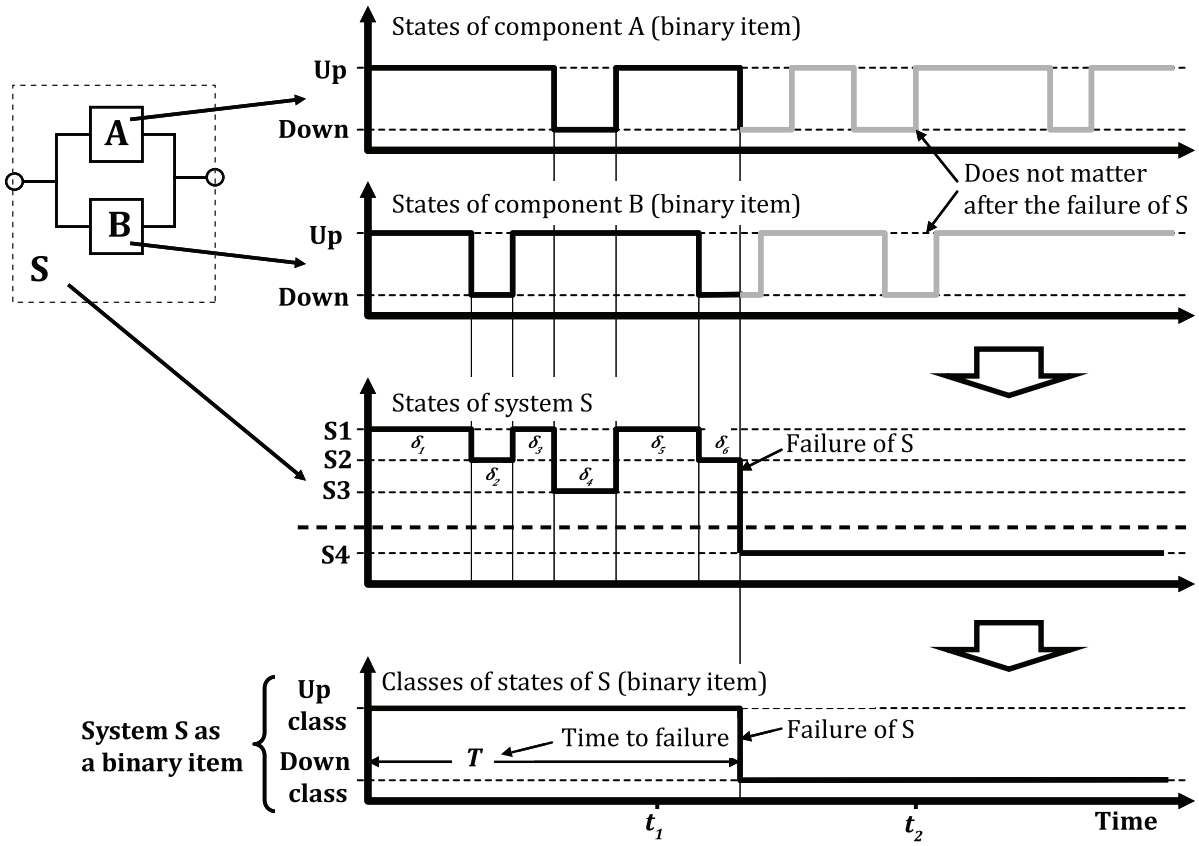
Note 3 to entry: IEC 60050-192:2015, 192-10-02 defines redundancy as "provision of more than one means for performing a function".

[SOURCE: ISO 14224:2016, 3.80]

3.1.50
reliability
ability of an item to perform a required function under given conditions for a given time interval

Note 1 to entry: The term "reliability" is also used as a measure of reliability performance and may also be expressed as a probability (see 3.1.57).

Note 2 to entry: In the figure below reliability is illustrated for a system S comprising two redundant components A and B. The system is reliable all over the interval [0, t_1] but has had a failure during [0, t_2]. See also Figure G.1 for further information.



[SOURCE: ISO 14224:2016, 3.81, modified — Notes 1 and 2 to entry have been added.]

3.1.51
reliability data
data for reliability, maintainability and maintenance support performance

[SOURCE: ISO 14224:2016, 3.84]

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3.1.52
reliability management
activities undertaken to achieve reliability related performance objectives and requirements

Note 1 to entry: Reliability management reflects production assurance activities on equipment and system level. In project/product–development and design phases this is often called "reliability engineering".

Note 2 to entry: A reliability management programme (RMP) can be used to describe such activities, see A.1.

3.1.53
required function
function, or combination of functions, of an item that is considered necessary to provide a given service

[SOURCE: ISO 14224:2016, 3.83]

3.1.54
risk
combination of the probability of an event and the consequences of the event

Note 1 to entry: This definition is based on ISO/IEC Guide 51:2014, 3.9 that defines risk as combination of the probability of occurrence of harm and the severity of that harm, where the probability of occurrence includes the exposure to a hazardous situation, the occurrence of a hazardous event and the possibility to avoid or limit the harm. "Harm" has been replaced by "event" in the definition to cope with production assurance purpose. It is also similar to the definition of the "level of risk" given in ISO Guide 73:2009, 3.6.1.8 (i.e. "combination of consequences and their likelihood").

Note 2 to entry: Events leading to production losses are considered within the production assurance field.

3.1.55
risk register
record of information about identified risks

[SOURCE: ISO Guide 73:2009, 3.8.2.4]

3.1.56
state capacity
state efficiency
processing ability of an item state

Note 1 to entry: The capacity of an item state is related to the amount of production the item is able to produce or process in this state. For example, in the figure in 3.1.33, component A has a capacity of 200 bpd.

EXAMPLE 1 A single oil production well with two states (binary item, 3.1.4) has, for example, a capacity of 100 barrels per day (bpd) when it is in up state and of 0 bpd when it is in down state (see component B in the figure in 3.1.33).

EXAMPLE 2 An oil production system made up of two wells, A and B, producing respectively 200 bpd and 100 bpd, has four states. This is illustrated in the figure in 3.1.37:

— S_1 (A and B producing) : capacity = 300 bpd;

— S_2 (A producing alone) : capacity = 200 bpd;

— S_3 (B producing alone) : capacity = 100 bpd;

— S_4 (A and B failed) : capacity = 0 bpd.

When the reference value is non-ambiguous, the capacity can be given in percentage. For example, with regard to the maximum capacity of the producing system, the capacity of S_1 is 100 %, the capacity of S_2 is 66,6 %, the capacity of S_3 is 33,3 % and the capacity of S_4 is 0 %.

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3.1.57
survival probability
reliability <measure>
$R(t)$
likelihood of the continued functioning of an item

Note 1 to entry: This likelihood is calculated by using Formula (1):

$$R(t) = \Pr(T > t) \quad (1)$$

where $\Pr(T > t)$ is the probability that the time to failure of an item, T, is greater than t, a time equal to or greater than 0.

Note 2 to entry: Reliability is illustrated in the figure in 3.1.50 for a system S comprising two redundant components A and B. As $T > t_1$ the system is reliable all over the interval $[0, t_1]$ and is surviving at time t_1. As $T < t_2$ the system is not surviving at time t_2.

3.1.58
technology qualification
process of providing evidence that the technology will perform as required for the specified application area

Note 1 to entry: The requirements include both functional (technical and operational) and associated reliability requirements for its design life. Application area refers to the operating conditions, environment or purpose for which the technology will be used.

Note 2 to entry: See further information in C.3 and I.21.

3.1.59
up state
available state
<of an item> state of being able to perform as required

Note 1 to entry: This concept is related to a binary item (3.1.4), which can have several up states forming the up state class of the item. All the states in the up state class are considered to be equivalent with regard to the availability of the considered item.

Note 2 to entry: Up state relates to the availability performance (3.1.2) of the item.

Note 3 to entry: See also ISO/TR 12489:2013, Figure 5.

EXAMPLE In the figure in 3.1.4, the up state class of the system S comprises three states $\{S_1, S_2, S_3\}$ and the system is in up state at time t_1.

[SOURCE: IEC 60050-192:2015, 192-02-01, modified — Notes 1 to 3 to entry have been added.]

3.1.60
up time
time interval during which an item is in an up state

Note 1 to entry: See also ISO/TR 12489:2013, Figure 3.

Note 2 to entry: Mean up time is defined in IEC 60050-192:2015 as “expectation of the up time”.

[SOURCE: ISO 14224:2016, 3.97]

3.1.61
upstream
business category of the petroleum industry involving exploration and production

Note 1 to entry: See ISO 14224:2016, A.1.4 for further details.

[SOURCE: ISO 14224:2016, 3.98]

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3.1.62
variability
variations in performance measures for different time periods under defined framework conditions

Note 1 to entry: The variations can be a result of the down time pattern for equipment and systems or operating factors, such as wind, waves and access to certain repair resources.

3.2 Abbreviations

ALT	accelerated life testing
BBN	Bayesian belief network
BOP	blowout preventer
bpd	barrels per day
CAPEX	capital expenditures
CMMIS	computerized maintenance management information system
DHSV	downhole safety valve
ESD	emergency shut down
FAT	factory acceptance test
FEED	front-end engineering and design
FMEA	failure modes and effects analysis
FMECA	failure modes, effects and criticality analysis
FN	flow network
FNA	flow network analysis
FPSO	floating production, storage and offloading
FSU	floating storage unit
FTA	fault tree analysis
HALT	highly accelerated life testing
HAZOP	hazard and operability (study)
HASS	highly accelerated stress screening
HSE	health, safety and environment
ITT	invitation to tender
KPI	key performance indicator
LCC	life cycle cost
LNG	liquefied natural gases
LOSTREV	lost revenue

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LTE	life time extension
MART	mean active repair time
MDT	mean down time
METBF	mean elapsed time between failures
MODU	mobile offshore drilling unit
MPA	Markov process analysis
MRT	mean overall repairing time
MTTF	mean time to failure
MTTR	mean time to repair
MTTRes	mean time to restoration
MUT	mean up time
NPV	net present value
OPEX	operational expenditure
PAP	production assurance programme
PE	production efficiency
PFD	process flow diagrams
PID	process instrumentation diagrams
PM	preventive maintenance
PN	Petri nets
PNA	Petri net analysis
POR	performance and operability review
QA	quality assurance
QRA	quantitative risk analysis
RBD	reliability block diagram
RBI	risk-based inspection
RCM	reliability-centred maintenance
RM	reliability and maintainability
RMP	reliability management programme
ROV	remote operated vehicle
SAT	site acceptance test
SCM	subsea control module

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SEM	subsea electronic module
SIL	safety integrity level
SIMOPS	simultaneous operations
SISV	subsea intervention and support vessel
SIT	system integration test
SRA	structural reliability analysis
SSIV	subsea isolation valve
TNC	technology novelty category
TQP	technology qualification programme
TRL	technology readiness level

4 Production assurance and decision support

4.1 Users of this document

This document is intended for users such as the following.

— Installation/plant/facility: Operating facility, e.g. safety, maintenance and engineering personnel.

— Owner/operator/company: Reliability staff or others analysing or responsible for production assurance, reliability management and associated activities. Other stakeholders are technology developers, concept and system planners, HSE staff, integrity management, maintenance management and professional subject-matter experts that manage and assess plants/system/equipment performance with respect to production assurance (production availability, system availability, equipment reliability, etc.).

— Manufacturer/designer and supplier: Use of reliability management activities in technology development, technology qualification, system design to ensure product quality and improvements, etc.

— Authority/regulatory body: Regulatory requirements that can refer to this document to enhance HSE, production availability, system availability, maintenance and resource utilisation.

— Consultant/contractor: Use of production assurance activities to support reliability management and undertaking reliability studies, analysis of production availability, system availability, maintenance, etc.

4.2 Framework conditions

The objective associated with systematic production assurance is to contribute to the alignment of design and operational decisions with corporate business objectives. Production assurance and reliability management activities also support quality management (see ISO 9000:2015, ISO 9001:2015 and ISO/TS 29001:2010).

In order to fulfil this objective, technical and operational measures as illustrated in Figure 1 may be used during design or operation to influence the production performance. Figure 1 shows measures that to a greater or lesser extent can have an effect on production performance. Some of these measures are purely technical and it is necessary that they will be adhered to in design; others are related purely to operation. Most of the measures have both technical and operational aspects, e.g. a bypass cannot be

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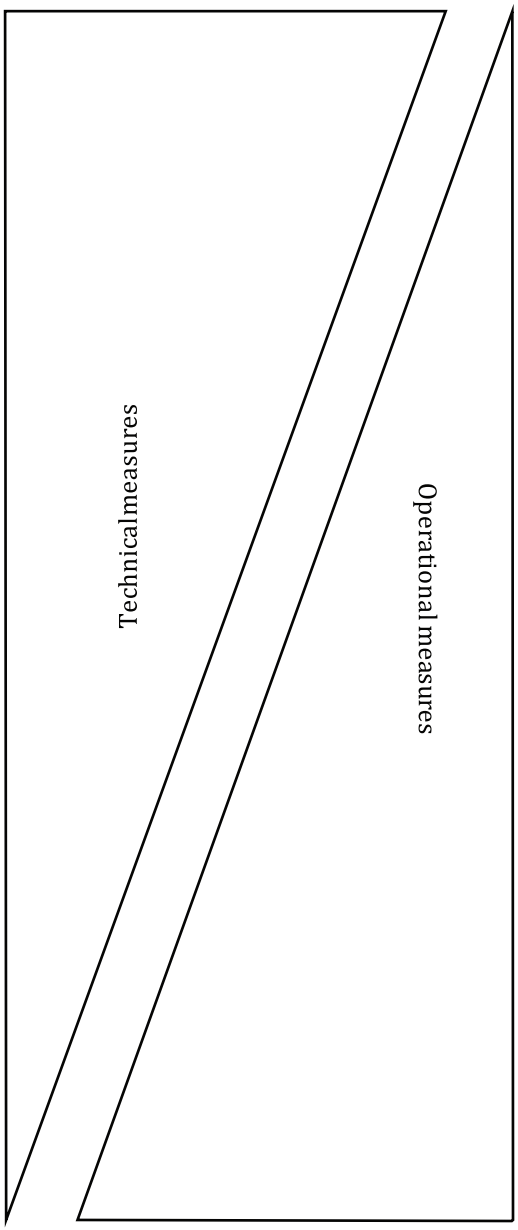
used in the operational phase unless provisions have been made for it in the design phase. In addition, there are dependencies between many of the listed measures.



Choice of technology

Redundancy at system level

Redundancy at equipment or component level

Functional dependencies

Capacities

Instrumentation/automation philosophy

Reduced complexity

Material selection

Selection of manufacturer

Man-machine interface

Ergonomic design

Protection from the environment

Reliability testing

Self-diagnosis

Buffer and standby storage

Bypass

Flaring

Utilization of design margins

Spare parts

Maintenance strategy

Maintenance support

Operational philosophy

Figure 1 — Typical technical and operational measures that affect production performance

This imposes two important recommendations for production assurance to be efficient:

— production assurance should be carried out throughout all project design and operational phases;

— production assurance should have a broad coverage of project activities.

An overview of cost and revenue factors to considered in conjunction with the economic optimization is shown in Figure 2. These factors can be used to better prioritize and understand the production assurance activities with respect to life cycle cost elements (CAPEX, OPEX and LOSTREV). The economic decision criteria depend on company as well as the business context (e.g. concept selection, field development, system configuration) that is subject to decision.

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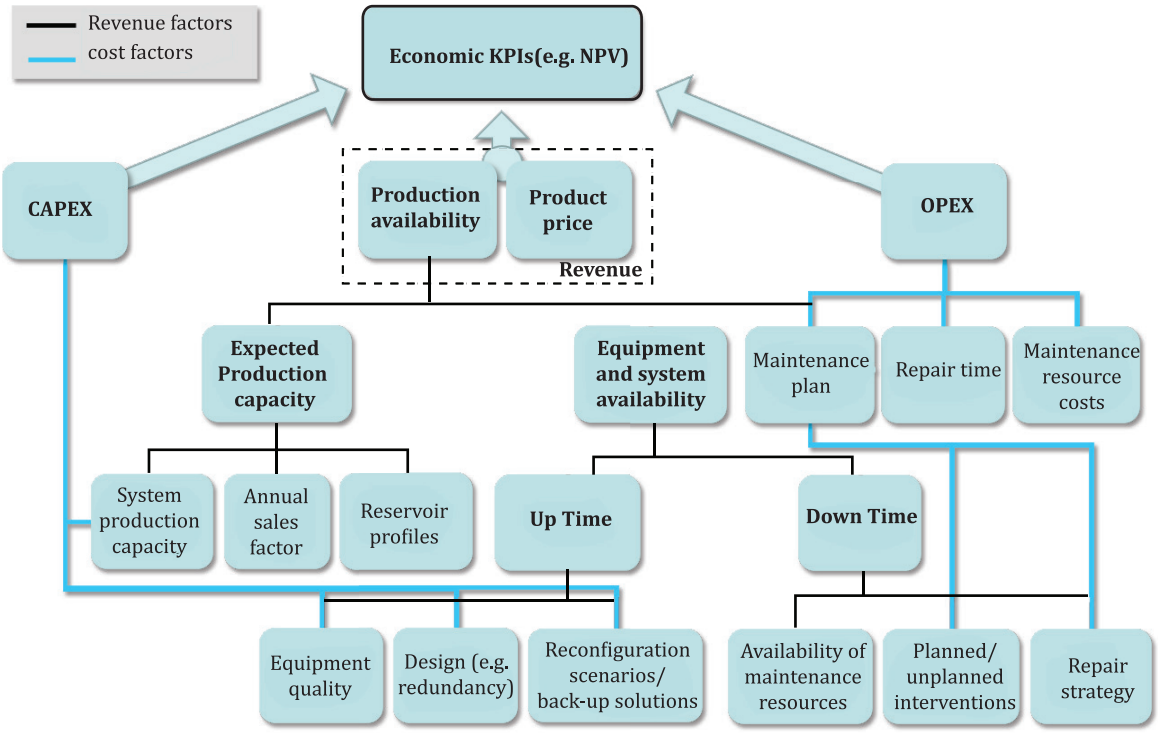

Figure 2 — Business model: Influence factors of production assurance on project economy

4.3 Optimization process

The main principle for optimization of design or selection between alternative design solutions is economic optimization within given constraints and framework conditions. The achievement of high performance is of limited importance, unless the associated costs are considered. Therefore, this document can be considered together with ISO 15663 (all parts).

Examples of constraints and framework conditions that affect the optimization process are:

— statutory health, safety and environmental regulations;

— requirements for safety equipment resulting from the risk analysis and the overall safety acceptance criteria;

— requirements to design or operation given by statutory and other regulatory bodies' regulations;

— project constraints, such as budget, implementation time, national and international agreements;

— conditions in the sales contracts;

— technical constraints.

The optimization process can be seen as a series of steps as follows (see Figure 3 for an illustration).

a) Assess the project requirements and generate designs that are capable of meeting the project requirements.

b) Identify all statutory, regulatory and other framework requirements that apply to the project.

c) Predict the appropriate production assurance parameters.

d) Identify the preferred design solution based on an economical evaluation/analysis, such as net present value analysis or another optimization criterion.

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e) Apply the optimization process as illustrated in Figure 3. Be aware that the execution of the optimization process requires that the production assurance and reliability function should be addressed by qualified team members.

f) If required, the process can be iterative, where the selected alternative is further refined and alternative solutions are identified. The iterative process is typical for "gated" or threshold project-execution phases.

g) Sensitivity analyses may be performed to take account of uncertainty in important input parameters.

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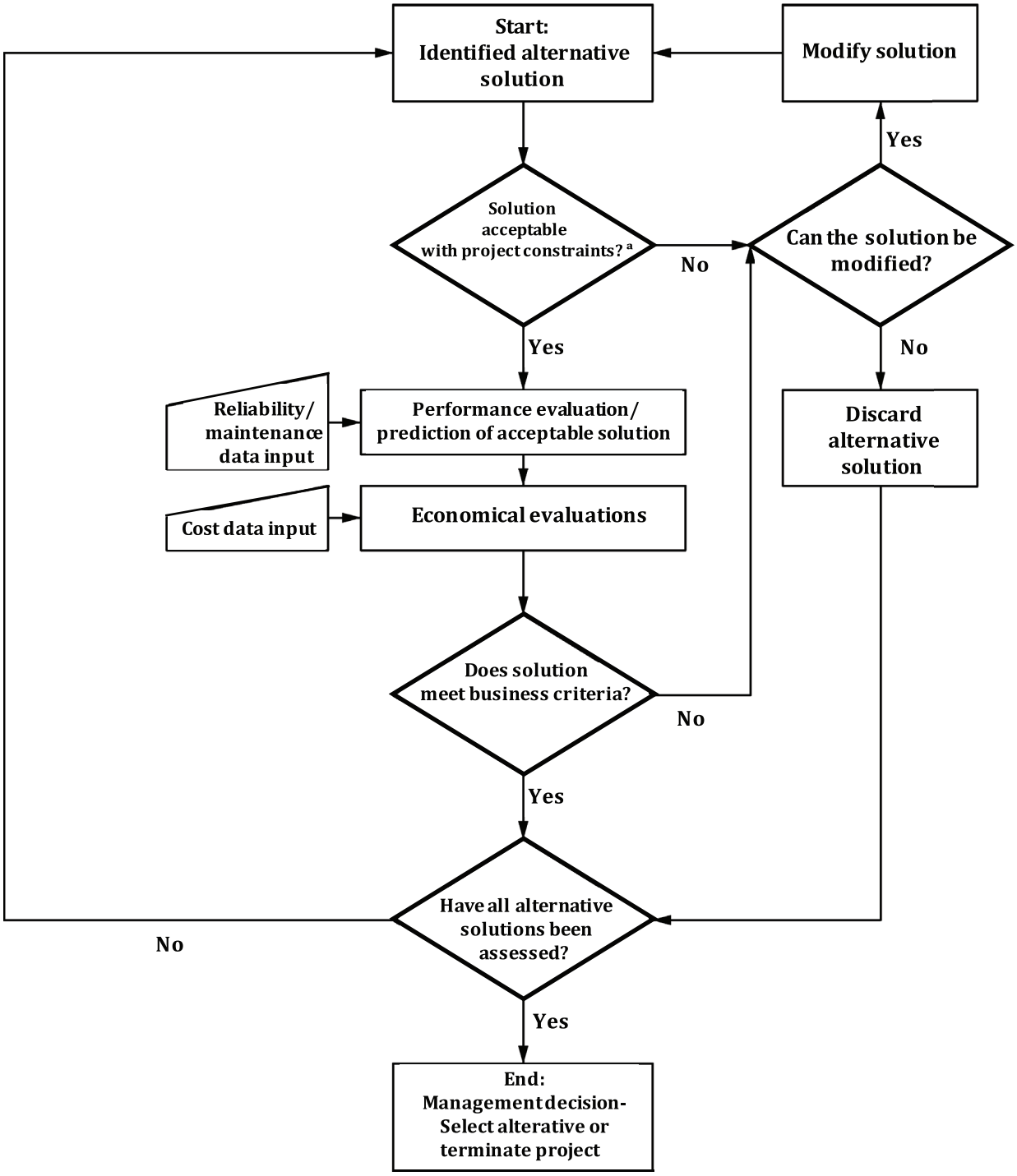

a Typical project constraints include HSE requirements; technical feasibility; compliance with acts, rules and regulations; economical constraints; schedule constraints.

Figure 3 — Optimization framework

4.4 Production assurance programme

4.4.1 Objectives

A production assurance programme (PAP) shall serve as a management tool in the process of complying with this document. The PAP may be either established for the various life cycle phases of a [illegible]

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development project or established for assets already in operation. As production assurance is a continuous activity throughout all life cycle phases, it shall be updated as and when required. It can contain the following:

— systematic planning of production assurance work within the scope of the programme;

— definition of optimization criteria;

— definition of performance objectives and requirements, if any;

— description of the production assurance activities necessary to fulfil the objectives, how they are carried out, by whom and when;

— statements and considerations on interfaces of production assurance and reliability with other activities;

— methods for verification and validation;

— a level of detail that facilitates easy updating and overall coordination.

Annex A provides an index for the PAP contents.

Conformity to this document shall result in the establishment and execution of a PAP.

The life cycle phases indicated in Table 2 apply for a typical asset development project. If the phases in a specific project differ from the life cycle phases indicated in Table 2, the activities should be defined and applied as appropriate.

Major modifications may be considered as a project with phases similar to those of an asset development project. The requirements to production assurance activities as given for the relevant life cycle phases apply.

Similarly, research or technology development projects (that in short or long term can be implemented on an installation, e.g. oil/gas production facility, drilling facility, pipeline) should also benefit from use of the reliability management principles and methods as described in this document.

Likewise, life time extension projects for further development of existing installations (see Clause I.24), will also need to apply production assurance and reliability management.

4.4.2 Project risk categorization

It is necessary to define the level of effort to invest in a PAP to meet the business objectives for each life cycle phase. In practice, the production assurance effort required is closely related to the level of technical risk in a project. Therefore, it is recommended that one of the first tasks to be performed is an initial categorization of the technical risks in a project. This enables project managers to make a general assessment of the level of investment in reliability resources that may have to be made in a project.

The project risk categorization typically varies depending on a number of factors such as financial situation, risk attitude, etc. Hence, specific risk categorization schemes may be established. However, to provide some guidance on the process, a simple risk categorization scheme is outlined in this subclause.

Projects can be divided into three risk classes:

— high risk;

— medium risk;

— low risk.

The features that describe the three risk classes are further outlined in Table 1. Typically, there is a gradual transition from one risk class to another. Hence, a certain degree of subjective assessment is

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required. However, the justification for the selected risk class for a project should be included in the PAP issued during the feasibility or concept phase.

Table 1 — Project risk categorization

Technology	Operating envelope	Technical system scale and complexity	Organizational scale and complexity	Risk class[a]	Description
Mature technology	Typical operating conditions	Small scale, low complexity, minimal change of system configuration	Small and consistent organization, low complexity	Low	Low-budget, low-risk project using field-proven equipment in the same configuration and with the same team under operating condition similar to previous projects.
Mature technology	Typical operating conditions	Moderate scale and complexity	Small to medium organization, moderate complexity	Low or medium	Low- to moderate-risk project using field-proven equipment in an operating envelope similar to previous projects but with some system and organizational complexity.
Novel or non-mature technology for a new or extended operating environment	New, extended or aggressive operating environment	Large scale, high complexity	Large organization, high complexity	Medium or high[b]	Moderate- to high-risk project using either novel or non-mature equipment or with new or extended operating conditions. Project involves large, complex systems and management organizations.

[a] The term "low or medium" indicates that projects comprising the indicated features can be classified as either low-risk or medium-risk projects, likewise for the term "medium or high".

[b] The novel or non-mature technology should have a potential significant impact on the project outcome to be classified as high-risk.

The risk categorization should not be detached from the overall project's risk management process (see Clause C.2).

The project risk categorization (i.e. high, medium and low) is further applied in Table 2 to indicate what processes should be performed for the different project categories. The risk categorization from different users perspective can require different approaches, but the importance is that risk categorization should be in place in the user company to prioritize the production assurance activities.

4.4.3 Programme activities

Production assurance activities should be carried out in all phases of the life cycle of facilities to provide input to decisions regarding feasibility, concept, design, manufacturing, construction, installation, operation, maintenance and modification. Processes and activities shall be initiated only if they are considered to contribute to added value of the project.

The production assurance activities specified in the PAP shall be defined in view of the actual needs, available personnel resources, budget framework, interfaces, milestones and access to data and general information. This is necessary to reach a sound balance between the cost and benefit of the activity.

Production assurance should consider organizational and human factors as well as technical aspects (see Clause I.10).

Important tasks of production assurance are to monitor the overall performance level, manage reliability and the continuous identification of the need for production assurance activities. A further objective of production assurance is to contribute technical, operational or organizational recommendations.

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The processes and activities specified in the PAP shall focus on the main technical risk items initially identified through a top-down screening process (see 4.4.2). A risk-classification activity can assist in identifying performance-critical systems that should be subject to more detailed analysis and follow-up.

The emphasis of the production assurance activities changes for the various life cycle phases. Early activities should focus on optimization of the overall configuration, while attention to critical detail increases in the later phases. The production assurance activities may also interact with integrity management activities.

Production assurance activities relate closely to the integrity management of the installations and system engineering activities, and the PAP should show such relationships.

In the feasibility and concept phases, the field layout configuration should be identified. This also includes defining the degree of redundancy (fault tolerance), overcapacity and flexibility, on a system level. This requires establishing the CAPEX, OPEX, LOSTREV, expected cost or benefit of risks and revenue for each alternative.

These financial values are, in turn, fed back into the operators' profitability tools, for evaluation of profitability and selection of the alternative that best fits with the attitude towards risk. Optimal production availability for field layouts requires that overemphasis on CAPEX is avoided, and it is recommended that this is achieved through long-term partnering between suppliers and operators, as well as between suppliers and their sub-suppliers. Such long-term relationships ensure mutual confidence and maturing of the technology. Early direct involvement of the above parties with focus on the overall revenue in a life cycle perspective is advised. This means, for example, implementing the resulting recommendations as specifications in the invitations to tender.

The production assurance principles outlined in this document require use of the reliability data methodology based on ISO 14224:2016, see the process "performance data tracking and analysis" (Process 9). See also guidance in Annex E. In addition, Annex G provides a framework for performance measures for production availability.

An overview of the production assurance processes is given in Table 2 and Clause 5, while descriptions of the recommended activities for the processes are given in Annex B and Annex C.

Table 2 provides recommendations (indicated by an "X") on which processes should be performed as a function of the project risk categorization (see 4.4.2). The table also provides recommendations (indicated by an "X") as to when the processes should be applied (in what life cycle phase). Production assurance requirements (process 1) can be used to illustrate the interpretation of the table. This process, which is further described in Annex B, should be implemented for medium- and high-risk projects, and performed in the feasibility, concept design, engineering and procurement life cycle phases.

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Table 2 — Overview of production assurance processes versus risk levels and life cycle phases

Production assurance processes for asset development				Life cycle phase[e, f]						
Low-risk projects	Medium-risk projects	High-risk projects	Process name and number[c]	Feasibility	Conceptual design[a]	Engineering[b]	Procurement[g]	Fabrication/ Assembly/ Testing	Installation and commissioning	Operation
—	X	X	1. Production assurance requirements	X	X	X	X	—	—	—
X	X	X	2. Production assurance planning	X	X	X	X	X	X	X
—	X	X	3. Design and manufacture for production assurance	—	X	X	X	X	X	X
X	X	X	4. Production assurance	X	X	X	X	X	X	X
—	X	X	5. Risk and reliability analysis[d]	X	X	X	—	—	—	X
X	X	X	6. Verification and validation	X	X	X	—	—	—	—
X	X	X	7. Project risk management	X	X	X	X	X	X	X
—	—	X	8. Qualification and testing	—	X	X	X	X	—	—
X	X	X	9. Performance data tracking and analysis	—	—	—	—	X	X	X
—	—	X	10. Supply chain management	—	—	—	X	—	—	X
X	X	X	11. Management of change	—	X	X	X	X	X	X
X	X	X	12. Organizational learning	X	X	X	X	X	X	X

[a] Including front-end engineering and design (FEED).

[b] Including pre-engineering and detailed engineering.

[c] The following production assurance processes are within the main scope of work for this document: 1, 2, 3, 4, 5, 6 and 9.

[d] This process is primarily meant to cover production availability, system/equipment availability and component reliability analyses, but in this context may also include availability/reliability of safety systems, see B.5 and G.1. The relations to risk analysis are described in Annex H and Clause I.20. Annex D provides guidance for planning, execution and reporting of production performance analyses.

[e] Technology development projects can use similar production assurance processes.

[f] Lifetime extension projects can use similar production assurance processes. See Clause I.24.

[g] The procurement activities relate to various life cycle phases.

NOTE A process can be applicable for a certain risk class or life cycle phase although no "X" is indicated in this table. Likewise, if it can be argued that a certain process does not add value to a project, it can be omitted.

4.5 Alternative standards

There are a number of other international standards, industry standards, national standards and guidelines that support and direct the implementation of production assurance and reliability activities in projects.

Table 3 shows how the production assurance and reliability processes described within this document link to some other international standards. Work processes carried out in accordance with these international standards can be considered to satisfy the requirements for relevant processes in this document. The alternative standards listed in Table 3 are not normative for this document. The list of standards in Table 3 is non-exhaustive. Other standards can also cover specific requirements in this document. If alternative standards are referred to for compliance to specific requirements, it is the responsibility of the user to demonstrate such compliance.

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