DEUTSCHE NORM

April 2007

DIN EN ISO 14224

DIN

ICS 75.180.01

Erdöl-, petrochemische und Erdgasindustrie – Sammlung und Austausch von Zuverlässigkeits- und Wartungsdaten für Ausrüstungen (ISO 14224:2006); Englische Fassung EN ISO 14224:2006

Petroleum, petrochemical and natural gas industries – Collection and exchange of reliability and maintenance data for equipment (ISO14224:2006); English version EN ISO 14224:2006

Industries du pétrole, de la pétrochimie et du gaz naturel – Recueil et échange de données de fiabilité et de maintenance des équipements (ISO 14224:2006); Version anglaise EN ISO 14224:2006

Gesamtumfang 176 Seiten

Normenausschuss Erdöl- und Erdgasgewinnung (NÖG) im DIN

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Nationales Vorwort

Diese Europäische Norm wurde vom Technischen Komitee CEN/TC 12 „Materialien, Ausrüstungen und Offshore-Bauwerke für die Erdöl-, petrochemische und Erdgasindustrie“ (Sekretariat: Frankreich) erstellt. Es handelt sich dabei um die unveränderte Übernahme von ISO/FDIS 14224:2006, erarbeitet von ISO/TC 67 „Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries“, Subkomitee SC 7 „Offshore-Konstruktionen“ (Sekretariat: England).

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN ISO 14224

December 2006

ICS 75.180.01; 75.200

English Version

Petroleum, petrochemical and natural gas industries - Collection and exchange of reliability and maintenance data for equipment (ISO 14224:2006)

Industries du pétrole, de la pétrochimie et du gaz naturel - Recueil et échange de données de fiabilité et de maintenance des équipements (ISO 14224:2006)

Erdöl-, petrochemische und Erdgasindustrie - Sammlung und Austausch von Zuverlässigkeits- und Wartungsdaten für Ausrüstungen (ISO 14224:2006)

This European Standard was approved by CEN on 14 December 2006.

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Foreword

This document (EN ISO 14224:2006) has been prepared by Technical Committee ISO/TC 67 “Materials, equipment and offshore structures for petroleum and natural gas industries” in collaboration with Technical Committee CEN/TC 12 “Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2007, and conflicting national standards shall be withdrawn at the latest by June 2007.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Endorsement notice

The text of ISO 14224:2006 has been approved by CEN as EN ISO 14224:2006 without any modifications.

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Introduction

This International Standard has been prepared based on ISO 14224:1999, experience gained through its use, and know-how and best practices shared through the international development process.

In the petroleum, natural gas and petrochemical industries, great attention is being paid to safety, reliability and maintainability of equipment. The industry annual cost of equipment unreliability is very large, although many plant owners have improved the reliability of their operating facilities by such attention. 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 of increased importance. It is necessary that this information be 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 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 reliability, 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 to optimize 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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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.

Annex A contains a summary of equipment that this International Standard covers.

- This International Standard recommends a minimum amount of data that is required to be collected and it focuses on two main issues:
  - data requirements for the type 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:
  - equipment data, e.g. equipment taxonomy, equipment attributes;
  - failure data, e.g. failure cause, failure consequence;
  - 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:
  - reliability, e.g. failure events and failure mechanisms;
  - availability/efficiency, e.g. equipment availability, system availability, plant production availability;
  - maintenance, e.g. corrective and preventive maintenance, maintenance supportability;
  - safety and environment, e.g. equipment failures with adverse consequences for safety and/or environment.

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- This International Standard does not apply to the following:
  - data on (direct) cost issues;
  - data from laboratory testing and manufacturing (e.g. accelerated lifetime testing);
  - complete equipment data sheets (only data seen relevant for assessing the reliability performance are included);
  - additional on-service data that an operator, on an individual basis, can consider useful for operation and maintenance;
  - 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 referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-1:2004, *Rotating electrical machines — Part 1: Rating and performance*

IEC 60076-1:2000, *Power transformers — Part 1: General*

IEC 60076-2:1993, *Power transformers — Part 2: Temperature rise*

EC 60076-3, *Power transformers — Part 3: Insulation levels, dialectric tests and external clearances in air*

IEC 60529:2001, *Degrees of protection provided by enclosures (IP Code)*

IEC 62114, *Electrical insulation systems — Thermal classification*

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
availability
ability of an item to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval, assuming that the required external resources are provided

NOTE For a more detailed description and interpretation of availability, see Annex C.

3.2
active maintenance time
that part of the maintenance time during which a maintenance action is performed on an item, either automatically or manually, excluding logistic delays

NOTE 1 A maintenance action can be carried out while the item is performing a required function.

NOTE 2 For a more detailed description and interpretation of maintenance times, see Figure 4 and Annex C.

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3.3
boundary
interface between an item and its surroundings

3.4
common-cause failure
failures of different items resulting from the same direct cause, occurring within a relatively short time, where these failures are not consequences of another

NOTE 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.

3.5
corrective maintenance
maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function

NOTE For more specific information, see IEC 60050-191:1990, Figure 191-10.

3.6
critical failure
failure of an equipment unit that causes an immediate cessation of the ability to perform a required function

NOTE 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.

3.7
degraded failure
failure that does not cease the fundamental function(s), but compromises one or several functions

NOTE 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.

3.8
demand
activation of the function (includes functional, operational and test activation)

NOTE For a more detailed description, see C.2.2.

3.9
down state
internal disabled state of an item characterized either by a fault or by a possible inability to perform a required function during preventive maintenance

NOTE This state is related to availability performance (see 3.1).

3.10
down time
time interval during which an item is in a down state

NOTE 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).

3.11
equipment class
class of similar type of equipment units (e.g. all pumps)

NOTE Annex A describes a variety of equipment classes.

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3.12
equipment data
technical, operational and environmental parameters characterizing the design and use of an equipment unit

3.13
equipment unit
specific equipment unit within an equipment class as defined by its boundary (e.g. one pump)

3.14
error
discrepancy between a computed, observed or measured value or condition and the true, specified or theoretically correct value or condition

NOTE 1 An error can be caused by a faulty item, e.g. a computing error made by faulty computer equipment.

NOTE 2 The French term “erreur” can also designate a mistake.

3.15
failure
termination of the ability of an item to perform a required function

NOTE 1 After the failure, the item has a fault.

NOTE 2 “Failure” is an event, as distinguished from a “fault,” which is a state.

NOTE 3 This concept as defined does not apply to items consisting of software only.

NOTE 4 See also Table B.1 and Clauses F.2 and F.3.

3.16
failure cause
root cause
circumstances associated with design, manufacture, installation, use and maintenance that have led to a failure

NOTE See also B.2.3.

3.17
failure data
data characterizing the occurrence of a failure event

3.18
failure impact
impact of a failure on an equipment's function(s) or on the plant

NOTE On the equipment level, failure impact can be classified in three classes (critical, degraded, incipient); see 3.6, 3.7 and 3.26). Classification of failure impact on taxonomy levels 3 to 5 (see Figure 3) is shown in Table 3.

3.19
failure mechanism
physical, chemical or other process that leads to a failure

NOTE See also B.2.2.

3.20
failure mode
effect by which a failure is observed on the failed item

NOTE See also B.2.6.

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3.21
failure on demand
failure occurring immediately when the item is solicited to start (e.g. stand-by emergency equipment)

NOTE See also Clause C.6.

3.22
fault
state of an item characterized by inability to perform a required function, excluding such inability during preventive maintenance or other planned actions, or due to lack of external resources

3.23
generic reliability data
reliability data covering families of similar equipment

3.24
hidden failure
failure that is not immediately evident to operations and maintenance personnel

NOTE Equipment that fails to perform an “on demand” function falls into this category. It is necessary that such failures be detected to be revealed.

3.25
idle time
part of the up time that an item is not operating

3.26
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

3.27
indenture level
level of subdivision of an item from the point of view of maintenance action

3.28
item
any part, component, device, subsystem, functional unit, equipment or system that can be individually considered

NOTE 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.

3.29
logistic delay
that accumulated time during which maintenance cannot be carried out due to the necessity to acquire maintenance resources, excluding any administrative delay

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

3.30
maintainable item
item that constitutes a part or an assembly of parts that is normally the lowest level in the equipment hierarchy during maintenance

3.31
maintenance
combination of all technical and administrative actions, including supervisory actions, intended to retain an item in, or restore it to, a state in which it can perform a required function

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3.32
maintenance data
data characterizing the maintenance action planned or done

3.33
maintenance impact
impact of the maintenance on the plant or equipment's function(s)

NOTE On the equipment level, two severity classes are defined: critical and non-critical. On plant level, three classes are defined: total, partial or zero impact.

3.34
maintenance record
part of maintenance documentation that contains all failures, faults and maintenance information relating to an item

NOTE This record can also include maintenance costs, item availability or up time and any other data where relevant.

3.35
maintainability
⟨general⟩ ability of an item under given conditions of use, to be retained in, or restored to, a state in which it can perform a required function, when maintenance is performed under given conditions and using stated procedures and resources

NOTE For a more detailed definition and interpretation of maintainability, see Annex C.

3.36
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 Maintenance man-hours are expressed in units of hours.

NOTE 2 As several people can work at the same time, man-hours are not directly related to other parameters like MTTR or MDT (see definitions in Annex C.5).

3.37
modification
combination of all technical and administrative actions intended to change an item

NOTE Modification is not normally a part of maintenance, but is frequently performed by maintenance personnel.

3.38
non-critical failure
failure of an equipment unit that does not cause an immediate cessation of the ability to perform its required function

NOTE Non-critical failures can be categorized as "degraded" (3.7) or "incipient" (3.26).

3.39
operating state
state when an item is performing a required function

3.40
operating time
time interval during which an item is in operating state

NOTE Operating time includes actual operation of the equipment or the equipment being available for performing its required function on demand. See also Table 4.

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3.41
opportunity maintenance
maintenance of an item that is deferred or advanced in time when an unplanned opportunity becomes available

3.42
preventive maintenance
maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item

3.43
redundancy
existence of more than one means for performing a required function of an item

NOTE For more detailed definitions and interpretations, see C.1.2.

3.44
reliability
ability of an item to perform a required function under given conditions for a given time interval

NOTE 1 The term “reliability” is also used as a measure of reliability performance and can also be defined as a probability.

NOTE 2 For more detailed definitions and interpretations, see Annex C.

3.45
required function
function or combination of functions of an item that is considered necessary to provide a given service

3.46
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

3.47
surveillance period
interval of time (calendar time) between the start date and end date of RM data collection

NOTE For more detailed definitions and interpretations, see Annex C.

3.48
tag number
number that identifies the physical location of equipment

NOTE For more detailed definitions and interpretations, see Annex C.

3.49
taxonomy
systematic classification of items into generic groups based on factors possibly common to several of the items

3.50
up state
state of an item characterized by the fact it can perform a required function, assuming that the external resources, if required, are provided

NOTE This relates to availability performance.

3.51
up time
time interval during which an item is in an up state

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4 Abbreviated terms

NOTE Specific abbreviations used for equipment types (e.g. BOP) and units (e.g. kW) are not included in the list below, but covered within each chapter where they are used.

CAPEX	capital expenditure
CDF	cumulative distribution function
CM	condition monitoring
CMMIS	computerized maintenance-management information system
DHSV	downhole safety value
ESD	emergency shutdown
FTA	fault-tree analysis
FMECA	failure mode, effect and criticality analysis
HIPPS	high-integrity process-protection system
KPI	key performance indicators
LCC	life cycle cost
LEL	lower explosion limit
MEG	monoethylene glycol
MI	maintainable item
MTBF	mean time between failures
MTTF	mean time to failure
MTTR	mean time to repair
MTTM	mean time to maintain
MUT	mean up time
MDT	mean down time
NDT	nondestructive testing
OPEX	operational expenditure
PM	preventive maintenance
P&ID	process and instrument diagram
PSD	process shutdown
PSV	process safety valve
QRA	quantitative risk assessment
RA	reliability and availability
RAM(S)	reliability, availability, maintainability (and safety)
RBI	risk-based inspection
RCM	reliability-centred maintenance
RM	reliability and maintenance
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 may be permanently installed at the facilities or used in conjunction with installation, maintenance or modification phases.

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.

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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 types. 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 excluded from the scope of this International Standard. It is, however, 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, and benefit from, past reliability knowledge to reveal potential improvement areas (see 8.3).

5.3 Users of this International Standard

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

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

b) 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.

c) 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”).

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

e) 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.

f) 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 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

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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.

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.

a) 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 rate 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) parameters may be used. Examples of such KPI parameters are given in Annex E.

b) 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.

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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 comply 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.

c) 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.

d) 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 reliability of their operating facilities, lost production and 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 a 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.

Improvement of equipment reliability is dependent on experiences from real-life usage. The collection, analysis and feedback of 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 do have impact on safety, production, environment or high repair/replacement cost as indicated below.

A typical feedback loop for potential uses of data is shown in Figure 1.

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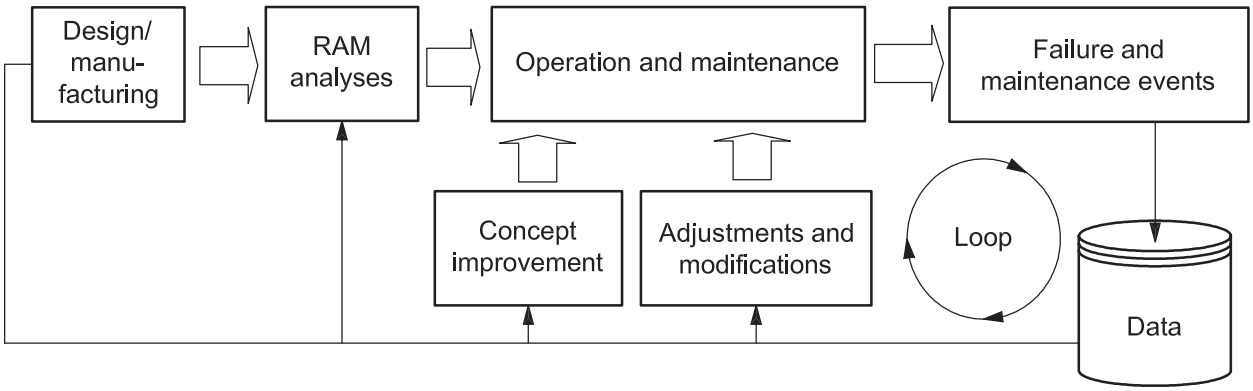

Figure 1 — Typical feedback of analysis from collected reliability and maintenance data

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

a) 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;

b) general aspects:

— “being able to operate” (operatorship license),

— life extension of capital equipment,

— improved product quality,

— better (data-based) equipment purchase,

— better resource planning;

c) 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;

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d) analytical:

— higher-quality data,

— larger population of data,

— improved decision-making,

— reduced uncertainty in decision-making,

— qualified benchmarking,

— facilitation of industrial co-operation,

— 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 to the data user’s need.

7.1.2 Planning measures

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

a) 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.)

b) 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.

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

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

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

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

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

h) 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. consistence 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.

i) 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 > 75 %);

   — LOW: desirable data (coverage > 50 %).

j) 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, regularity and/or other severity measures.

k) 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.

l) 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).

m) 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.

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n) 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. This verification of data quality shall be documented and may vary depending on whether 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 have a unique identification.

o) 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.

p) 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 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 have 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 he/she should focus on in accordance with the planning measures. The main objective of this early assessment is to look for any problems that can 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 and limitations and storage

Issue	Challenges
Source	The data source can lack 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. Proper definitions, training and quality checks can reduce this problem (see 7.1.2).
Data format	In order to limit database size and make it easier to analyse the data, coded information is preferable to a free-text format; however, take care to ensure that the codes selected are appropriate for the information required and be aware that, although codes reduce the size of the database, some information is not collected. 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 as (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.

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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 source 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 improper use of information fields in facility CMMIS to stimulate reporting quality, etc.

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, however, feasible only 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 sources 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 doing the data collection. Data collectors shall, as a pre-requisite, know this International Standard and 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.

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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.

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 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.

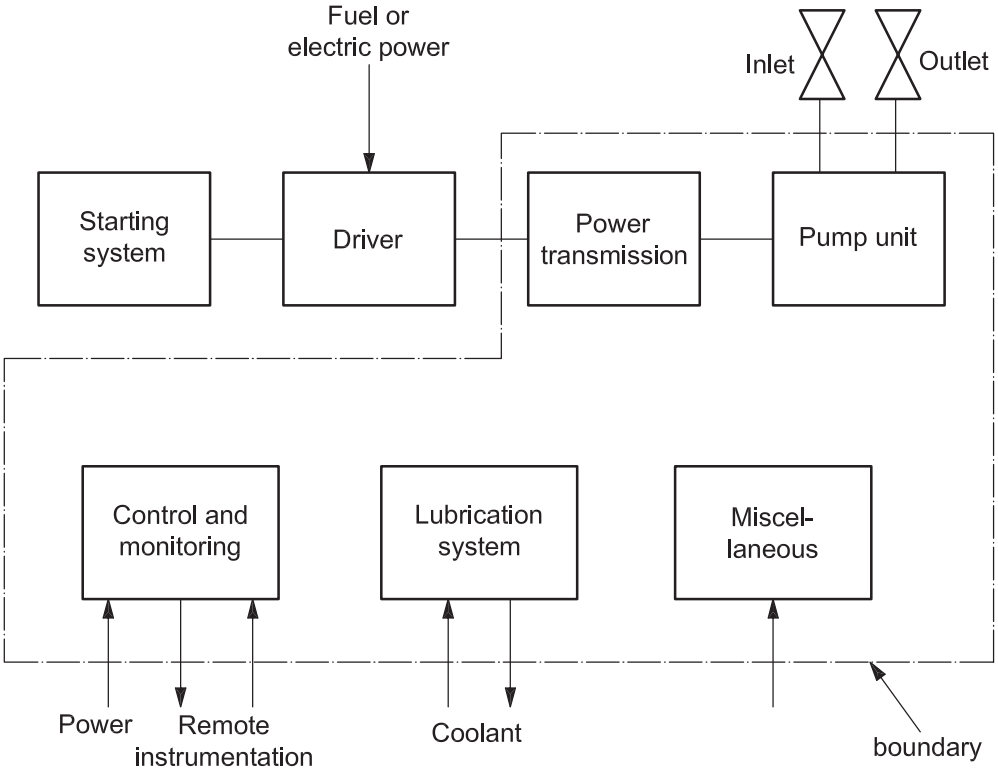

Figure 2 — Example of boundary diagram (pumps)

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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 boundaries (see the Example associated with Figure 2). 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.

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.

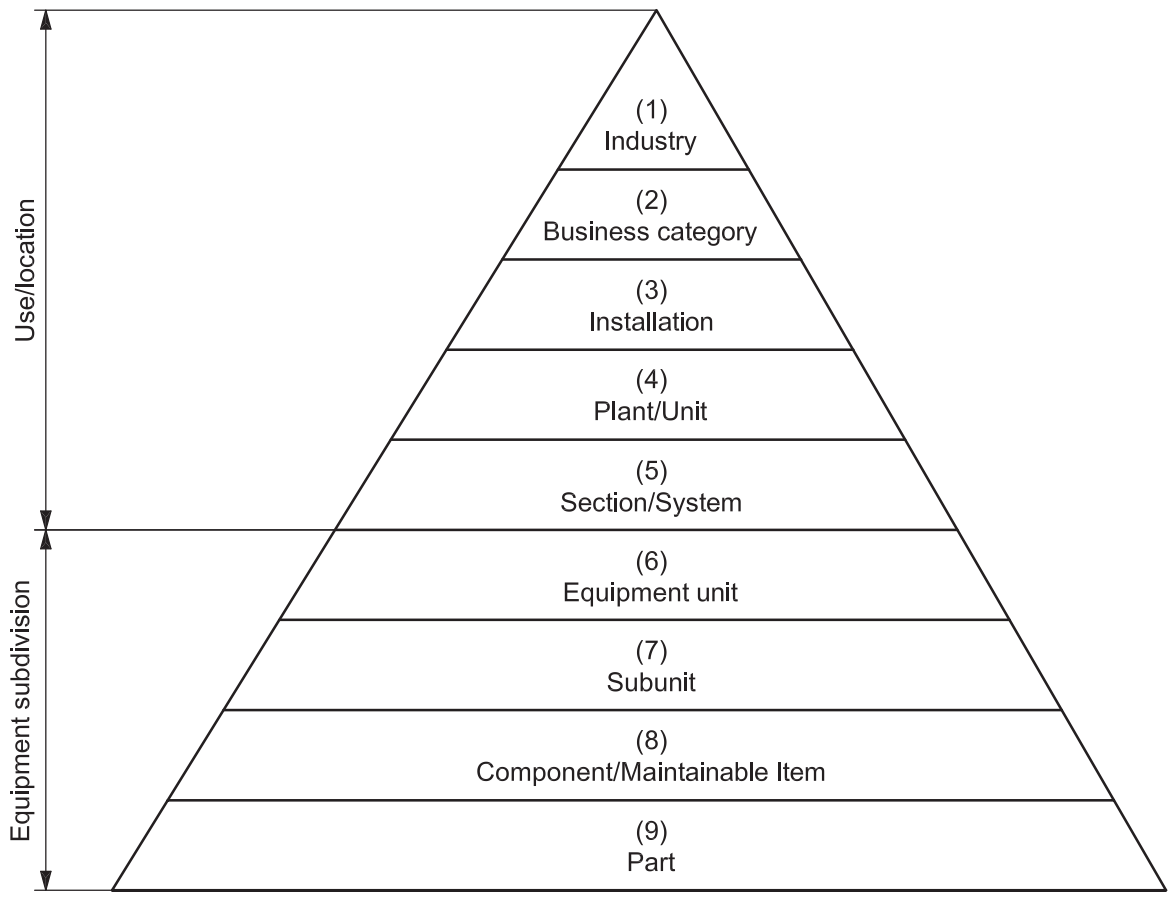

Figure 3 — Taxonomy

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Table 2 — Taxonomic 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 exchanger, compressor, piping, pump, boiler, gas turbine extruder, agitator, furnace, Xmas tree, blow-out preventer (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.

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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 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.

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. MTBF, 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.

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,

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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												
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					
Prepar-ation and/or delay	Active preventative maintenance (item being worked on)	Reserve [a]	“Cold ” stand-by	Modifi-cation [b]	Prepar-ation and/or delay	Active corrective maintenance (item being worked on) [c]	Shutdown, [d] operational problems/ restrictions etc.	Run-down	Ramp-up	Run-ning	“Hot” stand-by	Idle

[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) is defined in C.1.8.

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 both to cost and to getting 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 “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 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.

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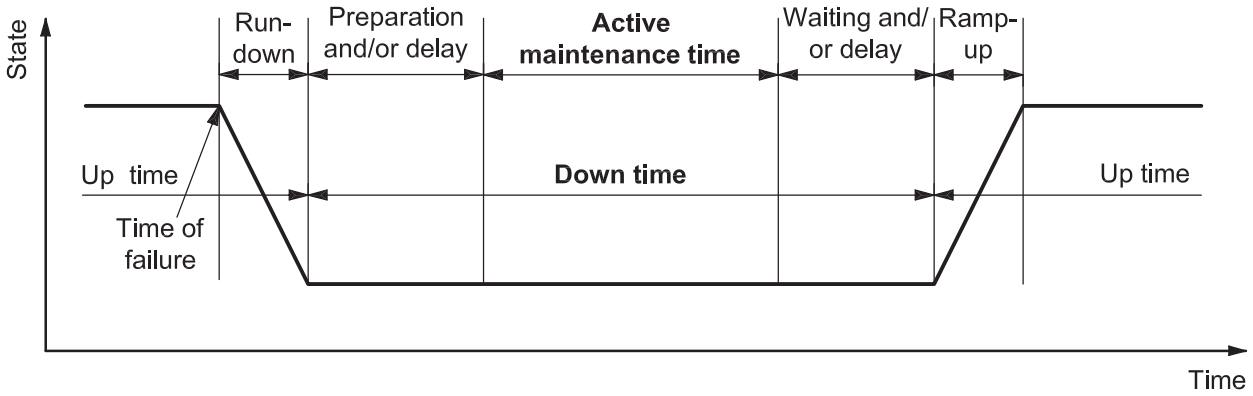

Figure 4 — Maintenance times

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 calendar time during which maintenance work on the item is actually being performed. By this definition, active repair time cannot normally be greater than the down time.

NOTE Exceptionally, active repair time can be greater than down time if the maintenance can be performed with the equipment unit operating.

The operational time required to run down the equipment before repair and ramp up after the repair is not considered to be part of the down time.

NOTE See also definitions in 3.2 and 3.10.

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)

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) operation 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;

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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 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.

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 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.

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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.).

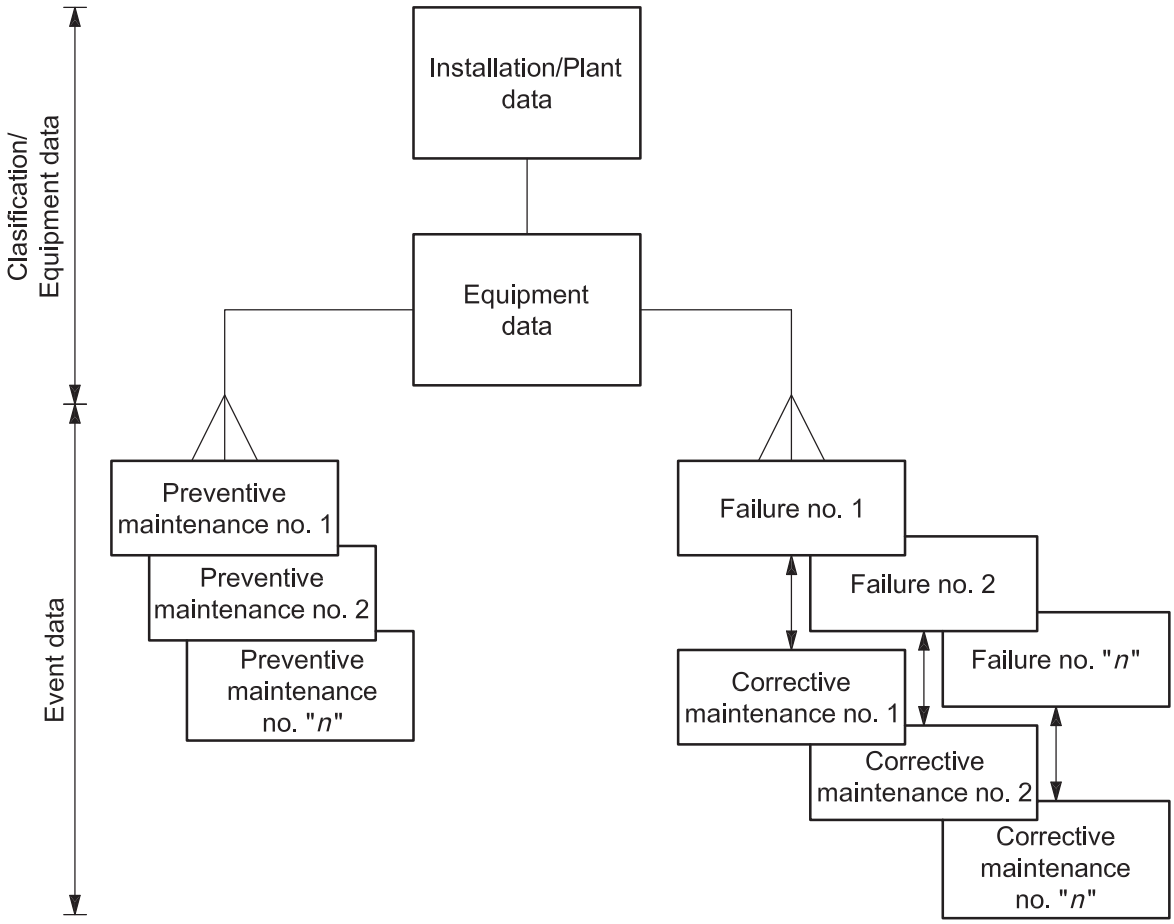

Figure 5 — Logical data structure (example)

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 in order of complexity and versatility.

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

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

c) 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.

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d) 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).

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.

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

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Table 5 (*continued*)

Data category	Data	Taxonomic level [a]	Business category (examples)			
			Upstream (E & P)	**Midstream**	**Downstream** (refining)	**Petro-chemical**
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 (*)	6	Johnson	Wiley	Smith	Anderson
	Manufacturer's model designation	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	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
	Surveillance time, h (calculated) (*)	6	8 950	8 000	5 400	26 300
	Operational time, h (measured/calculated)	6	3 460	100	5 200	4 950
	Number of demands during the surveillance period as applicable (includes both operational and test activation) (*)	6	340	2	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] The serial number is required for potential change-out at the equipment level. The tag number identifies only the physical location of equipment in the plant. If the equipment is replaced with, e.g. an overhauled unit, the tag number remains the same but the serial number changes.

(*) indicates the minimum data that is required to be collected.

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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.

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.

The minimum data needed to meet the objectives of this International Standard are identified by (*). However, the addition of certain other data categories can significantly improve the potential usability of the RM data; see Annex D.

Table 6 — Failure 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]	Usually zero, partial or total
	Failure impact on plant operations (e.g. production, drilling, intervention) [b]	Usually zero, partial or total
	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 maintainable item(s) (see Annex A)
	Detection method	How the failure was detected (see Table B.4)
	Operating condition at failure	Running, start-up, testing, idle, standby
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 B.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”).

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

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9.6 Maintenance data

9.6.1 General

Maintenance is carried out for the following reasons:

a) to correct a failure (corrective maintenance); the failure shall be reported as described in 9.5;

b) as a planned and normally periodic action to prevent failure from occurring (preventive maintenance).

A common report for all equipment classes shall be used for reporting maintenance data. The data required are given in Table 8. For some equipment classes, minor adaptations can be required (e.g. subsea equipment).

The minimum data needed to meet the objectives of this International Standard are identified by (*). However, the addition of other data categories can significantly improve the potential usability of the RM data; see Annex D.

9.6.2 Maintenance categories

There are two basic categories of maintenance:

a) that done to correct an item after it has failed (corrective maintenance);

b) that done to prevent an item from failing (preventive maintenance); part of this can be simply the checks (inspections, tests) to verify the condition of the equipment to decide whether or not any preventive maintenance is required.

NOTE "Modification" is not defined as a maintenance category but is a task often performed by the maintenance organization. A modification can have an influence on the reliability and performance of an item.

Figure 6 shows the main maintenance categories in more detail. Table B.5 presents the main types of maintenance activities commonly performed.

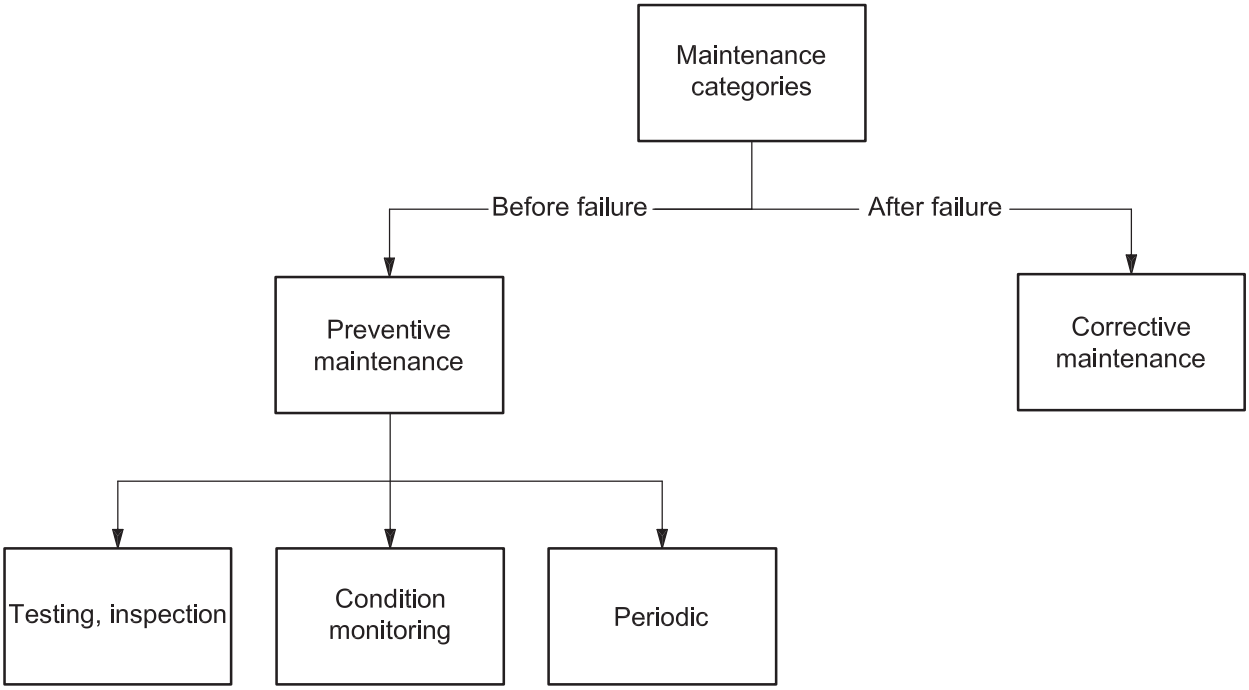

Figure 6 — Maintenance categorization

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9.6.3 Reporting maintenance data

9.6.3.1 Corrective maintenance

As a minimum for recording the reliability of an item, it is required that the corrective maintenance to correct a failure shall be recorded.

9.6.3.2 Preventive maintenance

It is recommended that the recording of the actual preventive maintenance (PM) be done essentially in the same way as for corrective actions. This can give the following additional information:

a) full lifetime story of an item (all failures and maintenance);

b) total resources used on maintenance (man-hours, spare parts);

c) total down time and, hence, total equipment availability, both technical and operational; see Annex C;

d) balance between preventive and corrective maintenance.

Recording PM actions is useful mainly for the maintenance engineer, but is also useful for the reliability engineer wanting to record or estimate the availability of equipment. A lifetime analysis takes into account not only failures but also maintenance actions intended to restore the item to “as-good-as-new” condition. PMs are often performed on a higher indenture level (e.g. “package” level); hence there might not be any data available that can be related to the items on the lower indenture level (subunit, maintainable item). It is necessary to consider this restriction when defining, reporting and analysing PM data.

During the execution of PM actions, impending failures can be discovered and corrected as part of the PM activities. In this case, the failure(s) shall be recorded as any other failure with the subsequent corrective action done, even though it initially was considered to be a PM-type activity. The failure-detection method shall, in this case, be considered as the type of PM being done. It is, however, realized that some failures, generally of minor character, can be corrected as part of the PM and not recorded individually. The practice on this can vary among companies and should be addressed by the data collector(s) in order to reveal the possible type and amount of failures being included within the PM program.

9.6.3.3 Preventive maintenance programme

A final option is to record the planned PM programme as well. In this case, it is possible to additionally record the differences between the planned PM and the PM actually performed (backlog). An increasing backlog indicates that control of the conditions of the plant is being jeopardized and can, in adverse circumstances, lead to equipment damage, pollution or personnel injury.

Table 7 shows a summary of data to be collected and possible added value for different data categories. Annex D contains a more detailed survey of data requirements for various applications.

Table 7 — Usefulness of maintenance data

Data to be collected	Priority with regard to data collection	Examples
Corrective maintenance	Required (see Table 8)	• Repair time (MTTR) • Amount of corrective maintenance • Replacement/repair strategy
Actual preventive maintenance	Recommended	• Full lifetime story of the equipment • Total resources used on maintenance • Total down time • Effect of PM on failure rate • Balance between corrective and preventive maintenance
Planned preventive maintenance (maintenance programme)	Optional	• Difference between real and planned PM (backlog) • Updating programme based on experiences (methods, resources, intervals)

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Table 8 —Maintenance data

Category	Data to be recorded	Description [a]
Identification	Maintenance record (*)	Unique maintenance identification
	Equipment identification/location (*)	e.g. tag number (see Table 5)
	Failure record (*)	Corresponding failure identification record (not relevant for preventive maintenance)
Maintenance data	Date of maintenance (*)	Date when maintenance action was undertaken or planned (start date)
	Maintenance category (*)	Main category (corrective, preventive)
	Maintenance priority	High, medium or low priority
	Interval (planned)	Calendar or operating interval (not relevant for corrective maintenance)
	Maintenance activity	Description of maintenance activity, see Annex B, Table B.5
	Maintenance impact on plant operations	Zero, partial or total
	Subunit maintained	Name of subunit maintained (see Annex A) [b] (May be omitted from preventive maintenance).
	Component/maintainable item(s) maintained	Specify the component/maintainable item(s) that were maintained (see Annex A) (May be omitted from preventive maintenance).
	Spare part location	Availability of spares (e.g. local/distant, manufacturer)
Maintenance resources	Maintenance man-hours, per discipline [c]	Maintenance man-hours per discipline (mechanical, electrical, instrument, others)
	Maintenance man-hours, total	Total maintenance man-hours
	Maintenance equipment resources [c]	e.g. intervention vessel, crane
Maintenance times	Active maintenance time [d] (*)	Time duration for active maintenance work being done on the equipment (see also definitions in Table 4)
	Down time [d] (*)	Time duration during which an item is in a down state (see also Table 4 and Figure 4)
	Maintenance delays/problems	Prolonged down time causes, e.g. logistics, weather, scaffolding, lack of spares, delay of repair crew
Remarks	Additional information	Give more details, if available, on the maintenance action and resources used

[a] Records to be entered for both corrective and preventive maintenance, except where shown.

[b] For corrective maintenance, the subunit maintained is normally identical to the one specified on the failure event report (see Table 6).

[c] For subsea equipment, the following apply:

— type of main resource(s) and number of days used, e.g. drilling rig, diving vessel, service vessel;

— type of supplementary resource(s) and number of hours used, e.g. divers, ROV/ROT, platform personnel.

[d] This information is desirable for RAM and RCM analyses. It is currently infrequently recorded in the maintenance-management systems. It is necessary to improve the reporting of this information to capture reasons for long down times.

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

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Annex A
(informative)

Equipment-class attributes

A.1 Advisory notes

A.1.1 General

Annex A provides examples on how typical equipment used in the petroleum, petrochemical and natural gas industries can be categorized as to their taxonomy, boundary definition, and inventory data. These data are informative for each equipment unit. Normative data, e.g. failure modes, for the equipment examples are shown in Annex B.

A standardized approach has been applied for some of the subunits that are used on a majority of equipment classes (e.g. control and monitoring, lubrication system, cooling system). The result that is the total number of tables required to describe the different data categories and definitions is reduced and, at the same time, there are fewer tailor-made definitions and codes for each individual equipment unit. The user should, therefore, apply those categories and codes that are applicable to the equipment for which data are being collected. Equipment having a unique design can require a more tailor-made categorization instead of that shown in these examples.

In the tables that describe the “equipment-unit subdivision" for the equipment, it is recommended to also include the following:

a) “Maintainable items/Parts” on an as-needed basis, e.g. to include instrumentation;

b) “Others”, if defined “Maintainable items/Parts” are lacking; or

c) “Unknown” category, if sufficient information is not available.

The priority classes given in this annex are high, medium and low. When interpreting or assessing the value of these classes, they can be equated to compulsory (high), highly desirable (medium) and desirable (low).

A.1.2 Boundary definitions

The purpose of the boundary definition is to ensure a common understanding of the “subunit/component” and “maintainable item/part” included within the boundary of a particular equipment unit and, hence, which failure and maintenance events to record. For definition of the boundaries, the following rules are recommended.

a) Do not include items of unique design or configuration-dependant items. Include only those items that are considered to be generic for the equipment class being considered in order to compare “like with like.”

b) Exclude connected items from the equipment-class boundary, unless specifically included by the boundary specification. Failures that occur in a connection (e.g. leak), and that cannot be solely related to the connected item, should be included within the boundary definition.

c) If a driver and the driven unit use a common subunit (e.g. lubrication system), relate failure and maintenance events on this subunit, as a general rule, to the driven unit ;

d) Include instrumentation only where it has a specific control and/or monitoring function for the equipment unit in question and/or is locally mounted on the equipment unit. Control and supervisory instrumentation of more general use (e.g. SCADA-systems) should not, as a rule, be included.

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In A.2.2 to A.2.9 examples of boundary diagrams for different equipment classes are presented. This list is not exhaustive for the equipment categories covered by this International Standard, but includes examples on how taxonomies may be defined for typical equipment found in the petroleum, petrochemical and natural gas industries.

A.1.3 Common equipment data

This International Standard recommends some common equipment data that should be collected for all equipment classes as shown in Table 5.

Additionally, some equipment-specific data for equipment classes are presented in this annex. These data have been found to be useful when comparing performance, or benchmarking, of equipment.

Such design features specific for each equipment class should be considered depending on how far down in equipment categorization the data collector wants, or is required, to go. Collection of data is a trade-off between the cost of obtaining it, which often can be high, and the value of the data in relation to the specific requirements to define each equipment class for the intended analyses. The accessibility of the data in the source(s) also sets a limit on the data that can be collected. An indication of the importance of each data type is indicated. This importance ranking can differ among different users and applications.

A.1.4 Equipment classification and application

Tables A.1 to A.4 provide a methodology for grouping different equipment examples and their application as covered by this International Standard. These lists are not meant to be exhaustive but are intended to show the main types of equipment classes and systems and how they can be grouped in categories. Any applied categorization should be appropriate for the intended use and purpose of the data being collected (see 7.1.2). Tables A.1 to A.4 show a categorization related to the taxonomic levels shown Figure 3.

— Table A.1 shows a recommendation for grouping equipment on installation level (level 3 in the taxonomic hierarchy).

— Table A.2 shows a recommendation for how equipment can be classified on plant/unit level (level 4), as shown in Table 5.

— Table A.3 shows a list of relevant sections/systems (level 5) within the petroleum, natural gas and petrochemical industries where equipment as covered by this International Standard can be used. The systems where the equipment is applied should be recorded as one parameter in the general equipment data shown in Table 5 (category “Use/Location”).

— Table A.4 lists typical examples of equipment units used in the petroleum, natural gas and petrochemical industry as covered by this International Standard (level 6). Table A.4 also indicates those equipment taxonomies that are illustrated by examples, as described in A.2.1. B.2.6 contains the associated failure modes for the same equipment examples.

In the classification shown in Tables A.1 to A.3, the terms “upstream,” “midstream,” “downstream” and “petrochemical” are used. The interpretation of these terms in this International Standard is as follows:

a) upstream — business category of the petroleum industry involving exploration and production (e.g. offshore oil/gas production facility, drilling rig, intervention vessel);

b) midstream — business category involving the processing, storage and transportation sectors of the petroleum industry (e.g. LNG, LPG and GTL; see Table A.1);

c) downstream — business process most commonly used in the petroleum industry to describe post-production processes (e.g. refining, transportation and marketing of petroleum products);

d) petrochemicals — business category producing petrochemical, i.e. chemicals derived from petroleum and used as feedstock for the manufacture of a variety of plastics and other related products (e.g. methanol, polypropylene).

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Table A.1 — Installation category — Level 3

Business category			
Upstream (E & P)	**Midstream**	**Downstream**	**Petrochemical**
Oil/gas production facility (offshore/ onshore) Gas processing Drilling rig Intervention vessel Terminal Pipeline	Liquefied natural gas plant (LNG) Liquefied petroleum gas plant (LPG) Gas to liquids plant (GTL) Combined heating and power (CHP) Terminal Storage Shipping (LNG, Oil) Pipeline	Refinery Gas Processing Pipeline Shipping Terminal	Petrochemical complex Shipping Terminal

Table A.2 — Plant/Unit level classification — Level 4

Business category			
Upstream (E & P)	**Midstream**	**Downstream (refining)**	**Petrochemical**
Offshore platform Onshore production plant Floating production storage and offloading (FPSO) Floating drilling, production storage and offloading (FDPSO) Floating storage unit (FSU) Compliant tower Semi-submersible Subsea production Tension leg platform (TLP) Jack-up Subsea intervention and support vessel (SISV)	Pipeline compressor station Pipeline pump station	Process Utility Offsite and support facilities	Methanol plant Ethylene plant Acetic Acid plant Polyethylene plant Polypropylene plant Polyvinylchloride plant

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Table A.3 — Section/System classification — Level 5

Business category			
Upstream (E & P)	**Midstream**	**Downstream (refining)**	**Petrochemical**
Process — General	**LNG process**	**Process — General**	**Process — General**
Oil process/treatment	CO_2/H_2S removal	Cracking	Hydrodesulfurization
Gas process/treatment	Dehydration/ Mercaptonization	Crude distillation	Hydrogen steam reforming
Water process/treatment	Liquefaction	Catalytic de-waxing	Hydrotreating
Oil/condensate-export systems	Mercury removal	Catalytic reforming	Isomerization
Gas-export systems	Fractionation	Lubes de-waxing	Kerosene hydroteater
Utilities [a]	Refrigeration	Lubes hydro-finishing	Naphtha hydrotreater
Chemical injection	LNG storage	Merox treating	Phenol extraction
Cooling system	LNG loading/unloading	Selective hydro-treating	Polymerization unit
Flare system	Boil-off gas (BOG) recovery	Sour-water stripping	Solvent deasphalting
Heating system	Vaporizers	Sulfur-recovery unit	Solvent dewaxing
Oily-water treatment	Recondensing	Tail-gas treating	Solvent extraction
Steam	**LNG utilities**	Vacuum distillation	Steam
Water injection	Fuel gas	Visbreaking	Steam cracking
Methanol	Cooling system	**Utilities**	Steam-methane reforming
Compressed air	Heating system	Steam	Sulfur recovery
Main power [b]	Main power	Power	Sweetening
Emergency power [b]	Blow-down and relief system	Instrument air	Vacuum distillation
Essential power [b]	Refrigerant storage	Utility air	Visbreaking
Fuel gas	Fiscal metering	Cooling water	**Utilities**
Materials handling		Nitrogen	Steam
HVAC		Emergency shutdown	Power
Fresh water systems		Fire and gas detection	Instrument air
Safety and control systems		Analysers	Utility air
Emergency/process shutdown			Cooling water
Fire and gas detection			Nitrogen
Fire water systems			Fire and gas detection
Fire-fighting systems			Analysers
Process control			Emergency shutdown
PA/alarm system			
Emergency preparedness systems			
Offshore installations			
Ballast water			
Seawater lift			
Position keeping			
Evacuation means			
Well and subsea systems			
Completion fluid			
Manifold control			
Multi-well manifold control			
Satellite well control			
Well servicing			
Combined function			

[a] These sections/systems may also be applicable for downstream and petrochemical unless defined specifically for these categories.

[b] Includes both power generation and distribution.

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Table A.4 — Equipment class — Level 6

Equipment category	Equipment class — Level 6	Example included in Annex A
Rotating	Combustion engines	Yes
	Compressors	Yes
	Electric generators	Yes
	Electric motors	Yes
	Gas turbines	Yes
	Pumps	Yes
	Steam turbines	Yes
	Turboexpanders	Yes
	Blowers and fans	No
	Liquid expanders	No
	Mixers	No
Mechanical	Cranes	Yes
	Heat exchangers	Yes
	Heaters and boilers	Yes
	Vessels	Yes
	Piping	Yes
	Winches	Yes
	Swivels	Yes
	Turrets	Yes
	Pipeline	No
	Storage tanks	No
	Loading arms	No
	Filters and strainers	No
	Steam ejectors	No
	Xmas trees (topside/onshore)	No
Electrical	Uninterruptible power supply	Yes
	Power transformers	Yes
	Switchgears/switchboards and distribution boards	No
	Frequency converters	No
	Power cables and terminations	No
Safety and control	Fire and gas detectors	Yes
	Input devices	Yes
	Control units	Yes
	Valves	Yes
	Nozzles	Yes
	Evacuation equipment	No
	Fire-fighting equipment	No
	Inert-gas equipment	No

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Table A.4 (*continued*)

Equipment category	Equipment class — Level 6	Example included in Annex A
Subsea production	Subsea production control	Yes
	Xmas trees	Yes
	Risers	Yes
	Subsea pumps	Yes
	Subsea processing equipment	No
	Templates	No
	Manifolds	No
	Pipelines	No
	Flowlines	No
	Subsea isolation equipment	No
	Intervention tools	No
	Electric-power distribution	No
Drilling	Blowout preventer [a]	Yes
	Top drive	Yes
	Derrick [b]	No
	Drawworks	No
	Mud pumps	No
	Mud-treatment equipment	No
	Diverter	No
	Choke manifold	No
	String-motion compensator	No
	Riser compensator	No
	Cementing equipment	No
	Drilling and completion risers	No
	Crown and travelling blocks	No
Well completion (downhole)	Downhole safety valves	Yes
	Casing	Yes
	Tubing	Yes
	Hangers	No
	Packers	No
	Electrical submersible pumps	No
	Downhole sensors	No
	Wellheads	No
Well intervention	Coiled tubing, surface equipment	No
	Coiled tubing, BOPs and control systems	No
	Coiled tubing, other pressure-control equipment and systems	No
	Coiled tubing, string and mechanical bottom hole assembly	No
	Coiled tubing, string and electrical bottom hole assembly	No

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Table A.4 (*continued*)

Equipment category	Equipment class — Level 6	Example included in Annex A
Well intervention	Wireline, surface equipment	No
	Wireline, BOPs and control systems	No
	Wireline, other pressure-control equipment and systems	No
	Wireline, slickline/braided cable and bottom-hole assembly	No
	Wireline, electric cable and bottom-hole assembly	No
	Rig-assisted snubbing (RAS), surface equipment	No
	Rig-assisted snubbing (RAS), BOPs and control systems	No
	Rig-assisted snubbing (RAS), other pressure-control equipment and systems	No
	Rig-assisted snubbing (RAS), tubing and bottom-hole assemblies	No
Marine	Anchor windlasses and mooring equipment	No
	Thrusters	No
	Dynamic positioning equipment	No
	Towing equipment	No
	Jacking equipment	No
	De-icing equipment	No
	Helicopter deck with equipment	No
Utilities [c]	Hydraulic power units	No
	Air-supply equipment	No
	De-superheaters	No
	Nitrogen-supply equipment	No
	Heating/cooling media	No
	HVACs	No

[a] Subsea blowout preventer.

[b] Including heave compensation.

[c] Utilities may be associated with a number of equipment classes in this International Standard (e.g. pumps, valves, instrumentation).

A.2 Equipment-specific data

A.2.1 General

The equipment examples, indicated by a “yes” in the last column of Table A.4, are presented in A.2.2 to A.2.8 and include a detailed description of the following:

— equipment-type classification;

— boundary definitions;

— subdivision into lower indenture levels;

— equipment-specific data.

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This information should be used to identify the data necessary to be collected for each equipment example presented and define the structure for a database for the relevant taxonomic elements. Many of the recommended parameters can be common across many equipment classes (e.g. capacity, rotational speed). The examples should not be considered exhaustive.

Examples of failure coding, such as failure modes, failure mechanism etc., are given in Annex B. For safety equipment, some specific failure definitions are given in Annex F.

A.2.2 Rotating-equipment data

A.2.2.1 Combustion engines

Table A.5 — Type classification — Combustion engines

Equipment class — Level 6		Equipment type	
Description	**Code**	**Description**	**Code**
Combustion engines — piston (diesel/gas engines)	CE	Diesel engine	DE
		Otto (gas) engine	GE

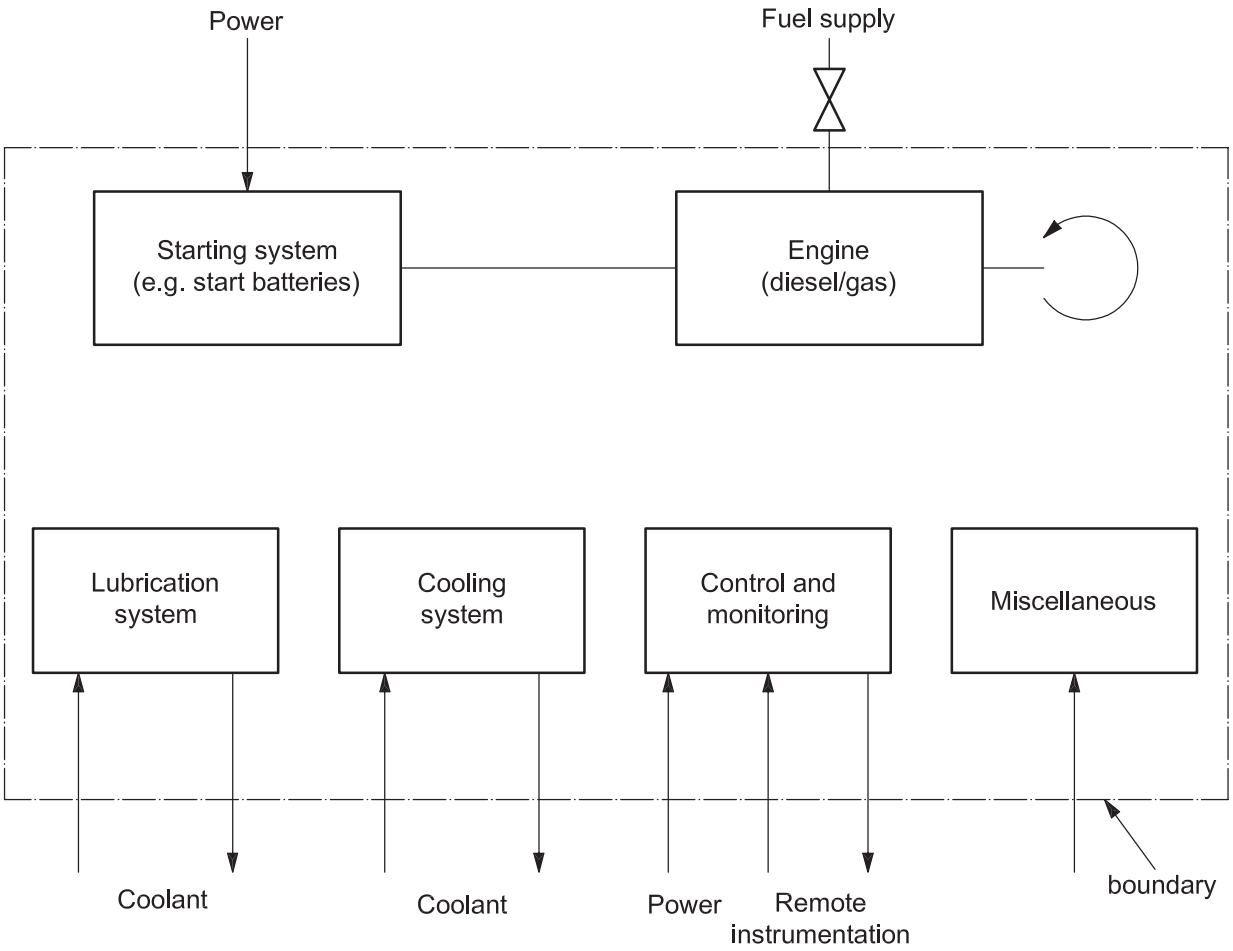

Figure A.1 — Boundary definition — Combustion engines

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Table A.6 — Equipment-class subdivision — Combustion engines

Equipment class Level 6	Combustion engines					
Subunit/ Component	**Start system**	**Combustion engine unit**	**Control and monitoring**	**Lubrication system**	**Cooling system [a]**	**Miscel-laneous**
Maintainable item/Part	Start energy (battery, air) Starting unit Start control	Air inlet Ignition system Turbocharger Fuel pumps Injectors Fuel filters Exhaust Cylinders Pistons Shaft Thrust bearing Radial bearing Seals Piping Valves	Actuating device Control unit Internal power supply Monitoring Sensors [b] Valves Wiring Piping Seals	Reservoir Pump Motor Filter Cooler Valves Piping Oil Temperature-control sensor	Heat exchanger Fan Motor Filter Valves Piping Pump Temperature-control sensor	Hood Flange joints

[a] May include water-cooled or air-cooled systems.

[b] Specify type of sensor, e.g. pressure, temperature, level, etc.

Table A.7 — Equipment-specific data — Combustion engines

Name	Description	Unit or code list	Priority
Driven unit	Driven unit (equipment class, type and identification code)	Specify	High
Power - design	Maximum rated output (design)	Kilowatt	High
Power - operating	Specify the approximate power at which the unit has been operated for most of the surveillance time	Kilowatt	High
Speed	Design speed	Revolutions per minute	High
Number of cylinders	Specify number of cylinders	Integer	Low
Cylinder configuration	Type	Inline, vee, flat	Low
Starting system	Type	Electric, hydraulic, pneumatic	Medium
Ignition system	Otto, diesel	Compression ignition (diesel), spark plugs	Medium
Fuel	Type	Gas, light oil, medium oil, heavy oil, dual	Low
Air-inlet filtration type	Type	Free text	Low
Engine-aspiration type	Type of engine aspiration	Turbo, natural	Medium

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A.2.2.2 Compressors

Table A.8 — Type classification — Compressors

Equipment class — Level 6		Equipment type	
Description	**Code**	**Description**	**Code**
Compressor	CO	Centrifugal	CE
		Reciprocating	RE
		Screw	SC
		Blowers/fans	BL
		Axial	AX

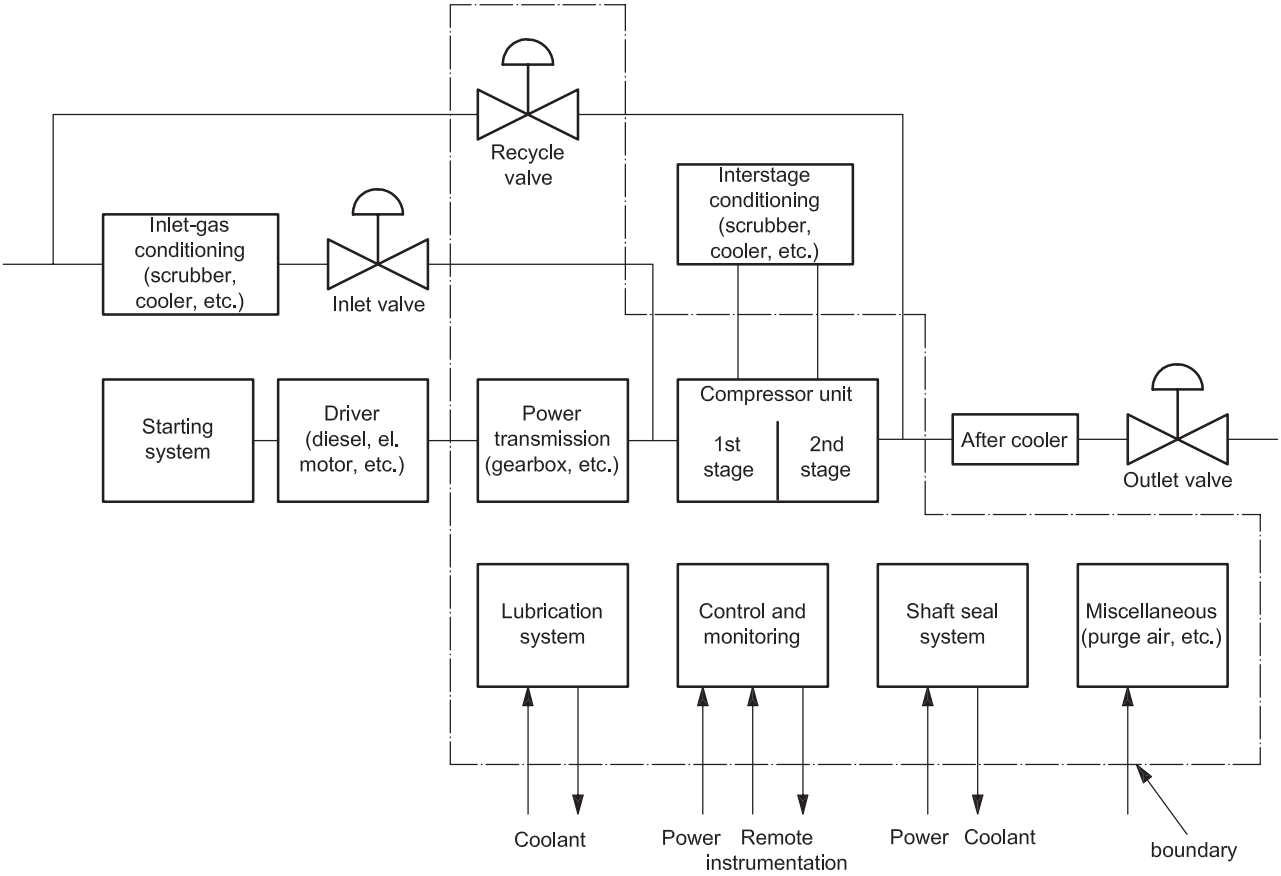

Figure A.2 — Boundary definition — Compressors

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A.2.2.2.1 Equipment boundary definition for compressors

Figure A.2 shows the boundary definition for compressors. Inlet and outlet valves, and the compressor driver with connected auxiliaries, are not included within the boundary. Driver units are recorded as separate inventories (electric motor, gas turbine or combustion engine) and the failures on the driver, if recorded, should be recorded separately for the driver. A number in the compressor inventory shall give a reference to the appropriate driver inventory.

Compression is normally done in stages where a number of subunits are connected into a train.

A compressor train is considered as one inventory. Each compressor train can consist of up to four compressor stages. Recompression trains on an offshore oil platform normally perform compression in four stages. Each compression stage is usually performed by one compressor unit (casing) but in some cases one compressor unit can perform two stages. Each compressor (stage) normally contains several impellers that are the physical assembly of rotating blades that raise the pressure one step in the compressor unit.

If there are subunits that are common to the driver (e.g. a gas turbine) and the driven unit (i.e. the compressor), these are regarded as a part of the driven unit. For compressors with common lubrication-oil and seal-oil systems, failures should, as a general rule, be assigned to the subunit that is assumed to be the one most affected. Otherwise, the failure should be assigned to the lubrication-oil system.

Table A.9 — Equipment subdivision — Compressors

Equipment class	Compressors					
Subunit	**Power transmission**	**Compressor**	**Control and monitoring**	**Lubrication system**	**Shaft seal system**	**Miscellaneous**
Maintainable item/Part	Gearbox/ variable drive Bearings Coupling to the driver Coupling to the driven unit Lubrication Seals	Casing Rotor with impellers Balance piston Interstage seals Radial bearing Thrust bearing Shaft seals Internal piping Valves Antisurge system [b] Piston Cylinder liner Packing	Actuating device Control unit Cables and junction boxes Internal power supply Monitoring Sensors [a] Valves Wiring Piping Seals	Oil tank with heating system Pump Motor Check valves Coolers Filters Piping Valves Lube oil	Oil tank with heating Reservoir Pump Motor Gear Filters Valves Seal oil Dry gas seal Mechanical seal Scrubber	Base frame Piping, pipe support and bellows Control valves Isolation valves Check valves Coolers Silencers Purge air Magnetic-bearing control system Flange joints

[a] Specify type of sensor, e.g. pressure, temperature, level, etc.

[b] Including recycle valve and controllers.

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Table A.10 — Equipment-specific data — Compressors

Name	Description	Unit or code list	Priority
Type of driver	Driver unit (equipment class, type and identification code)	Specify	High
Gas handled	Average molar mass (specific gravity × 28,96)	Grams per mole	Medium
Suction pressure	Design – first stage	Pascal (bar)	Medium
Suction pressure	Operating – first stage	Pascal (bar)	Low
Discharge pressure	Design – last stage	Pascal (bar)	High
Discharge pressure	Operating – last stage	Pascal (bar)	Medium
Flow rate	Design	Metres cubed per hour	High
Flow rate	Operating	Metres cubed per hour	Low
Discharge temperature	Design	Degrees Celsius	Medium
Discharge temperature	Operating	Degrees Celsius	Low
Power	Design power	Kilowatt	High
Utilization	Percent utilization compared to design	Percent	Medium
Polytropic head	—	Kilojoules per kilogram	Low
Number of casings	Number of casings in the train	Integer	High
Number of stages	Number of compressor stages (not impellers) in this train	Integer	Medium
Body type	Type	Vertical split case (barrel type), axial split case	Low
Shaft sealing	Type	Mechanical, oil, dry gas-packed, dry gland, labyrinth, combined	Low
Intercooler fitted	Specify if cooler is fitted	Yes/no	Medium
Shaft seal system	Separate, combined, dry, etc.	Separate, combined, dry	High
Radial bearing	Type	Antifrictional, journal, magnetic	Low
Thrust bearing	Specify as relevant in comment field whether any thrust pressure regulator is installed	Antifrictional, journal, magnetic	Low
Speed	Design speed	Revolutions per minute	Low
Coupling	Type	Fixed, flexible, hydraulic, disconnect	Low
Reciprocating compressors only			
Cylinder configuration	—	Inline, opposed, V, W	Low
Cylinder orientation	—	Horizontal, vertical, inclined	Low
Working principle	—	Single-acting, double-acting	Low
Packing type	—	Lubricated, dry	Low

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A.2.2.3 Electric generators

Table A.11 — Type classification — Electric generators

Equipment class — Level 6		Equipment type	
Description	**Code**	**Description**	**Code**
Electric generator	EG	Gas-turbine driven	TD
		Steam-turbine driven	SD
		Turboexpander	TE
		Engine driven, e.g. diesel engine, gas engine	MD

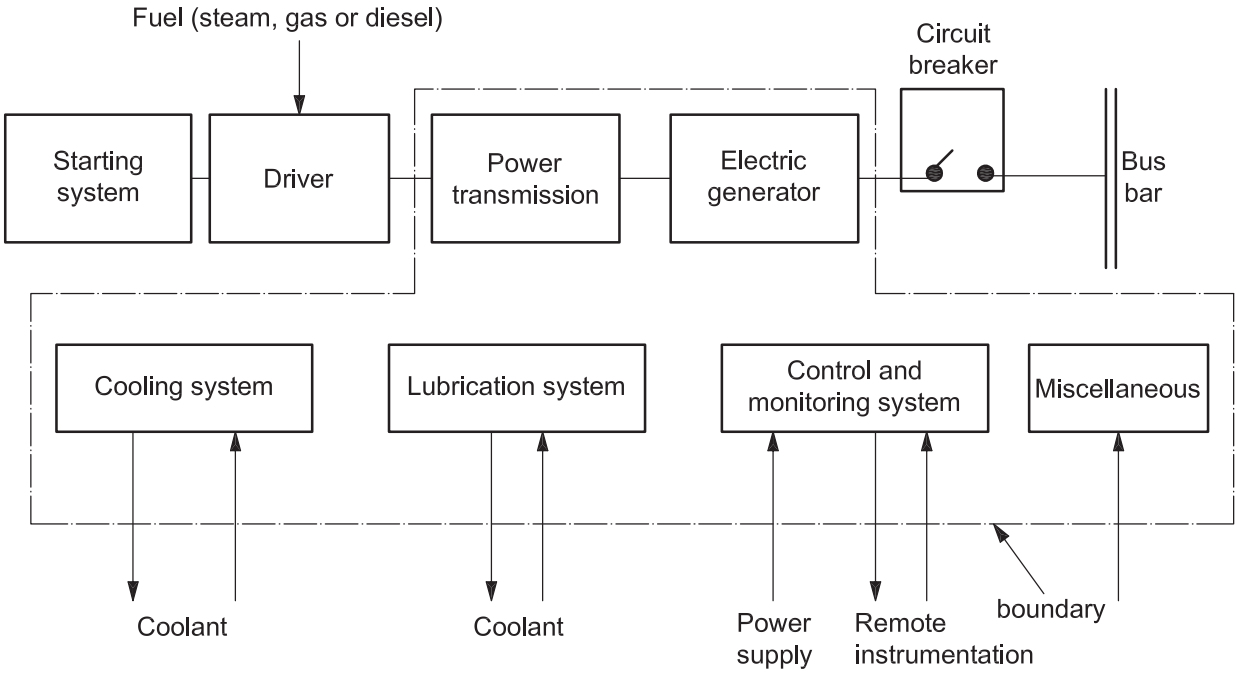

Figure A.3 — Boundary definition — Electric generators

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Table A.12 — Equipment subdivision — Electric generators

Equipment unit	Electric generators					
Subunit	**Power transmission**	**Electric generator**	**Control and monitoring** [a]	**Lubrication system**	**Cooling system**	**Miscellaneous**
Maintainable items	Gearbox Radial bearing Thrust bearing Seals Lubrication Coupling to driver Coupling to driven unit	Stator Rotor Radial bearing Thrust bearing Excitation Cabling and junction boxes	Actuating device Control unit (e.g. AVR) Internal power supply Monitoring Sensors [b] Valves Wiring Piping Seals	Reservoir Pump Motor Filter Cooler Valves Piping Oil	Heat exchanger Fan Motor Filter Valves Piping Pump	Hood Purge air

[a] The automatic voltage regulator (AVR) is an element within “Control”. Temperature and vibration surveillance are elements within “Monitoring”.

[b] Specify type of sensor, e.g. pressure, temperature, level, etc.

Table A.13 — Equipment-specific data — Electric generators

Name	Description	Unit or code list	Priority
Type of driver	Equipment class, type and identification code	Specify	High
Coupling	Specify (fixed, flexible, etc.)	Fixed, flexible, hydraulic, disconnect	Low
Speed	Synchronous	Revolutions per minute	Medium
Frequency	Design frequency	Hertz	Low
Voltage	Design voltage	Kilovolts	High
Power – design	Design power	Kilovolts	High
Power factor	$\cos\varphi$	Number	Low
Excitation control	Type	Automatic, manual	Medium
Excitation type	Brushless/slip-ring	Brushless, slip-ring	Medium
Degree of protection	Protection class in accordance with IEC 60529	IP	Low
Insulation class – stator	Insulation class in accordance with IEC 60034-1	Y, A, E, B, F, H	Medium
Temperature rise – stator	Temperature rise in accordance with IEC 60034-1	Y, A, E, B, F, H	Low
Insulation class – rotor	Insulation class in accordance with IEC 60034-1	Y, A, E, B, F, H	Medium
Temperature rise – rotor	Temperature rise in accordance with IEC 60034-1	Y, A, E, B, F, H	Medium
Radial bearing	Type	Antifrictional, journal, magnetic	Low
Thrust bearing	Type	Antifrictional, journal, magnetic	Low
Lubrication of bearings	Type of bearing lubrication	Grease, oil bath, pressurized oil, oil ring	Low
Generator cooling	Type	Air/air, air/water, open ventilated	Low

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