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Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data for equipment

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This Australian Standard ® was prepared by ME-092, Materials, equipment, structures and related services for petroleum, petrochemical and natural gas industries. It was approved on behalf of the Council of Standards Australia on 20 January 2023.

This Standard was published on 17 February 2023.

The following are represented on Committee ME-092:

Australian Industry Group
Australian Organisation for Quality
Australian Petroleum Production and Exploration Association
Australian Pipelines and Gas Association
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Department of Industry, Tourism and Trade, NT
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This Standard was issued in draft form for comment as DR AS ISO 14224:2022.

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ISBN 978 1 76139 062 3

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First published as AS ISO 14224:2023.

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Preface

This Standard was prepared by the Standards Australia Committee ME-092, Materials, equipment, structures and related services for petroleum, petrochemical and natural gas industries.

The objective of this document is to provide a comprehensive basis for the collection of reliability and maintenance (RM) data in a standard format for equipment in all facilities and operations within the petroleum, natural gas and petrochemical industries during the operational life cycle of equipment. It describes data collection principles and associated terms and definitions that constitute a "reliability language" that can be useful for communicating operational experience. The failure modes defined in the normative part of this document can be used as a "reliability thesaurus" for various quantitative as well as qualitative applications. This document also describes data quality control and assurance practices to provide guidance for the user.

Standardization of data collection practices facilitates the exchange of information between parties, e.g. plants, owners, manufacturers and contractors. This document establishes requirements that any in-house or commercially available RM data system is required to meet when designed for RM data exchange. Examples, guidelines and principles for the exchange and merging of such RM data are addressed. This document also provides a framework and guidelines for establishing performance objectives and requirements for equipment reliability and availability performance.

Annex A contains a summary of equipment that is covered by this document.

This document defines a minimum amount of data that is required to be collected, and it focuses on two main issues —

(a) data requirements for the categories of data to be collected for use in various analysis methodologies; and

(b) standardized data format to facilitate the exchange of reliability and maintenance data between plants, owners, manufacturers and contractors.

This document does not apply to the following:

(i) Data on (direct) cost issues.

(ii) Data from laboratory testing and manufacturing (e.g. accelerated lifetime testing), see also Clause 5.2.

(iii) Complete equipment data sheets (only data seen relevant for assessing the reliability performance are included).

(iv) Additional on-service data that an operator, on an individual basis, can consider useful for operation and maintenance.

(v) Methods for analysing and applying RM data (however, principles for how to calculate some basic reliability and maintenance parameters are included in the annexes).

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The terms “normative” and “informative” are used in Standards to define the application of the appendices or annexes to which they apply. A “normative” appendix or annex is an integral part of a Standard, whereas an “informative” appendix or annex is only for information and guidance.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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. www.iso.org/directives

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received. www.iso.org/patents

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries.*

This third edition cancels and replaces the second edition (ISO 14224:2006), which has been technically revised. The main changes are:

— Clause 3 — several new definitions;

— Clauses 8 and 9 — changes in some figures and tables;

— Annex A — new equipment classes;

— Annex B — associated new and aligned failure modes;

— Annex C — some changes and new subclauses, e.g. C.3.4 and C.7;

— Annex D — new subclause D.5;

— Annex E — new KPIs;

— Annex F — alignment with ISO/TR 12489:2013.

This corrected version of ISO 14224:2016 incorporates various editorial corrections.

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Introduction

This International Standard has been prepared based on the previous edition (ISO 14224:2006), experience gained through its use, and know-how and best practices shared through the international development process.

In the petroleum, petrochemical and natural gas industries, great attention is being paid to safety, availability, reliability and maintainability of equipment. The industry annual cost of equipment unavailability is very large, although many plant owners have improved the availability of their operating facilities by addressing this challenge. A stronger emphasis has recently been put on cost-effective design and maintenance for new plants and existing installations among more industrial parties. In this respect, data on failures, failure mechanisms and maintenance related to these industrial facilities and its operations have become more important. It is necessary that this information is used by, and communicated between, the various parties and its disciplines, within the same company or between companies. Various analysis methodologies are used to estimate the risk of hazards to people and environment, or to analyse plant or system performance. For such analyses to be effective and decisive, equipment reliability and maintenance (RM) data are vital.

These analyses require a clear understanding of the equipment's technical characteristics, its operating and environmental conditions, its potential failures and its maintenance activities. It can be necessary to have data covering several years of operation before sufficient data have been accumulated to give confident analysis results and relevant decision support. It is necessary, therefore, to view data collection as a long-term activity, planned and executed with appropriate goals in mind. At the same time, clarity as to the causes of failures is key to prioritizing and implementing corrective actions that result in sustainable improvements in availability, leading to improved profitability and safety.

Data collection is an investment. Data standardization, when combined with enhanced data-management systems that allow electronic collection and transfer of data, can result in improved quality of data for reliability and maintenance. A cost-effective way of optimizing data requirements is through industry co-operation. To make it possible to collect, exchange and analyse data based on common viewpoints, a standard is required. Standardization of data collection practices facilitates the exchange of information between relevant parties e.g. plants, owners, manufacturers and contractors throughout the world.

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Petroleum, petrochemical and natural gas industries — Collection and exchange of reliability and maintenance data for equipment

1 Scope

This International Standard provides a comprehensive basis for the collection of reliability and maintenance (RM) data in a standard format for equipment in all facilities and operations within the petroleum, natural gas and petrochemical industries during the operational life cycle of equipment. It describes data collection principles and associated terms and definitions that constitute a "reliability language" that can be useful for communicating operational experience. The failure modes defined in the normative part of this International Standard can be used as a "reliability thesaurus" for various quantitative as well as qualitative applications. This International Standard also describes data quality control and assurance practices to provide guidance for the user.

Standardization of data collection practices facilitates the exchange of information between parties, e.g. plants, owners, manufacturers and contractors. This International Standard establishes requirements that any in-house or commercially available RM data system is required to meet when designed for RM data exchange. Examples, guidelines and principles for the exchange and merging of such RM data are addressed. This International Standard also provides a framework and guidelines for establishing performance objectives and requirements for equipment reliability and availability performance.

Annex A contains a summary of equipment that is covered by this International Standard.

This International Standard defines a minimum amount of data that is required to be collected, and it focuses on two main issues:

— data requirements for the categories of data to be collected for use in various analysis methodologies;

— standardized data format to facilitate the exchange of reliability and maintenance data between plants, owners, manufacturers and contractors.

The following main categories of data are to be collected:

a) equipment data, e.g. equipment taxonomy, equipment attributes;

b) failure data, e.g. failure cause, failure consequence;

c) maintenance data, e.g. maintenance action, resources used, maintenance consequence, down time.

NOTE Clause 9 gives further details on data content and data format.

The main areas where such data are used are the following:

1) reliability, e.g. failure events and failure mechanisms;

2) availability/efficiency, e.g. equipment availability, system availability, plant production availability;

3) maintenance, e.g. corrective and preventive maintenance, maintenance plan, maintenance supportability;

4) safety and environment, e.g. equipment failures with adverse consequences for safety and/or environment.

This International Standard does not apply to the following:

i. data on (direct) cost issues;

ii. data from laboratory testing and manufacturing (e.g. accelerated lifetime testing), see also 5.2;

iii. complete equipment data sheets (only data seen relevant for assessing the reliability performance are included);

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iv. additional on-service data that an operator, on an individual basis, can consider useful for operation and maintenance;

v. methods for analysing and applying RM data (however, principles for how to calculate some basic reliability and maintenance parameters are included in the annexes).

2 Normative references

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

ISO 20815:2008, *Petroleum, petrochemical and natural gas industries — Production assurance and reliability management*

3 Terms and definitions

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

NOTE Some derived RM parameters, which can be calculated from collected RM data covered by this International Standard, are contained in Annex C. References to Annex C are given as deemed appropriate.

3.1
active maintenance time
duration of a maintenance action, excluding logistic delay

Note 1 to entry: Technical delays are included in the active maintenance time.

Note 2 to entry: See Figure 4 and Annex C for a more detailed description and interpretation of maintenance times. See also ISO/TR 12489:2013, Figure 5.

Note 3 to entry: A maintenance action can be carried out while the item is performing a required function.

[SOURCE: IEC 60050-192:2015, 192-07-04, modified – Notes 2 and 3 to entry have been added.]

3.2
active repair time
effective time to achieve repair of an item

Note 1 to entry: See also ISO/TR 12489:2013, Figures 5 and 6.

Note 2 to entry: See also definition of "mean active repair time (MART)" in ISO/TR 12489:2013, 3.1.34, that is defined as "expected active repair time".

3.3
availability
ability to be in a state to perform as required

Note 1 to entry: See Annex C for a more detailed description and interpretation of availability.

Note 2 to entry: Further terms are given in ISO/TR 12489:2013.

[SOURCE: IEC 60050-192:2015, 192-01-23, modified – Notes 1 and 2 to entry have been added.]

3.4
boundary
interface between an item and its surroundings

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3.5
common cause failures
failures of multiple items, which would otherwise be considered independent of one another, resulting from a single cause

Note 1 to entry: Common cause failures can also be common mode failures.

Note 2 to entry: The potential for common cause failures reduces the effectiveness of system redundancy.

Note 3 to entry: It is generally accepted that the failures occur simultaneously or within a short time of each other.

Note 4 to entry: Components that fail due to a shared cause normally fail in the same functional mode. The term common mode is therefore sometimes used. It is, however, not considered to be a precise term for communicating the characteristics that describe a common cause failure.

Note 5 to entry: See also ISO/TR 12489:2013, 3.2.14 and 5.4.2.

Note 6 to entry: See also C.1.6

[SOURCE: IEC 60050-192:2015, 192-03-18, modified – Notes 3-6 to entry have been added.]

3.6
common mode failures
failures of different items characterized by the same failure mode

Note 1 to entry: Common mode failures can have different causes.

Note 2 to entry: Common mode failures can also be common cause failures (3.5).

Note 3 to entry: The potential for common mode failures reduces the effectiveness of system redundancy.

[SOURCE: IEC 60050-192:2015, 192-03-19, modified]

3.7
condition-based maintenance
CBM
preventive maintenance based on the assessment of physical condition

Note 1 to entry: The condition assessment can be by operator observation, conducted according to a schedule, or by condition monitoring of system parameters.

[SOURCE: IEC 60050-192:2015, 192-06-07, modified]

3.8
corrective maintenance
maintenance carried out after fault detection to effect restoration

Note 1 to entry: Corrective maintenance of software invariably involves some modification

Note 2 to entry: See also ISO/TR 12489:2013, Figures 5 and 6, which illustrate terms used for quantifying corrective maintenance.

[SOURCE: IEC 60050-192:2015, 192-06-06, modified – Note 2 to entry has been added.]

3.9
critical failure
failure of an equipment unit that causes an immediate cessation of the ability to perform a required function

Note 1 to entry: Includes failures requiring immediate action towards cessation of performing the function, even though actual operation can continue for a short period of time. A critical failure results in an unscheduled repair.

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Note 2 to entry: See also definition of "critical dangerous failure" and "critical safe failure" in ISO/TR 12489:2013, 3.2.4 and 3.2.7, respectively.

3.10
cycle
operation and subsequent release/reset

[SOURCE: IEC 60050-444:2002, 444-02-11]

3.11
degraded failure
failure that does not cease the fundamental function(s), but compromises one or several functions

Note 1 to entry: The failure can be gradual, partial or both. The function can be compromised by any combination of reduced, increased or erratic outputs. An immediate repair can normally be delayed but, in time, such failures can develop into a critical failure if corrective actions are not taken.

3.12
demand
activation of the function (includes functional, operational and test activation)

Note 1 to entry: See C.1.3 for a more detailed description.

Note 2 to entry: Annex F.3 gives a list of safety critical equipment which are subject to periodic testing.

Note 3 to entry: See also relevant definitions in ISO/TR 12489:2013: "mean time to demand (MTTD)" is defined in 3.1.38, "failure due to demand" is defined in 3.2.13, and "demand mode of operation safety system" is defined in 3.3.1.

3.13
design life
planned usage time for the total system

Note 1 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.

[SOURCE: ISO 20815:2008, 3.1.5]

3.14
detection method
method or activity by which a failure is discovered

Note 1 to entry: A categorization of detection methods (e.g. periodic testing or continuous condition monitoring) is shown in Table B.4.

3.15
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: Down state relates to unavailability of the item.

Note 2 to entry: The adjectives "down" or "unavailable" designate an item in a down state.

Note 3 to entry: See also Table 4 and Figure 4.

Note 4 to entry: See also ISO/TR 12489:2013, Figures 5 and 6.

[SOURCE: IEC 60050-192:2015, 192-02-20, modified – Notes 3 and 4 to entry have been added.]

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3.16
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 Table 4).

Note 2 to entry: Mean downtime is in IEC 60050-192, 192-08-10, defined as the 'expectation of the down time'.

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

3.17
downstream
business category most commonly used in the petroleum industry to describe post-production processes

EXAMPLE	Refining, transportation and marketing of petroleum products

Note 1 to entry: See also A.1.4 for further details.

3.18
equipment class
class of similar type of equipment units (e.g. all pumps)

Note 1 to entry: Annex A contains equipment-specific data for the equipment covered in this International Standard.

3.19
equipment data
technical, operational and environmental parameters characterizing the design and use of an equipment unit

3.20
equipment type
particular feature of the design which is significantly different from the other design(s) within the same equipment class

3.21
equipment unit
specific equipment within an equipment class as defined by its boundary

Note 1 to entry: Equipment unit is given at level 6 of the equipment taxonomy classification with taxonomic levels shown in Figure 3.

3.22
error
discrepancy between a computed, observed or measured value or condition and the true, specified or theoretically correct value or condition

Note 1 to entry: An error within a system can be caused by failure of one or more of its components, or by the activation of a systematic fault.

Note 2 to entry: An error can be caused by a faulty item, e.g. a computing error made by faulty computer equipment.

Note 3 to entry: In this International Standard, error is also specifically used for software and human errors.

[SOURCE: IEC 60050-192:2015, 192-03-02, modified – Notes 2 and 3 to entry have been added.]

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3.23
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 of that item: see fault (3.22).

Note 2 to entry: A failure of an item is an event, as distinct from a fault of an item, which is a state [source: ISO/TR 12489:2013].

Note 3 to entry: This concept as defined does not apply to items consisting of software only.

Note 4 to entry: See Table B.1, and also F.2 and F.3.

[SOURCE: IEC 60050-192:2015, 192-03-01, modified – Notes 2 through 4 to entry have been added.]

3.24
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 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.]

3.25
failure data
data characterizing the occurrence of a failure event

Note 1 to entry: See also Table 6.

3.26
failure due to demand
failure occurring on demand

Note 1 to entry: See further details in ISO/TR 12489:2013, 3.2.13.

[SOURCE: ISO/TR 12489:2013, modified – Note 1 to entry has been added.]

3.27
failure frequency
unconditional failure intensity; conditional probability per unit of time that the item fails between t and $t + \mathrm{d}t$, provided that it was working at time 0

Note 1 to entry: Another term used for failure frequency is “rate of occurrence”.

Note 2 to entry: See also ISO/TR 12489:2013, 3.1.22 and 3.1.23.

[SOURCE: ISO/TR 12489:2013, modified – Notes 1 and 2 to entry have been added.]

3.28
failure impact
effect of a failure on an equipment's function(s) or on the plant

Note 1 to entry: On the equipment level, failure impact can be classified in three classes (critical, degraded, incipient); see definitions of “critical failure” (3.9), “degraded failure” (3.11) and “incipient failure” (3.40). Classification of failure impact on taxonomy levels 3 to 5 (see Figure 3) is shown in Table 3.

Note 2 to entry: Classification of failure impact on taxonomy levels 4 and 5 (see Figure 3) is shown in Table 3. See also C.1.10.

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3.29
failure mechanism
process that leads to failure

Note 1 to entry: The process can be physical, chemical, logical, or a combination thereof.

Note 2 to entry: See also B.2.2 and Table B.2, which define failure causes for all equipment classes.

[SOURCE: IEC 60050-192:2015, 192-03-12, modified – Note 2 to entry has been added.]

3.30
failure mode
manner in which failure occurs

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

Note 2 to entry: Analysis might require data collection to be established on different taxonomy levels, see Table 3.

[SOURCE: IEC 60050-192:2015, 192-03-17, modified – Notes 1 and 2 to entry have been added.]

3.31
failure on demand
failure likely to be observed when a demand occurs

Note 1 to entry: Failure on demand includes the failures occurred before the demand and the failures due to the demand.

Note 2 to entry: See also C.6 on testing for hidden failures in safety systems.

Note 3 to entry: See also definition on *failure due to demand* (3.26).

Note 4 to entry: See ISO/TR 12489:2013, 3.1.15 for definition of the probability of failure on demand (PFD).

Note 5 to entry: Different failure modes are used to reflect failure on demand (see the tables in B.2.6).

[SOURCE: ISO/TR 12489:2013, modified – Notes 1 through 5 to entry have been added.]

3.32
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

Note 1 to entry: See also definition of failure rate in ISO/TR 12489:2013, 3.1.18.

Note 2 to entry: See also definition of failure rate in IEC 60050-192:2015, 192-05-06 (instantaneous failure rate).

[SOURCE: ISO/TR 12489:2013, modified – Notes 1 and 2 to entry have been added.]

3.33
fault
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* (3.44).

Note 2 to entry: A fault is often a result of a failure of the item itself but the state can exist without a failure (see ISO 20815:2008, 3.1.14).

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

[SOURCE: IEC 60050-192:2015, 192-04-01, modified – Notes 2 and 3 to entry have been added.]

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3.34
generic reliability data
reliability data covering families of similar equipment

Note 1 to entry: See Annex D.5 and Table D.5.

3.35
hidden failure
failure that is not immediately evident to operations and maintenance personnel

Note 1 to entry: Equipment failures that occurred at an earlier point of time, but were first observed at demand, fall into this category. Such failures are first revealed when the relevant functionality is tested (activated).

Note 2 to entry: See definition with notes to entry in ISO/TR 12489:2013, 3.2.11.

Note 3 to entry: See also *latent fault* (3.44).

3.36
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 [303]).

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 [298]).

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.]

3.37
human fatigue
loss of physiological and psychological function as a result of extended wakefulness, heavy work, excessive stimulation, illness or stress

Note 1 to entry: Human fatigue can be related to some of the failure causes in Table B.3, e.g. operating error.

[SOURCE: Moore-Ede M.:2009, modified – Note 1 to entry has been added.]

3.38
idle state
non-operating up state during non-required time

Note 1 to entry: The adjective "idle" designates an item in an idle state.

Note 2 to entry: In some applications, an item in an idle state has some functioning subsystems, and is therefore considered to be operating.

Note 3 to entry: The non-operating time comprises the idle time, the stand-by time and the externally disabled time

[SOURCE: IEC 60050-192:2015, 192-02-14, modified – Note 3 to entry has been added.]

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3.39
idle time
time interval for which the item is in an idle state

[SOURCE: IEC 60050-192:2015, 192-02-15]

3.40
incipient failure
imperfection in the state or condition of an item so that a degraded or critical failure might (or might not) eventually be the expected result if corrective actions are not taken

Note 1 to entry: The recording of incipient failure requires some criteria for when a fault of this nature requires registration as opposed to a state/condition where no corrective actions are required.

3.41
indenture level
level of subdivision of an item from the point of view of maintenance action

3.42
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, well (see ISO 16530-1:—, 2.73), mechanical, safety (see ISO/TR 12489:2013, 3.1.2), structural and technical.

3.43
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 International Standard, the common term "item" is used on all taxonomy levels 6 to 9 in Figure 3. See also 3.30, which defines a specific item level.

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

3.44
latent fault
undetected fault
<of an item> fault that has not become apparent

Note 1 to entry: A latent fault can eventually be revealed by preventive maintenance or by a system failure.

[SOURCE: IEC 60050-192:2015, 192-04-08, modified]

3.45
life cycle
series of identifiable stages through which an item goes, from its conception to disposal

Note 1 to entry: See 5.2 for the purpose of data collection.

Note 2 to entry: See also ISO 20815:2008, Table 2 for the purpose of production assurance.

[SOURCE: IEC 60050-192:2015, 192-01-09, modified – Notes 1-2 to entry have been added.]

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3.46
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.]

3.47
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 Annex C for a more detailed definition and interpretation of maintainability.

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

3.48
maintainable item
item that constitutes a part or an assembly of parts that is normally the lowest level in the equipment hierarchy during maintenance

3.49
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

Note 1 to entry: See also definition of "maintenance" in ISO/TR 12489:2013, 3.4.1.

[SOURCE: IEC 60050-192:2015, 192-06-01, modified – Note 1 to entry has been added.]

3.50
maintenance concept
definition of the maintenance objectives, line of maintenance, indenture levels, maintenance levels, maintenance support, and their interrelationships

Note 1 to entry: The maintenance policy provides the basis for maintenance planning, determining supportability requirements, and developing logistic support.

Note 2 to entry: See also ISO/TR 12489:2013, 3.4.2.

[SOURCE: IEC 60050-192:2015, 192-06-02, modified – Note 2 to entry has been added.]

3.51
maintenance data
data characterizing the maintenance action planned or done

Note 1 to entry: Refers to the type of data dealt with in this International Standard.

Note 2 to entry: See also 9.6.3, Table 8.

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

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3.52
maintenance impact
effect of the maintenance on the plant or equipment's function(s)

Note 1 to entry: On the equipment level, two classes of impact are defined: critical and non-critical. On plant level, three classes are defined: total, partial or zero impact.

3.53
maintenance man-hours
accumulated duration of the individual maintenance times used by all maintenance personnel for a given type of maintenance action or over a given time interval

Note 1 to entry: Maintenance man-hours are expressed in units of hours.

Note 2 to entry: As several people can work at the same time, man-hours are not directly related to other parameters like the "mean time to repair" and "mean down time".

3.54
maintenance plan
structured and documented set of tasks that include the activities, procedures, resources and the time scale required to carry out maintenance

Note 1 to entry: See also ISO/TR 12489:2013, 3.4.6.

[SOURCE: EN 13306:2010, 2.5, modified – Note 1 to entry has been added.]

3.55
maintenance record
part of maintenance documentation that contains all failures, faults and maintenance information relating to an item

Note 1 to entry: This record can also include maintenance costs, item availability or up time and any other data where relevant.

3.56
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 (3.47), 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 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.]

3.57
mean cycles to failure
MCTF
expected number of cycles before the item fails

Note 1 to entry: See also C.3.4.

Note 2 to entry: Refer to definition of *cycle* (3.10).

3.58
mean number of cycles
expected number of cycles per time unit

Note 1 to entry: See also C.3.4.

Note 2 to entry: Refer to definition of *cycle* (3.10).

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3.59
mean active repair time
MART
expected active repair time

Note 1 to entry: The MART is the expected effective time to repair.

Note 2 to entry: See also definition of active repair time

[SOURCE: ISO/TR 12489:2013, 3.1.34, modified – Note 2 to entry has been added.]

3.60
mean elapsed time between failures
METBF
expected elapsed time between successive failures of a repairable item

Note 1 to entry: See further details in ISO/TR 12489:2013, 3.1.30.

Note 2 to entry: IEC 60050-192:2015, 192-05-13 defines mean operating time between failures (abbreviated by MTBF or MOTBF) as “expectation of the duration of the operating time between failures”.

Note 3 to entry: See also Annex C.

3.61
mean overall repairing time
MRT
expected time to achieve the following actions:

- the time spent before starting the repair; and,
- the effective time to repair; and,
- the time before the item is made available to be put back into operation

Note 1 to entry: See ISO/TR 12489:2013, Figures 5 to 7.

[SOURCE: ISO/TR 12489:2013, 3.1.33]

3.62
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, 192-05-11, defines MTTF as ”expectation of the operating time to failure”.

Note 3 to entry: See also Annex C.

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

3.63
mean time to repair
MTTR
expected time to achieve the repair of a failed item

Note 1 to entry: See further details in ISO/TR 12489:2013, 3.1.31.

Note 2 to entry: IEC 60050-192:2015 defines the term as "expectation of the time to restoration".

Note 3 to entry: See also definition of ‘mean time to restoration’ in ISO/TR 12489:2013, 3.1.32.

Note 4 to entry: In actual life the detection time is either 0 (immediately revealed failures) or unknown (failures detected by tests). Only MRT and MART can be collected.

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Note 5 to entry: See also C.5.5.2.

3.64
mean time to restoration
MTTRes
expected time to achieve the following actions:

a) the time to detect the failure; and,

b) the time spent before starting the repair; and,

c) the effective time to repair; and,

d) the time before the component is made available to be put back into operation

Note 1 to entry: See further details in ISO/TR 12489:2013, 3.1.32.

Note 2 to entry: See also ISO/TR 12489:2013, Figures 5 to 7.

Note 3 to entry: See also definition of "mean overall repairing time" and "mean active repair time" in ISO/TR 12489:2013, 3.1.33 and 3.1.34, respectively.

Note 4 to entry: Mean time to restoration is abbreviated as MTTR in IEC 60050-192:2015, 192-07-23.

[SOURCE: ISO/TR 12489:2013, 3.1.32, modified – Notes 1 through 4 to entry have been added.]

3.65
midstream
business category involving the processing, storage and transportation sectors of the petroleum industry

EXAMPLE Transportation pipelines, terminals, gas processing and treatment, LNG, LPG and GTL.

Note 1 to entry: See also A.1.4 for further details.

3.66
mobilization time
time to get all necessary resources available to execute maintenance

Note 1 to entry: Time spent before starting the maintenance is dependent on access to resources e.g. spare parts, tools, personnel, subsea intervention and support vessels.

Note 2 to entry: See also ISO/TR 12489:2013, Figure 5 and Figure 7.

3.67
modification
combination of all technical and administrative actions intended to change an item

Note 1 to entry: Modification is not normally a part of maintenance, but is frequently performed by maintenance personnel.

Note 2 to entry: Care is needed in the collection and analysis of RM data to distinguish between maintenance due to failures and maintenance due to equipment modification.

Note 3 to entry: See also Table B.5.

3.68
non-critical failure
failure of an equipment unit that does not cause an immediate cessation of the ability to perform its required function

Note 1 to entry: Non-critical failures can be categorized as "degraded" or "incipient" (see separate definitions on degraded failure and incipient failure).

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Note 2 to entry: The term "critical" does not have the same meaning in ISO/TR 12489:2013 as in this International Standard; see further details in F.4.1.

3.69
operating state
<of an item> state of performing as required

Note 1 to entry: See also Table 4.

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

[SOURCE: IEC 60050-192:2015, 192-02-04, modified – Note 1 to entry has been added.]

3.70
operating time
time interval during which an item is in an operating state

Note 1 to entry: The duration of operating time can be expressed in units appropriate to the item concerned, e.g. calendar time, operating cycles, distance covered, and the units should always be clearly stated.

Note 2 to entry: Operating time includes actual operation of the equipment or the equipment being available for performing its required function.

Note 3 to entry: See also Table 4.

Note 4 to entry: The point in time of start-up time can differentiate depending on item subject to data collection, and could start from time of installation, time of commissioning, or time of start of service/production/injection.

[SOURCE: IEC 60050-192:2015, 192-02-05, modified – Note 1 to entry has been amended and notes 2 through 4 to entry have been added.]

3.71
opportunity maintenance
maintenance of an item that is deferred or advanced in time and is performed when an unplanned opportunity becomes available

3.72
performance objective
indicative level for the desired performance

Note 1 to entry: See further details in ISO 20815:2008, 3.1.32 and Annex F.

[SOURCE: ISO 20815:2008, 3.1.32, modified – Note 1 to entry has been added.]

3.73
performance requirement
required minimum level for the performance of a system

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

[SOURCE: ISO 20815:2008, 3.1.33, modified]

3.74
periodic test
proof test
planned operation performed at constant time intervals in order to detect the potential hidden failures which can have occurred in the meantime

Note 1 to entry: The unsafe hidden failures of a safety system which are not detected by the diagnostic tests can be detected by periodic tests. Such tests are named “proof tests” in the standards dealing with functional safety (e.g. IEC 61508-4:2010, 3.8.5).

Note 2 to entry: See ISO/TR 12489:2013, 3.4.8, 3.4.9 and 3.4.10 for further details.

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[SOURCE: ISO/TR 12489:2013, 3.4.8, modified – Note 2 to entry has been added.]

3.75
petrochemical
business category producing chemicals derived from petroleum and used as feedstock for the manufacture of a variety of plastics and other related products

EXAMPLE Methanol and polypropylene.

Note 1 to entry: See A.1.4 for further details.

3.76
planned maintenance
scheduled maintenance
planned preventive maintenance
maintenance carried out in accordance with a specified time schedule

Note 1 to entry: Scheduled maintenance can identify the need for some corrective maintenance action.

[SOURCE: IEC 60050-192:2015, 192-06-12, modified]

3.77
predictive maintenance
PdM
maintenance based on the prediction of the future condition of an item estimated or calculated from a defined set of historic data and known future operational parameters

Note 1 to entry: See 9.6, Table B.4 and B.5, and also Table E.3.

3.78
preventive maintenance
PM
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]

3.79
random failure
failure, occurring in a random way

[SOURCE: ISO/TR 12489:2013]

3.80
redundancy
existence of more than one means for performing a required function of an item

Note 1 to entry: See 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 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”.

3.81
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 can also be defined as a probability; see ISO/TR 12489:2013, 3.1.8.

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Note 2 to entry: See also Annex C.

Note 3 to entry: IEC 60050-192:2015, 192-01-24 defines reliability as “ability to perform as required, without failure, for a given time interval, under given conditions”.

Note 4 to entry: The examples of equipment specific data in Annex A list technical and operational conditions that can cause differences in equipment reliability performance.

3.82
reliability data
data for reliability, maintainability and maintenance support performance

[SOURCE: ISO 20815:2008, 3.1.42]

3.83
required function
function or combination of functions of an item that is considered necessary to provide a given service

3.84
safety critical equipment
equipment and items of permanent, temporary and portable equipment playing an important role in safety systems/functions

3.85
safety critical failure
critical dangerous failures that are undetected

EXAMPLE Failures revealed by periodic tests.

Note 1 to entry: Critical dangerous failures are in ISO/TR 12489:2013, 3.2.4 defined as "dangerous failure leading to the complete inhibition of the safety action (i.e., leading to a dangerous situation for the protected system)".

Note 2 to entry: See also Annex F, and specifically F.4.1. regarding the indicator “failure fraction”.

[SOURCE: ISO/TR 12489:2013, notes 1 and 2 to entry have been added.]

3.86
safety system
system which is used to implement one or more safety functions

Note 1 to entry: Safety function is in ISO/TR 12489:2013, 3.1.6 defined as “function which is intended to achieve or maintain a safe state, in respect of a specific hazardous event’.

Note 2 to entry: Systems with safety functions are defined in ISO/TR 12489:2013, Annex A. These systems are also cross-related in Table A.3.

[SOURCE: ISO/TR 12489:2013, 3.1.7, modified – Notes 1 and 2 to entry have been added.]

3.87
software error
erroneous result produced by the use of software product

EXAMPLE Bad code in a computer program resulting in an error.

Note 1 to entry: See Table B.2 for list of relevant equipment failure mechanisms.

Note 2 to entry: See also ISO/TR 12489:2013, B.3, and Note 5 to entry 3.2.17 (Systematic failure) in ISO/TR 12489:2013.

Note 3 to entry: See also definition of “error” (3.22).

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3.88
subunit
assembly of items that provides a specific function that is required for the equipment unit within the main boundary to achieve its intended performance

3.89
surveillance period
interval of time (calendar time) between the start date and end date of RM data collection

Note 1 to entry: See Annex C for further details.

Note 2 to entry: Surveillance time in data collection is a part of the total accumulated operating time (see definition of operating time).

3.90
systematic failure
failure that consistently occurs under particular conditions of handling, storage or use

Note 1 to entry: See also Annex F.

Note 2 to entry: See also further details in ISO/TR 12489:2013, 3.2.17.

Note 3 to entry: Reliability data covers random and systematic failures as described in ISO/TR 12489:2013, Figure B.5.

[SOURCE: ISO/TR 12489:2013, 3.2.17, modified – Notes to entry 1 to 3 have been added.]

3.91
tag number
unique code that identifies the equipment function and its physical location

Note 1 to entry: See Annex C for more detailed definitions and interpretations.

Note 2 to entry: Normally includes the system for which it belongs. The systems covered are shown in Table A.3.

Note 3 to entry: Also entitled "functional location" in some CMMIS.

Note 4 to entry: The equipment is allocated to a tag for only so long as it occupies that function and location. See also footnote b in Table 5.

3.92
taxonomy
systematic classification of items into generic groups based on factors possibly common to several of the items

3.93
trip
shutdown of machinery from normal operating condition to full stop

Note 1 to entry: Trip: The shutdown is activated automatically by the control/monitoring system:

- real trip The shutdown is effectuated as a result of a monitored (or calculated) value in the control system exceeding a pre-set limit;
- spurious trip Unexpected shutdown resulting from failure(s) in the control/monitoring system or error(s) imposed on the control/monitoring system originating from the environment or people.

Note 2 to entry: See also ISO/TR 12489:2013, 3.4.14.

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3.94
turnaround
revision shutdown
planned event wherein an entire process unit is taken off stream for revamp or renewal

Note 1 to entry: See also ISO 20815:2008, Table G.1.

3.95
uncertainty
<of a quantity> inability to determine accurately what is or will be the true value of a quantity

Note 1 to entry: Uncertainty can have different meanings within reliability data collection and exchange. It can be used as a measure of variability within a population, which is a type of uncertainty often referred to as stochastic (or aleatory) uncertainty. Uncertainty can also have a subjective meaning (epistemic uncertainties).

3.96
up state
available state
<of an item> state of being able to perform as required

Note 1 to entry: Up state relates to the availability performance of the item.

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

[SOURCE: IEC 60050-192:2015, 192-02-01, modified – Notes 1 and 2 to entry have been added.]

3.97
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”.

3.98
upstream
business category of the petroleum industry involving exploration and production

EXAMPLE Offshore oil/gas production facility, drilling rig, intervention vessel.

Note 1 to entry: See also A.1.4 for further details.

4 Abbreviated terms

NOTE Some specific abbreviations used for equipment types (e.g. BOP) and units (e.g. kW) are not included in this clause, but covered within each clause/sub-clause where they are used. There are also some abbreviations used in the document (see e.g. Table D.1), which are not included in this clause.

CAPEX	capital expenditure
CBM	condition-based maintenance
CDF	cumulative distribution function
CM	condition monitoring
CMMIS	computerized maintenance-management information system
DHSV	downhole safety valve
ESD	emergency shutdown

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FTA	fault tree analysis
FMECA	failure mode, effect and criticality analysis
HIPPS	high integrity pressure protection system
KPI	key performance indicators
LCC	life cycle cost
LEL	lower explosive limit
MART	mean active repair time
MCTF	mean cycles to failure
MEG	monoethylene glycol
MI	maintainable item
METBF	mean elapsed time between failures
MTTF	mean time to failure
MTTR	mean time to repair
MTTRes	mean time to restoration
MUT	mean up time
MDT	mean down time
MRT	mean overall repairing time
NCR	non-compliance reporting
NDT	non-destructive testing
OPEX	operational expenditure
PdM	predictive maintenance
PM	preventive maintenance
PFD	probability of failure on demand
P&ID	piping and instrumentation diagram
PSD	process shutdown
PSV	pressure safety valve
QA	quality assurance
QN	quality notification
QRA	quantitative risk assessment
RAM(S)	reliability, availability, maintainability (and safety)
RBI	risk-based inspection

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RCM	reliability-centred maintenance
RM	reliability and maintenance
SCSSV	surface-controlled subsurface safety valve
SIS	safety instrumented system
SIF	safety instrumented function
SIL	safety integrity level
SSIV	subsea isolation valve
TEG	triethylene glycol
TTF	time to failure
TTR	time to repair
WO	work order

5 Application

5.1 Equipment coverage

This International Standard is applicable to equipment types used in the petroleum, natural gas and petrochemical industry including, but not limited to, equipment categories such as process equipment and piping, safety equipment, subsea equipment, pipeline systems, loading/unloading equipment, downhole well equipment and drilling equipment. The equipment can be permanently installed at the facilities or used in conjunction with installation, maintenance or modification phases. The principles of this International Standard can also be relevant for the pre-production phases, e.g. how experience is gained and systematized during technology qualification, fabrication and associated testing (QN, NCR, etc.).

Annex A contains examples of how this International Standard should be used for specific equipment types. The users are expected to define taxonomies for additional equipment classes as needed based on the principles given by this International Standard.

Some principles for RM data collection at equipment level can be applied for monitoring and analysing performance at plant and system levels constituted by various equipment classes. However, facility- and plant-performance monitoring also requires other types of data not covered by this International Standard.

5.2 Time periods

This International Standard is applicable to data collected during the operational life cycle of equipment, including installation, start-up, operation, maintenance and modification. Laboratory testing, manufacturing and fabrication phases are not specifically addressed in this International Standard. Many of the principles in this standard can however be used by equipment manufacturer to collect and systematize failures occurring on equipment during fabrication and detected during acceptance testing, e.g. for non-compliance reporting (NCR). In addition, it is, emphasized that analysis of relevant historic RM data shall be used in the dimensioning of such testing prior to operation. Technology qualification and development require also, and benefit from, past reliability knowledge to reveal potential improvement areas (see 8.3).

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5.3 Users of this International Standard

This International Standard is intended for users such as the following.

Installation/plant/facility: Operating facility, e.g. maintenance and engineering personnel logging equipment failures or recording maintenance events into facility information management systems.

Owner/operator/company: Reliability staff or others creating (generic) equipment reliability databases for equipment located in company facilities; reliability engineers requiring data or maintenance engineers preparing maintenance plans. This International Standard provides a format for analysing any RM data element as appropriate associated with an analysis (as described in Annex D); e.g. root-cause analysis, analysis of historic performance, prediction of future performance, use in a design process, etc.

Industry: Groups or companies exchanging equipment RM data or joint industry reliability database project co-operation. Improved communication of equipment reliability performance requires the principles in this International Standard to be adhered to (as a "reliability language").

Manufacturers/designers: Use of RM data to improve equipment designs and learn from past experience.

Authorities/regulatory bodies: A format for communicating any RM data on an individual event basis or as otherwise required from the operating company. This International Standard is, for example, vital for authorities addressing safety equipment reliability.

Consultant/contractor: A format and quality standard for data collection projects and analyses of safety, reliability or maintenance aspects commonly performed by contractors/consultants for the asset owners (e.g. oil companies).

While others, such as developers of computer-maintenance-management software, can find this International Standard to be useful, the primary users are expected to be owners and/or operators who should find the data to be collected readily available within their operating facilities.

5.4 Limitations

Through analysis of data, RM parameters can be determined for use in design, operation and maintenance. This International Standard does not provide detailed descriptions of methods for analysing data. However, it does give recommendations for defining and calculating some of the vital RM parameters (Annex C) and reviews the purposes and benefits of some analytical methodologies for which data can be used. Such analytical methodologies and application areas can be found in other International Standards, and relevant International Standards have been exploited for the purpose of identifying and co-ordinating the RM data requirements (see Annex D).

Although cost data are important in establishing priorities for improvement opportunities and are frequently included in the analysis of reliability performance, cost data (parameters) are not specifically included in this International Standard. Most facilities track the costs of maintenance (man-hours), equipment replacements, capital improvements, business interruption and environmental events. These data may be maintained in the computerized maintenance management information system (CMMIS). When costs are required for setting the analysis of reliability in an economic perspective or performing calculation of life cycle costing, the user should obtain that information from the appropriate sources within the operating facility or company.

Due to the variety of uses for RM data, requirements for data in a data collection programme should be adapted to the expected application(s). Credible analysis results are directly related to the quality of the data collected. While this International Standard does not specify detailed quality measures, data quality control and assurance practices are outlined to provide guidance for the user.

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The technical information gathered to describe the equipment and its location within a plant, facility or system is, in this International Standard, not meant to be exhaustive and complete like the overall plant technical information system, but rather used to identify and explain variables for the purposes of the analytical functions. Use of common technical terms is, however, recommended and linked to life cycle information-system and equipment technical standards. Even though this International Standard describes how to record maintenance activities for the purpose of equipment reliability and availability optimization, this International Standard is not meant to act as a standard to specify in detail how maintenance programmes are documented.

The technical status of equipment and degradation of equipment performance can be recorded through condition-monitoring systems, which requires details beyond the equipment data covered in this International Standard. However, this International Standard contains RM data elements that can be used in such condition-monitoring systems.

This International Standard is not meant to be a software specification of such database systems but can, in general, be complied with to facilitate and improve the industry RM data exchange.

5.5 Exchange of RM data

A major objective of this International Standard is to make it possible to exchange RM data in a common format within a company, between companies, within an industrial arena or in the public domain. Measures for ensuring the quality of data are discussed in Clause 7. Some additional aspects to be considered with respect to exchange of RM data are the following.

- Detailed versus processed data: Data can be exchanged on various levels from the actual failure and maintenance records to data on a more aggregated level. For example, if only the number of failures of a certain category is required, it is necessary to exchange only the failure quantity for these failures. This sort of information is commonly given in public data sources (e.g. reliability data books). For exchanging data on the overall performance of a unit or a plant (benchmarking), the so-called key performance indicators (KPI) may be used. Examples of KPIs are given in Annex E.

- Data sensitivity: Some data fields can be of a certain sensitive character and/or possibly be used for purposes for which they were not intended (e.g. to obtain commercial advantages, non-qualified communication of plant/equipment experience). To avoid this, two options can be utilized:

  — “blank” such data;

  — make such data anonymous.

The latter can be achieved by defining some anonymous codes representing the data element where only a few authorized persons know the conversion between the codes and the actual data. This is recommended if these data fields are essential for the data taxonomy.

It is important to recognize the potential commercial sensitivity of exchanging reliability and other performance data. Competition law prohibits “collective boycott” agreements or arrangements between competitors where competitors agree not to deal with certain suppliers/contractors. A benchmarking study where competitors exchange information so that suppliers/contractors can be “ranked” incurs a real risk that the parties to the benchmarking study will arrive at a common conclusion not to use particular suppliers/contractors and this should be avoided. Collective boycott arrangements are violations of competition law and can leave individuals and companies exposed to criminal actions.

It is necessary, therefore, that any exchange complies with the national and international laws governing anti-competitive practices. Hence, it is recommended that prior to embarking upon such an exercise, clarification of the local guidelines is sought to avoid possible infringement.

- Data security: Systematized operational-equipment performance (i.e. quality RM data that have a cost to obtain) is an asset generally of great value, and data not open to the public domain shall be treated with appropriate security measures to avoid misuse and not affect the reputation of associated parties. This relates to storage of data (e.g. safe location), transmission of data (e.g. Internet), access to data for authorized users (e.g. password), etc.

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- Value of data: In some cases, it is useful to define a "value measure" for an amount of reliability data. This can be the case in joint industry projects where several contributors are supposed to contribute with an equal "value" of data. Two approaches may be used:
  - calculating the actual cost of collecting the data;
  - value the data by combining the population with aggregated surveillance time.

6 Benefits of RM data collection and exchange

Although many plant owners have improved the availability of their operating facilities, lost production and maintenance costs from poor equipment reliability still represent a high annual industrial cost. Even though most failure events are not catastrophic, increased clarity as to the causes of failure events is key to prioritizing and implementing corrective maintenance actions. This results in sustainable improvements in reliability, leading to improved profitability and safety.

Benefits of reliability data analysis are wide-ranging, including the opportunity to optimize the timing of equipment overhauls and inspections, the content of maintenance procedures, as well as the life cycle costing of sparing and upgrade programmes in operating facilities world-wide. Other benefits resulting from the collection and analysis of RM data include improvements in decision-making, reductions in catastrophic failures, reduced environmental impacts, more effective benchmarking and trending of performance, and increased process unit availability. The data collection and exchange principles outlined in this International Standard require the production assurance given in ISO 20815:2008, Table 2 (e.g. "performance data tracking and analysis").

Improvement of equipment reliability is dependent on experiences from real-life usage. The collection, analysis and feedback of performance data to equipment designers and manufacturers are, therefore, paramount. Also, when purchasing new equipment, RM data are key parameters to take into account.

In order to merge data from several equipment units, plants or across an industry arena, it is required that parties agree on what data are useful to collect and exchange and that those data are contained in a compatible format.

Recently, several nations with oil and gas industries have issued regulations requiring the companies to have a system for the collection, analysis and implementation of corrective and preventive actions, including improvement of systems and equipment. Some of these regulations refer to International Standards, including this International Standard.

Collecting RM data is costly and therefore it is necessary that this effort be balanced against the intended use and benefits. Commonly one would select equipment for RM data collection where the consequences of failures have an impact on safety, production, environment or high repair/replacement cost as indicated below.

A typical feedback loop for potential uses of data and describing a continuous improvement process is shown in Figure 1.

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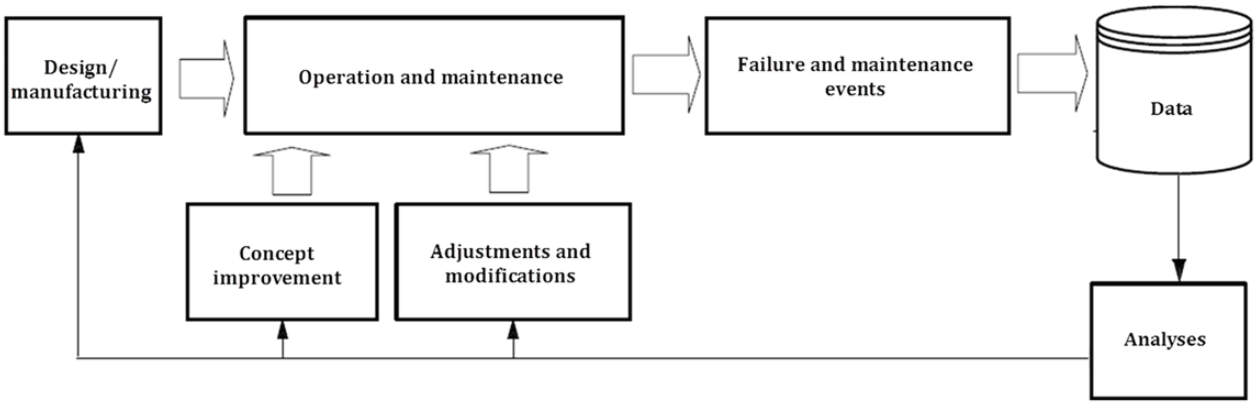

Figure 1 — Typical feedback of analysis from collected reliability and maintenance data

Industry and business value elements of utilizing this International Standard are summarised below:

- economic aspects:
  - cost-effective design to optimize CAPEX,
  - cost-effective operation to optimize OPEX,
  - improved profitability (reduced revenue loss),
  - LCC/whole-life management,
  - reduced cost of insurance;
- general aspects:
  - "being able to operate" (operatorship license),
  - life extension of capital equipment,
  - improved product quality,
  - better (data-based) equipment purchase,
  - better resource planning;
- safety and environmental aspects:
  - improved personnel safety,
  - reduced catastrophic failures,
  - reduced environmental impact,
  - improvement of safety procedures and regulations (e.g. extend test interval based on RM performance),
  - compliance with authority requirements;
- analytical:
  - higher-quality data,
  - larger population of data,
  - improved decision-making,

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— reduced uncertainty in decision-making,

— qualified benchmarking,

— exchange of experience in industrial collaboration,

— creation of a common "reliability" language (understanding, various disciplines),

— verification of analysis techniques,

— better predictability,

— basis for a risk-based inspection and reliability-availability-maintainability studies.

7 Quality of data

7.1 Obtaining quality data

7.1.1 Definition of data quality

Confidence in the collected RM data, and hence any analysis, is strongly dependent on the quality of the data collected. High-quality data are characterized by the following:

a) completeness of data in relation to specification;

b) compliance with definitions of reliability parameters, data types and formats;

c) accurate input, transfer, handling and storage of data (manually or electronic);

d) sufficient population and adequate surveillance period to give statistical confidence;

e) relevance of the data to the need of the users.

7.1.2 Planning measures

The following measures shall be emphasized before the data collection process starts.

— Define the objective for collecting the data in order to collect data relevant for the intended use. Examples of analyses where such data may be used are quantitative risk analysis (QRA); reliability, availability and maintainability analysis (RAM); reliability-centred maintenance (RCM); life cycle cost (LCC); safety integrity level (SIL) analysis. (See also Annex D.)

— Investigate the source(s) of the data to ensure that relevant data of sufficient quality are available. Sources cover inventory/technical equipment information, RM event data and associated plant impacts.

— Define the taxonomical information to be included in the database for each equipment unit (see Clause 8).

— Identify the installation date, population and operating period(s) for the equipment from which data can be collected.

— Define the boundaries for each equipment class, indicating what RM data are to be collected (see Clause 8).

— Apply a uniform definition of failure and a method of classifying failures (see Clause 9).

— Apply a uniform definition of maintenance activities and a method of classifying maintenances (see Clause 9).

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— Define the checks used in data quality verification (see 7.1.3 and 7.1.9). At a minimum, the following shall be verified.

1) The origin of the data is documented and traceable.

2) The data originate from similar equipment type, technology and operating conditions.

3) The equipment is relevant for the purpose (e.g. not outdated models).

4) The data comply with definitions and interpretation rules (e.g. definition of failure).

5) Recorded failures are within the defined equipment boundary and surveillance period.

6) The information is consistent (e.g. consistency between failure modes and failure impact).

7) Data are registered in the correct format.

8) Sufficient data are collected to give acceptable statistical confidence, e.g. not biased by outliers. (See recommendations for calculating confidence limits in C.3.2.)

9) Operating and maintenance personnel are consulted to validate the data.

— Define a priority level for the completeness of data by a suitable method. One method of weighting the importance of the different data to be collected is by using three classes of importance in accordance with the following classification:

  — HIGH: compulsory data (coverage ≈ 100 %)

  — MEDIUM: highly desirable data (coverage > 85 %)

  — LOW: desirable data (coverage > 50 %)

— Define the level of detail of RM data reported and collected and link it closely to the production and safety importance of the equipment. Base prioritization on safety, production performance and/or other severity measures.

— Prepare a plan for the data collection process (see 7.2), e.g. schedules, milestones, data collection sequence for installations and equipment units, surveillance periods to be covered (see 8.3.1), etc.

— Plan how the data will be assembled and reported and devise a method for transferring the data from the data source to the reliability data bank using any suitable method (see 7.2).

— Train, motivate and organize the data collection personnel, e.g. interpretation of sources, equipment know-how, software tools, involvement of operating personnel and equipment experts, understanding/ experience in analysis application of RM data, etc. Ensure that they have an in-depth understanding of the equipment, its operating conditions, this International Standard and the requirements given for data quality.

— Make a plan for quality assurance of the data collection process and its deliverables. This shall, as a minimum, include procedures for quality control of the data and recording and correcting deviations (see 7.1.3).

— It is recommended to carry out a cost-benefit analysis of the data collection by running a pilot exercise before the main data collection phase is started and to revise the plan if necessary.

— Review the planning measures after a period of using the system (see 7.2.3).

7.1.3 Verification of quality

During and after the data collection exercise, analyse the data to verify consistency, reasonable distributions, proper codes and correct interpretations in accordance with the planning measures (see 7.1.2). This verification-of-quality process shall be documented and may vary depending on whether

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the data collection is for a single plant or involves several company or industry facilities. When merging individual databases, it is imperative that each data record has a unique identification.

Assess the quality of data being collected as early as feasible in the data collection process in accordance with the planning measures (see 7.1.2). A suitable procedure is an assessment by the data collector, who shall be provided with guidelines for what quality measures should be focused on in accordance with the planning measures. The main objective of this early assessment is to look for any problems that require the planning measures to be immediately revised to avoid unacceptable data being collected.

Personnel other than those having collected the data shall verify the quality of each individual data record and the overall reliability pattern reflected by the sum of individual events in accordance with the planning measures (see 7.1.2).

7.1.4 Limitations and problems

Some of the problems and limitations to be aware of, when obtaining quality data are summarized in Table 1.

Table 1 — Problems, limitations and storage

Issue	Challenges
Source	The data source can lack the required data and the source information can be spread over several different systems (computers, files, books, drawings). It is recommended to carefully evaluate this aspect in the planning measures (see 7.1.2) in order to assess data quality, collection method and cost.
Interpretation	Commonly, data are compiled from the source into a standardized format (database). In this process, the source data can be interpreted differently by various individuals. Correct definitions, training and quality checks can reduce this problem (see 7.1.2).
Data format	The use of coded fields is fundamental to ensure data collection efficiency and consistency of data entered (e.g. correct coding of a manufacturer). Free text should, however, be included in addition to codes to describe unexpected or unclear situations
Data collection method	Most data needed for this category of data collection are today stored in computerized systems (e.g. CMMIS). By using state-of-the-art conversion algorithms and software, it is possible to transfer data among different computer databases in a (semi-)automated way, thereby saving cost.
Competence and motivation	Data collection in the "normal" manual way can become a repetitive and tedious exercise. Therefore, take care to employ people with sufficient know-how to do the jobs, avoid using personnel with low competence/experience, as data quality can suffer, and find measures to stimulate the RM data collection staff, e.g. by training, doing plant visits and involving them in data analyses and application of results. Other examples are feedback on data collection results, involvement in QA processes, relevant information fields in facility CMMIS to stimulate reporting quality, etc.

7.2 Data collection process

7.2.1 Data sources

The facility CMMIS constitutes the main source of RM data. The quality of the data that can be retrieved from this source is dependent on the way RM data are reported in the first place. Reporting of RM data according to this International Standard shall be allowed for in the facility CMMIS, thereby providing a more consistent and sound basis for transferring RM data to equipment RM databases. Other sources of information can be spread across several different systems (computers, files, books, drawings), for example, feedback on data collection results, involvement in QA processes. Adequate or proper use of information fields in facility CMMIS will stimulate reporting quality, etc.

Such data collection creates reliability data sources for various applications, as classified in Table D.5:

1) generic data;

2) operator/company specific data;

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3) manufacturer data;

4) expert judgement;

5) human error data.

7.2.2 Data collection methods

The typical data collection process consists of compiling data from different sources into one database where the type and the format of the data are pre-defined. The most common method is as follows.

a) Address all the data sources that are available, and extract the relevant "raw" data into an intermediate storage. If the information is contained in a computerized database, use any suitable methods for extracting the relevant information; viz. extraction of targeted information by specific software methods or printing reports with desired information.

b) Interpret this information and translate it into the type and format desired for the target database. In most cases, this is done by manual interpretation.

c) Transfer the data from the source(s) to the reliability data bank using any suitable method. Suitable "off-the-shelf" software can be used to transfer data from one database to another with the desired "language" conversion done by software algorithms. This is only feasible as long as a conversion algorithm, sufficiently robust to make a confident conversion, can be defined. These methods do require some extra effort upfront and, therefore, are only cost-effective for large quantities of data or repetitive data collection of the same category. It may also be used for maintenance when transferring data from one CMMIS to another.

d) Data collection methods significantly impact the cost-benefit analysis for data collection and shall, therefore, be carefully planned and tested before the main data collection process is started.

7.2.3 Organization and training

Data collection may be done either within the company using internal resources or as a task done by more specialized companies or personnel. As data are, by nature, "historical", it evidently takes some time before sufficient data are accumulated to draw valid conclusions based on statistics only. The cost-benefit analysis for collecting data can take some time to become evident but annual tracking of equipment performance captures a useful history.

Data collection can require skills from several categories, viz. IT, reliability/statistics, maintenance, operation and data collection. Key personnel shall be familiar, in particular, with the data collection concept and any specific software for the data collection activity, and, to a reasonable extent, know the technical, operational and maintenance aspects of the equipment for which data are collected. Proper training of key personnel on these issues is necessary in order to obtain quality data. The personnel who check the quality of the data shall be different from those performing the data collection. Data collectors shall, as a pre-requisite, know this International Standard and should give feedback as appropriate.

Before data collection starts, it is useful to do a pilot exercise to check the available population, the quality of source information and the feasibility of the data collection methods. This serves as a model for what can be achieved within a given time and budget.

A system for dealing with deviations encountered in the data collection process, such as ambiguous definitions, lack of interpretation rules, inadequate codes, etc., shall be established and problems solved as soon as possible. It can be a major task to correct corrupt data after many data have been collected.

A data collection exercise shall also provide feedback by summarizing and evaluating all quality lessons learned during the planning and execution of the data collection effort. Recommendations shall then be fed back to the relevant personnel for improvement on definitions, maintenance systems (e.g. CMMIS-systems) and the data collection process and personnel.

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8 Equipment boundary, taxonomy and time definitions

8.1 Boundary description

A clear boundary description is imperative for collecting, merging and analysing RM data from different industries, plants or sources. It also facilitates communication between operators and equipment manufacturers. Otherwise, the merging and analysis is based on incompatible data.

For each equipment class, a boundary shall be defined indicating what RM data are to be collected. This may be given by using a figure, a text definition or a combination of both.

An example of a boundary diagram is shown in Figure 2 and an example of a definition to accompany the diagram is as follows:

EXAMPLE The boundary applies to both general-service and fire-fighting pumps. Inlet and outlet valves and suction strainer are not within the boundary. Furthermore, the pump drivers along with their auxiliary systems are not included. Driver units are recorded as separate inventories (electric motor, gas turbine or combustion engine) and it is important that the failures on the driver, if recorded, be recorded as part of the driver units. A number in the pump inventory gives a reference to the appropriate driver inventory.

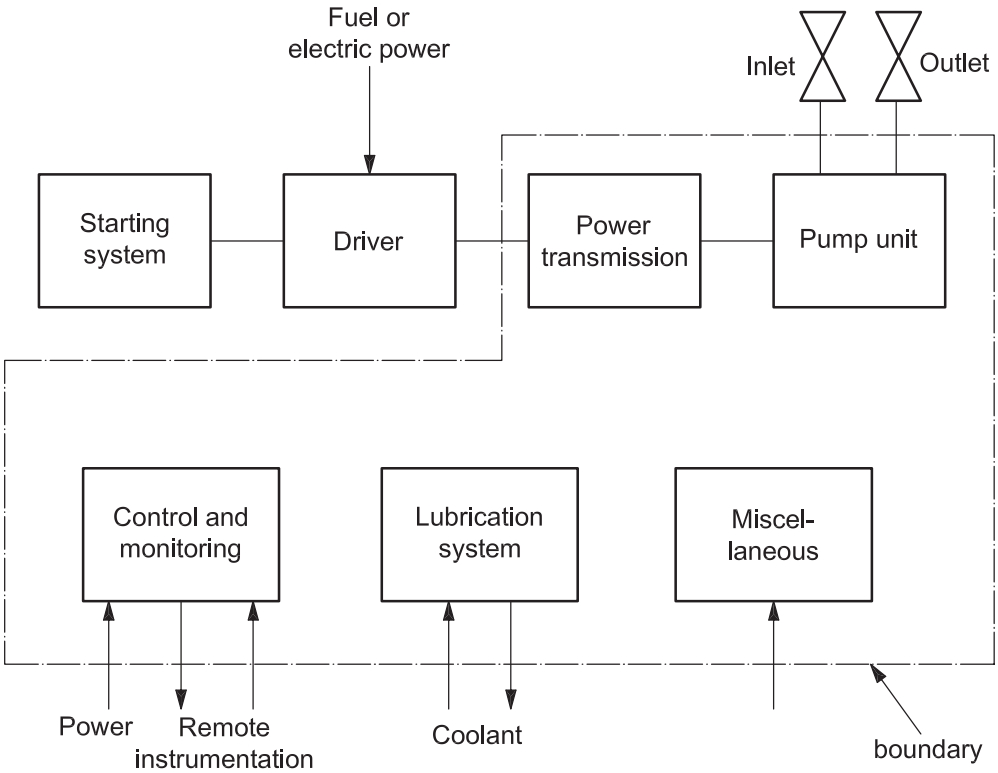

Figure 2 — Example of boundary diagram (pump)

Due attention shall be paid to the location of the instrument elements. In the above example, the central control and monitoring items are typically included within the "control and monitoring" subunit, while individual instrumentation (trip, alarm, control) is typically included within the appropriate subunit, e.g. lubrication system.

The boundary diagram shall show the main lower-level items and the interfaces to the surroundings. Additional textual description shall, when needed for clarity, state in more detail what shall be considered inside and outside the relevant boundary (see the Example associated with Figure 2 where e.g. the driver of the pump is outside the boundary). When referring to this International Standard, it is vital that any deviation from the boundaries given in this International Standard, or new boundaries not given by this International Standard, be specified.

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Boundaries shall avoid overlapping among different equipment classes. For example, when collecting data on instruments as separate equipment units, one shall avoid including those instruments that are also included within the boundaries of other equipment units on which data are being collected. Some overlapping can be difficult to avoid; however, such case(s) shall be identified and treated appropriately during the data analyses.

Recommended boundary diagrams for some selected equipment units are given in Annex A.

8.2 Taxonomy

The taxonomy is a systematic classification of items into generic groups based on factors possibly common to several of the items (location, use, equipment subdivision, etc.). A classification of relevant data to be collected in accordance with this International Standard is represented by a hierarchy as shown in Figure 3. Definitions of each segment are provided below, in addition to examples of different business streams and equipment types, as illustrated in Table 2.

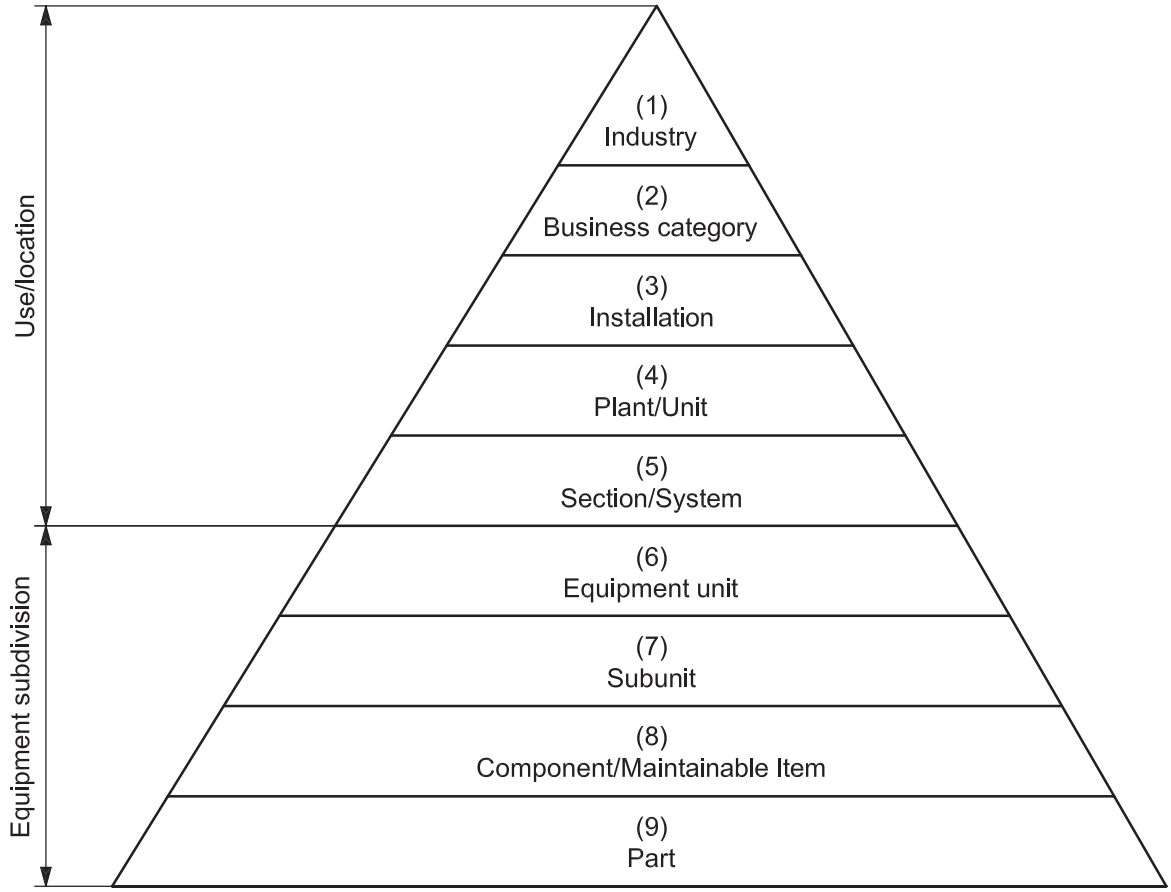

Figure 3 — Taxonomy classification with taxonomic levels

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Table 2 — Taxonomy examples

Main category	Taxonomic level	Taxonomy hierarchy	Definition	Examples
Use/location data	1	Industry	Type of main industry	Petroleum, natural gas, petrochemical
	2	Business category	Type of business or processing stream	Upstream (E and P), midstream, downstream (refining), petrochemical
	3	Installation category	Type of facility	Oil/gas production, transportation, drilling, LNG, refinery, petrochemical (see Table A.1)
	4	Plant/Unit category	Type of plant/unit	Platform, semi-submersible, hydrocracker, ethylene cracker, polyethylene, acetic acid plant, methanol plant (see Table A.2)
	5	Section/ System	Main section/system of the plant	Compression, natural gas, liquefaction, vacuum gas oil, methanol regeneration, oxidation section, reaction system, distillation section, tanker loading system (see Table A.3)
Equipment subdivision	6	Equipment class/unit	Class of similar equipment units. Each equipment class contains comparable equipment units (e.g. compressors).	Heat exchangers, compressors, piping, pumps, gas turbines, subsea wellhead and X-mas trees, lifeboats, extruders, subsea BOPs (see Table A.4)
	7	Subunit	A subsystem necessary for the equipment unit to function	Lubrication subunit, cooling subunit, control and monitoring, heating subunit, pelletizing subunit, quenching subunit, refrigeration subunit, reflux subunit, distributed control subunit
	8	Component/ Maintainable item (MI) [a]	The group of parts of the equipment unit that are commonly maintained (repaired/restored) as a whole	Cooler, coupling, gearbox, lubrication oil pump, instrument loop, motor, valve, filter, pressure sensor, temperature sensor, electric circuit
	9	Part [b]	A single piece of equipment	Seal, tube, shell, impeller, gasket, filter plate, bolt, nut, etc.

[a] For some types of equipment, there might not be a MI; e.g. if the equipment class is piping, there might be no MI, but the part could be "elbow".

[b] While this level can be useful in some cases, it is considered optional in this International Standard.

Levels 1 to 5 represent a high-level categorization that relates to industries and plant application regardless of the equipment units (see level 6) involved. This is because an equipment unit (e.g. pump) can be used in many different industries and plant configurations and, for analysing the reliability of similar equipment, it is necessary to have the operating context. Taxonomic information on these levels (1 to 5) shall be included in the database for each equipment unit as "use/location data" (see Table 2).

Levels 6 to 9 are related to the equipment unit (inventory) with the subdivision in lower indenture levels corresponding to a parent-child relationship. This International Standard focuses on the equipment unit level (level 6) for the collection of RM data and also indirectly on the lower indenture items, such as subunits and components. The number of subdivision levels for the collection of RM data depends on the complexity of the equipment unit and the use of the data. A single instrument might need no further breakdown, while several levels can be required for a large compressor. For data used in availability analyses, the reliability at the equipment-unit level can be the only data required, while an RCM analysis and root-cause analysis can require data on failure mechanism at the component/maintainable item, or parts, level. This International Standard does not specifically address level 9.

It is necessary that RM data be related to a certain level within the taxonomic hierarchy in order to be meaningful and comparable. For example, a failure mode shall be related to the equipment unit, while

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a failure mechanism shall be related to the lowest achievable level in the item hierarchy. Table 3 gives guidance on this.

Table 3 — Reliability and maintenance parameters in relation to taxonomy levels

Recorded RM data	Hierarchy level [a]				
	4 Plant/Unit	5 Section/ System	6 Equipment unit	7 Subunit	8 Component/ Maintainable item
Impact of failure on safety	X [b]				
Impact of maintenance on safety	X				
Impact of failure on operations	X	(X) [c]			
Impact of maintenance with regard to operations	X	(X)			
Failure impact on equipment			X	(X)	(X)
Failure mode		(X)	X	(X)	(X)
Failure mechanism			(X)	(X)	X
Failure cause				(X)	X
Detection method		(X)	X	(X)	(X)
Subunit failed				X	
Component/maintainable item failed					X
Down time	(X)	(X)	X		
Active maintenance time			X	(X)	(X)

[a] See Figure 3.

[b] X = default.

[c] (X) = possible alternatives.

Regarding items on different hierarchy levels, many items may be found on different levels in the taxonomic hierarchy, depending on the context or the size of the item. For instance, valve and pump are equipment classes, but may also be maintainable items in a gas turbine. The valve is typically a maintainable item subsea and an equipment unit topside. Due care should be taken to avoid double-counting failure events when RM data are collected on such equipment.

For some systems it may be relevant to apply RM data collection also on Level 5 (system level, see Table A.3). Although many of the same principles as used for equipment data collection on Level 6-8 may apply, these should be used carefully as there could be large differences between the individual systems selected for the data collection.

8.3 Timeline issues

8.3.1 Surveillance and operating period

The equipment surveillance period is typically used as the time period for determining time-related reliability parameters, e.g. MTTF, component life, etc. For many equipment units, the operating, or in-service, period is less than the surveillance period due to maintenance, sparing of equipment or intermittent operation of the equipment (e.g. tank-transfer pumps).

When equipment is in an idle state or in “hot” standby, i.e. being ready for immediate operation when started, it is considered to be operating (or “in-service”) by the definitions in this International Standard. Equipment on standby, which would require some activities to be performed before being ready for operation (“cold” standby) is not considered to be in an operating state. The various time-period definitions are illustrated in Table 4.

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Data may also be collected for actual preventive maintenance if one wants the full picture of down time caused by all maintenance actions (see Table 4). Periods when equipment is deliberately taken out of service for an extended period, or is being modified, are not considered to be relevant for data collection.

The surveillance period may also cover several states in the life of the item. For example, in the subsea environment, equipment can be installed and functioning, i.e. a barrier to the escape of downhole hydrocarbons, but the well might not start producing for several months. Failures can occur on the equipment during this phase, requiring it to be repaired with a potential delay to start-up. Likewise, equipment can fail during a refinery turnaround, which is not a "production" phase, again requiring repair and possible delay to start-up.

Table 4 — Timeline definitions

Total time [h]													
Down time								Up time					
Planned down time				Unplanned down time				Operating time				Non-operating time	
Preventive maintenance		Other planned outages		Corrective maintenance			Other unplanned outages						
Preparation and/or delay	Active preventive maintenance (item being worked on) [f]	Reserve [a]	"Modification [b]	Undetected faults [g]	Preparation and/or delay	Repair (item being worked on) [c]	Shut-down, operational problems/ restrictions etc. [d]	Run-down	Start-up	Running [e]	Hot stand-by	Idle	Cold stand-by

[a] Means that item is available for operation, but not required for some time. Does not include items considered as "spare parts" or items taken out of service on a more permanent basis.

[b] Modification can change the reliability characteristics of an item and can, therefore, require that the collection of reliability data for the surveillance period be terminated before the modification and be re-started with a new surveillance period after the modification.

[c] Includes fault diagnosis, repair action and testing (as required).

[d] Shutdown of machinery (trip and manual shutdown), see definition of trip (3.93) and also C.1.8.

[e] Running is the active operational period for equipment in oil & gas production systems. For drilling and workover systems, this is not sufficient since there are many different operational phases. The operational phases for drilling could include: Running, drilling, tripping, set casing; and, the phases for workover could include: well equipment removal, replace completion string, replace casing string, and various workover activities.

[f] Includes testing

[g] It is difficult to determine downtime associated with undetected faults. These faults are eventually revealed by test or demand.

[h] See also ISO/TR 12489:2013, Figures 5, 6, and 7.

8.3.2 Data collection periods

Depending on use and feasibility, data may be recorded for the whole equipment lifetime or for shorter intervals. The latter is common due to both cost and obtaining the data within a reasonable time frame. As shown in Annex C, the lifetime of many items is assumed to follow the so-called "bathtub" curve. If only the RM data for the steady-state operating part of an item are required, data collection shall start after the burn-in period is considered to have ended. The length of this period can vary among equipment categories from no burn-in to several months. Data recorded during the steady-state operating period often follows, or is assumed to follow, the exponential lifetime curve (constant failure rate). For some equipment, it is also useful and essential to collect data from "day one" in order to accumulate experience on burn-in failures. In this case, data collected from what may be considered as an initial burn-in period shall be distinguished from data collected from the subsequent steady-state operating period.

The length of the data collection period shall be balanced against the expected failure rate, size of population and access to data. For equipment of high importance (safety) and equipment where one knows that few failures normally occur (subsea), a longer surveillance period is desirable (e.g. the whole lifetime history). It is even useful to collect data for equipment with no failures during the surveillance period because, by observing no failures in a given period, it is possible to estimate the failure rate by

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"censoring" the data. Methods within statistics shall be used to estimate the confidence of the data (upper/lower confidence limits), as shown in Annex C.

While the surveillance period is just an interval in the calendar time between two specific times and can, therefore, be defined exactly, operating time is not always that straightforward to determine. For some rotating equipment, the operating time is recorded on a counter and can be read exactly. For other equipment, this might not be true. Hence, it is often necessary to estimate operating time based on knowledge from the operating and/or maintenance staff. As the "true" failure rate for an item shall be calculated based on actual operation, high priority should be given to collecting or estimating this parameter.

8.3.3 Maintenance times

Two main calendar times during maintenance are recommended to be collected, viz. down time and active repair time. The difference between the two is illustrated in Figure 4. For further information on breakdown of the downtimes, see also ISO/TR 12489:2013, Figures 5 to 7, and ISO 20815:2008, Figure I.5.

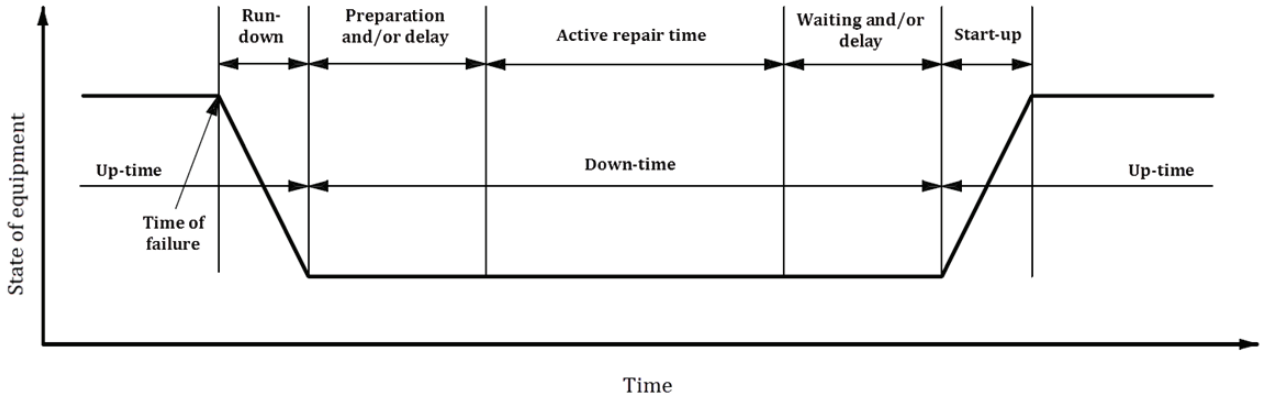

Figure 4 — Maintenance times

Down time includes the calendar time from the time the equipment is stopped for a repair until it is reconnected to its intended service after having been tested.

Active maintenance time" is the "active corrective maintenance time" then see ISO/TR 12489:2013, Figure 5, where "active corrective maintenance time" consists of the "active repair time" (MRT) and the "technical delay. Active maintenance time is the calendar time during which maintenance work on the item is actually performed. Hence, active repair time cannot normally be greater than the down time. However, exceptionally, active repair time can be greater than down time if the maintenance can be performed with the equipment unit operating. Note that the operational time required to run down the equipment before repair and start-up up after the repair is not considered to be part of the down time. Mobilization time is part of the preparation and/ or delay.

NOTE See relevant definitions regarding maintenance times in Clause 3.

9 Recommended data for equipment, failures and maintenance

9.1 Data categories

The RM data shall be collected in an organized and structured way. The major data categories for equipment, failure and maintenance data are the following.

a) Equipment unit data (inventory data)

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The description of an equipment unit (level 6 in Figure 3) is characterized by the following:

1) classification data, e.g. industry, plant, location, system;

2) equipment attributes, e.g. manufacturer's data, design characteristics;

3) operational data, e.g. operating mode, operating power, environment.

These data categories shall be general for all equipment classes. Additionally, some data specific for each equipment class (e.g. number of stages for a compressor) are required. Recommended data for some equipment classes are given in Annex A.

b) Failure data

These data are characterized by the following:

1) identification data, e.g. failure record number and related equipment that has failed;

2) failure data for characterizing a failure, e.g. failure date, items failed, failure impact, failure mode, failure cause, failure detection method.

c) Maintenance data

These data are characterized by the following:

1) identification data, e.g. maintenance record number, related failure and/or equipment record;

2) maintenance data, parameters characterising a maintenance action, e.g. date of maintenance, maintenance category, maintenance activity, impact of maintenance, items maintained;

3) maintenance resources, maintenance man-hours per discipline and total, utility equipment/ resources applied;

4) maintenance times, active maintenance time, down time.

The type of failure and maintenance data shall normally be common for all equipment classes, with exceptions where it is necessary to collect specific types of data, e.g. subsea equipment.

Corrective-maintenance events shall be recorded in order to describe the corrective action following a failure. Preventive-maintenance records are required to retain the complete lifetime history of an equipment unit.

9.2 Data format

Each record, e.g. a failure event, shall be identified in the database by a number of attributes. Each attribute describes one piece of information, e.g. failure mode. It is recommended that each piece of information be coded where possible. The advantages of this approach versus free text are

— facilitation of queries and analysis of data,

— ease of data input,

— consistency check undertaken at input, by having predefined code lists,

— minimization of database size and response time of queries.

The range of predefined codes shall be optimized. A short range of codes is too general to be useful. A long range of codes gives a more precise description, but slows the input process and might not be used fully by the data collector. Selected codes shall, if possible, be mutually exclusive.

The disadvantage of a predefined list of codes versus free text is that some detailed information can be lost. For all categories mentioned in 9.1 a), b) and c), it is recommended to include some additional free text giving more explanatory information as available and deemed relevant, e.g. to include a narrative

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of the occurrence leading to a failure event. This would assist in quality checking the information and browsing through single records to extract more detailed information.

Examples of codes are given in Annexes A and B for different equipment types and reliability data. Generic reliability data will use such equipment data, and failure and maintenance characteristics. Regarding the generic reliability data, see also D.5 and Table D.5.

9.3 Database structure

9.3.1 Description

The data collected shall be organized and linked in a database to provide easy access for updates, queries and analysis. Several commercial databases are available that can be used as the main building blocks for designing a reliability database. Two aspects of organizing the structure of data shall be addressed as described in 9.3.2 and 9.3.3.

9.3.2 Logical structure

The logical structure defines the logical links among the main data categories in the database. This model represents an application-oriented view of the database. The example in Figure 5 shows a hierarchical structure with failure and maintenance records linked to the equipment unit (inventory). Records describing preventive maintenance (PM) are linked to the inventory description in a many-to-one relation. The same applies for failures, which additionally have related corrective-maintenance records linked to each failure record. Each record (e.g. failure) may consist of several attributes (e.g. failure date, failure mode, etc.).

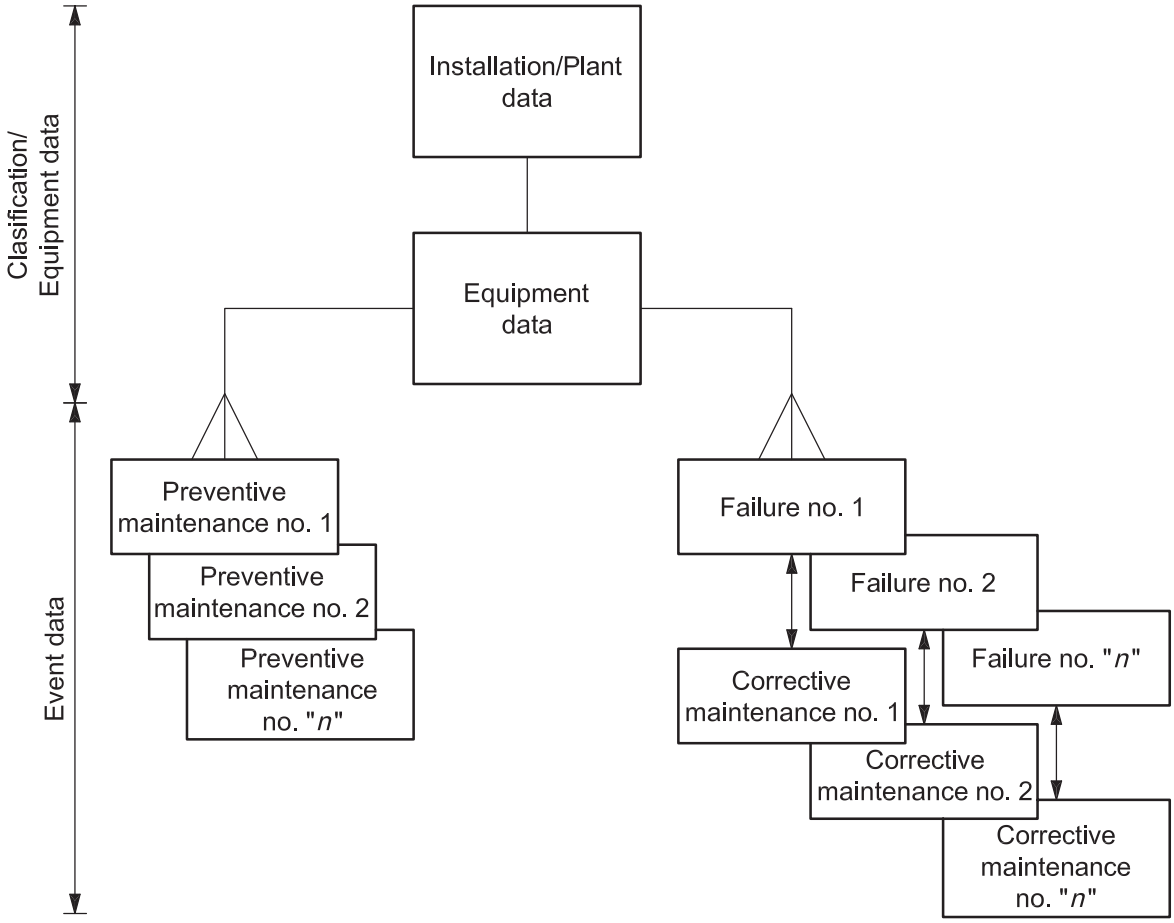

Figure 5 — Logical data structure (example)

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9.3.3 Database architecture

This defines the design of the database as to how the individual data elements are linked and addressed. The following four model categories are commonly available, ranked from lowest to highest complexity and versatility:

Hierarchical model: Data fields within records are related by a "family tree" relationship. Each level represents a particular attribute of data.

Network model: This is similar to the hierarchical model; however, each attribute can have more than one parent.

Relational model: The model is constructed from tables of data elements, which are called relations. No access path is defined beforehand; all types of manipulation of the data in tabular form are possible. The majority of database designs use this concept.

Object model: The software is considered as a collection of objects, each of which has (1) a structure and (2) an interface. The structure is fixed within each object while the interface is the visible part that provides the link address between the objects. Object modelling enables the database design to be very flexible, extendable, reusable and easy to maintain. This model seems to be popular in new database concepts.

9.4 Equipment data

The classification of equipment into technical, operational and environmental parameters is the basis for the collection of RM data. This information is also necessary to determine whether the data are suitable or valid for various applications. Some data are common to all equipment classes and other data are specific to a particular equipment class.

To ensure that the objectives of this International Standard are met, a minimum of data shall be collected. These data are identified by an asterisk (*) in Tables 5, 6 and 8. However, the addition of certain other data categories can significantly improve the potential usability of the RM data (see Annex D). In all cases, the minimum data collected on equipment level should allow a data exchange between the equipment owner (user) and the manufacturer. The minimum data shall encompass all data required to identify the equipment physical location at any given point in time, the main design attribute identifier used by both parties (e.g. manufacturer's part number), manufacturer and unique identifier of each specific equipment item (typically manufacturer's serial number).

Equipment data consists of two parts:

- equipment data common to all equipment classes;
- equipment specific.

Table 5 contains the data common to all equipment classes. In addition, some data that are specific for each equipment class shall be recorded. Annex A gives examples of such data for some equipment classes. In the examples in Annex A, the priority data are suggested, but they can vary according to each case or application. For some equipment specific data, low priority data can be difficult to obtain, but if available can be valuable for analysis of the specific equipment.

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Table 5 — Equipment data common to all equipment classes

Data category	Data	Taxonomic level [a]	Business category (examples)			
			Upstream (E & P)	**Midstream**	**Downstream** (refining)	**Petro-chemical**
Use/ Location attributes	Industry	1	Petroleum	Natural gas	Petroleum	Petrochemical
	Business category (*)	2	E & P	Midstream	Refining	Petrochemical
	Installation category	3	Oil/gas production	Pipeline	Refinery	Petrochemical
	Installation code or name (*)	3	Delta	Beta gas line	Charlie refinery	Delta chemical
	Owner code or name	4	Smith Ltd.	Johnsen Inc.	JPL Corp.	ABC ASA
	Geographic location	3	UKCS	Europe	Mid-west USA	UK
	Plant/Unit category (*)	4	Oil/gas platform	Compressor station	Hydro-cracker	Ethylene cracker
	Plant/Unit code or name (*)	4	Alpha 1	CS 3	HH 2	EC 1
	Section/System (see Annex A) (*)	5	Oil processing	Compression	Reaction	Reaction system
	Operation category	5	Remote control	Remote control	Manned	Manned
Equipment attributes	Equipment class (see Annex A) (*)	6	Pump	Compressor	Heat exchanger	Heater
	Equipment Type (see Annex A) (*)	6	Centrifugal	Centrifugal	Shell and tube	Fired
	Equipment identification/ Location (e.g. tag number) (*) [b]	6	P101-A	C1001	C-21	H-1
	Equipment description (nomenclature)	6	Transfer	Main compressor	Reactor effluent	Charge heater
	Unique equipment identification number [b]	6	12345XL	10101	Cxy123	909090
	Manufacturer's name (*) [c]	6	Johnson	Wiley	Smith	Anderson
	Manufacturer's model designation [g]	6	Mark I	CO_2	GTI	SuperHeat A
	Design data relevant for each equipment class and subunit/component as applicable, e.g. capacity, power, speed, pressure, redundancy, relevant standard(s) (see also Annex A)	6 - 8	Equipment-specific	Equipment-specific	Equipment-specific	Equipment-specific
Operation (normal use)	Normal operating state/ Mode (*)	6	Running	Active standby	Intermittent	Running
	Initial equipment commissioning date	6	2003.01.01	2003.01.01	2003.01.01	2003.01.01
	Start date of current service (*)	6	2003.02.01	2003.02.01	2003.02.01	2003.02.01

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Table 5 *(continued)*

Data category	Data	Taxonomic level [a]	Business category (examples)			
			Upstream (E & P)	Midstream	Downstream (refining)	Petro-chemical
	Surveillance time, h (calculated) (*)	6	8 950	8 000	5 400	26 300
	Operational time, h [d] (measured/calculated)	6	7 540	675	2 375	22 870
	Number of periodic test demands during the surveillance period as applicable (*)[e]	6 - 8	4	2	2	4
	Number of operational demands during the surveillance period as applicable (*)[e]	6 - 8	4	5	11	3
	Total wells drilled during surveillance period (*)[f]	4	42	N.A.	N.A.	N.A.
	Operating parameters as relevant for each equipment class; e.g. ambient conditions, operating power (see Annex A)	6	Equipment-specific	Equipment-specific	Equipment-specific	Equipment-specific
Additional information	Additional information in free text as applicable	6	Specify as needed	Specify as needed	Specify as needed	Specify as needed
	Source of data, e.g. P & ID, data sheet, maintenance system	6	Specify as needed	Specify as needed	Specify as needed	Specify as needed

[a] See definitions in Figure 3.

[b] A specific individual equipment unit has an "Unique equipment identification number" (serial number), and this may be required for documenting potential change-out at the equipment level. The tag number identifies the equipment function and its physical location. If the equipment is replaced with, e.g. an overhauled unit, the tag number (and part number) remains the same, but the serial number changes. Operator and equipment supplier may have different "Unique equipment identification number" for same specific equipment unit. See also ISO 15926-2:2003, E.3.3 which describes this relationship in more detail.

[c] Manufacturer may be relevant for lower hierarchical levels, i.e. level 7 and 8.

[d] Equipment may be subject to different operational phases, such as for example for equipment used in drilling operations

[e] See further information on number of demands in C.1.3.

[f] This applies only to drilling related equipment classes.

[g] Equipment classes, subunits or maintainable items within some equipment classes can have the need to have a separate information field in the equipment specific data (Level 6-8 in the taxonomy in Figure 3) to reflect the technology generation, to distinguish between older and new technology in reliability data collection and analysis.

(*) indicates the minimum data that shall be collected.

9.5 Failure data

A uniform definition of failure and a method of classifying failures are essential when it is necessary to combine data from different sources (plants and operators) in a common RM database.

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A common report, as given in Table 6 (see also Table 3), for all equipment classes shall be used for reporting failure data. For some equipment classes, e.g. subsea equipment, minor adaptations can be necessary.

Table 6 — Failure data

Data category	Data to be recorded	Description
Identification	Failure record (*)	Unique failure record identification
	Equipment identification/Location (*)	E.g. tag number (see Table 5)
Failure data	Failure date (*)	Date of failure detection (year/month/day)
	Failure mode (*)	Usually at equipment-unit level (level 6) (see B.2.6) [a]
	Failure impact on plant safety (e.g. personnel, environment, assets) [b]	Qualitative or quantitative failure consequence categorization (see also C.1.10)
	Failure impact on plant operations (e.g. production, drilling, intervention) [b]	Qualitative or quantitative failure consequence categorization (see also C.1.10)
	Failure impact on equipment function (*)	Effect on equipment-unit function (level 6): critical, degraded, or incipient failure [c]
	Failure mechanism	The physical, chemical or other processes which have led to a failure (see Table B.2)
	Failure cause [d]	The circumstances during design, manufacture or use which have led to a failure (see Table B.3)
	Subunit failed	Name of subunit that failed (see examples in Annex A)
	Component/Maintainable item(s) failed	Name of the failed component/maintainable item(s) (see Annex A)
	Detection method	How the failure was detected (see Table B.4)
	Operating condition at failure (*)	Run-down, start-up, running, hot standby, idle, cold standby, testing
	Operational phase at failure [e]	Type of operation at the time of failure
	SIS failure mode classification [f]	Classify the failure for the specific event (DU, DD, SU, SD; see F.2) [g]
Remarks	Additional information	Give more details, if available, on the circumstances leading to the failure: failure of redundant units, failure cause(s) etc.

[a] For some equipment categories such as subsea equipment, it is recommended to also record failure modes on taxonomic levels lower than the equipment-unit level.

[b] See example of failure consequence classification in Table C.2

[c] For some equipment categories and applications it may be sufficient to record critical and non-critical (degraded + incipient) failures only.

[d] The failure cause and sometimes the failure mechanism are not known when the data are collected, as they commonly require a root cause analysis to be performed. Such analysis shall be performed for failures of high consequence, high repair/down time cost, or failures occurring significantly more frequent than what is considered "normal" for this equipment unit class ("worst actors").

[e] Relevant for some equipment, e.g. drilling, completion and workover equipment. The code table depends on equipment category. The operation at the time of failure should be specified, such as drilling, tripping, cementing, perforating, well killing, etc.

[f] This is for data collection purposes internally for the company and for applications on the specific installation where it is collected. Carefulness if generalizing due to possible differences in classification for the same equipment class on same or different installations.

[g] The classes, DU (dangerous undetected), DD (dangerous detected), SU (safe undetected), SD (safe detected), are defined in IEC 61508-4:2010. See also ISO/TR 12489:2013.

(*) indicates the minimum data that shall be collected.

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