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

*Industries du pétrole et du gaz naturel — Recueil et échange de données
de fiabilité et de maintenance des équipements*



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## Foreword

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

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 14224 was prepared by Technical Committee ISO/TC 67, *Materials, equipment and offshore structures for petroleum and natural gas industries*.

Annexes A, B, C and D of this International Standard are for information only.

## Introduction

This International Standard has been prepared based on know-how and experience gained through the data collection project OREDA<sup>1)</sup>, which has been carried out by several major oil companies since the early 1980s. During these years, a large amount of data have been collected and substantial knowledge in reliability data collection accumulated. The text of this International Standard relating to downhole equipment is based on know-how and experience gained through the WELLMASTER<sup>2)</sup> project.

In the petroleum and natural gas industry, great attention is being paid to safety, reliability and maintainability of equipment. Various analyses are used to estimate the risk of hazards, pollution or damage to equipment. For such analyses, Reliability and Maintenance (RM) data are vital.

More emphasis has recently been put on cost-effective design and maintenance for new plants and existing installations. In this respect data on failures, failure mechanisms and maintenance have become of increased importance.

Data collection is an investment. By standardization and improved facility information management systems that allow electronic collection and transfer of data, quality can be improved. A cost-effective way to maximize the amount and type of data is through industry cooperation. To make it possible to collect, exchange and analyse data based on common ground, a standard is required. This International Standard gives recommendations to the petroleum and natural gas industry on specification and execution of RM data collection, both as a separate exercise and in the day-to-day recording of historical data in maintenance management systems.

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1) Guideline for Data Collection.

2) User's Guide and Reliability Data Collection Guidelines for Well Completion Equipment (1995): ISBN 82-595-8586-3.



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

## 1 Scope

This International Standard provides a comprehensive basis for the collection of Reliability and Maintenance (RM) data in a standard format in the areas of drilling, production, refining and transport by pipeline of petroleum and natural gas.

This International Standard presents guidelines for the specification, collection and quality assurance of RM data, facilitating the collection of RM data. The data will enable the user to quantify the reliability of the equipment and to compare the reliability of equipment with similar characteristics.

By analysing the data, reliability parameters can be determined for use in design, operation and maintenance. However, this International Standard is not applicable to the method of analysis for RM data.

The main objectives of this International Standard are:

- a) to specify the data to be collected for analysis of:
  - system design and configuration;
  - safety, reliability and availability of systems and plants;
  - life cycle cost;
  - planning, optimization and execution of maintenance.
- b) to specify data in a standardized format in order to:
  - permit exchange of RM data between plants, owners, manufacturers and contractors;
  - ensure that RM data are of sufficient quality for the intended analysis.

This International Standard is applicable to all equipment types used in the petroleum and natural gas industry, such as process equipment (used on onshore and offshore installations), subsea equipment, well-completion equipment and drilling equipment. In annex A several examples are included.

This International Standard is applicable to data collected in the operational phase.

Due to the variety of different uses for RM data, it is stressed that, for each data collection programme, attention should be given to the appropriate level of data required.

**NOTE** It is recognized that to strengthen the goal of this International Standard, a normative reference detailing all the taxonomy codes for each of these equipment classes is appropriate. However, since no comprehensive taxonomy listing covering all equipment classes exists at the time of publication of this International Standard, a sample of taxonomies for process equipment, subsea equipment, well-completion equipment and drilling equipment is contained in informative annex A.

## 2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, this publication do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60050-191:1990, *International Electrotechnical Vocabulary. Chapter 191: Dependability and quality of service.*

## 3 Terms, definitions and abbreviated terms

### 3.1 Terms and definitions

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

#### 3.1.1 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

[IEC 60050-191:1990]

#### 3.1.2 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

[IEC 60050-191:1990]

NOTE For more specific information, refer to Figure 191-10 "Maintenance time diagram" in IEC 60050-191.

#### 3.1.3 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

[IEC 60050-191:1990]

NOTE For more specific information, refer to Figure 191-10 "Maintenance time diagram" in IEC 60050-191.

#### 3.1.4 critical failure

failure of an equipment unit which causes an immediate cessation of the ability to perform its required function

NOTE For well-completion equipment, see additional information in A.4.5.

#### 3.1.5 data acquirer

person or organization in charge of the data collection process

#### 3.1.6 demand

activation of the function (includes both operational and test activation)



**3.1.7  
down state**

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

[IEC 60050-191:1990]

**3.1.8  
down time**

time interval during which an item is in a down state

[IEC 60050-191:1990]

NOTE For more specific information, refer to Figure 191-10 "Maintenance time diagram" in IEC 60050-191.

**3.1.9  
equipment class**  
class of equipment units

EXAMPLE All pumps.

NOTE For well-completion equipment, see additional information in A.4.5.

**3.1.10  
equipment unit**  
specific equipment unit within an equipment class as defined within the main boundary

EXAMPLE A pump.

**3.1.11  
equipment unit redundancy**  
(on the equipment unit level) existence of more than one means for performing the required function

EXAMPLE  $3 \times 50\%$ .

**3.1.12  
failure**  
termination of the ability of an item to perform a required function

[IEC 60050-191:1990]

**3.1.13  
failure cause**  
circumstances during design, manufacture or use which have led to a failure

[IEC 60050-191:1990]

NOTE Identification of the failure cause normally requires some in-depth investigation to uncover the underlying human or organizational factors as well as the technical cause.

**3.1.14  
failure descriptor**  
apparent, observed cause of a failure

NOTE As normally reported into the maintenance management system.

**3.1.15  
failure mechanism**  
physical, chemical or other process which has led to a failure

[IEC 60050-191:1990]

**3.1.16****failure mode**

observed manner of failure

**3.1.17****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

[IEC 60050-191:1990]

**3.1.18****item**

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

[IEC 60050-191:1990]

**3.1.19****maintainable item**

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

**3.1.20****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

[IEC 60050-191:1990]

**3.1.21****maintenance man-hour**

accumulated durations of the individual maintenance times, expressed in hours, used by all maintenance personnel for a given type of maintenance action or over a given time interval

[IEC 60050-191:1990]

NOTE For more specific information, refer to Figure 191-10 "Maintenance time diagram" in IEC 60050-191.

**3.1.22****non-critical failure**

failure of an equipment unit which does not cause an immediate cessation of the ability to perform its required function

NOTE For well-completion equipment, see additional information in A.4.5.

**3.1.23****operating state**

state when an item is performing a required function

[IEC 60050-191:1990]

**3.1.24****operating time**

time interval during which an item is in an operating state

[IEC 60050-191:1990]

NOTE For well-completion equipment, see additional information in A.4.5.

**3.1.25****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

[IEC 60050-191:1990]

**3.1.26****redundancy**

(in an item) existence of more than one means for performing a required function

[IEC 60050-191:1990]

**3.1.27****reliability performance**

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

[IEC 60050-191:1990]

**3.1.28****required function**

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

[IEC 60050-191:1990]

**3.1.29****severity class**

effect on equipment unit function

**3.1.30****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

**3.1.31****surveillance period**

interval of time between the start date and end date of data collection

**3.2 Abbreviations**

|            |                                                                                           |
|------------|-------------------------------------------------------------------------------------------|
| BEN        | Benchmarking                                                                              |
| LCC        | Life Cycle Cost                                                                           |
| MI         | Maintainable Item                                                                         |
| OREDA      | Project for collection of oil and gas industry equipment reliability and maintenance data |
| PM         | Preventive Maintenance                                                                    |
| QRA        | Quantitative Risk Assessment                                                              |
| RAM        | Reliability, Availability and Maintainability analysis                                    |
| RCM        | Reliability-Centred Maintenance                                                           |
| RM         | Reliability and Maintenance                                                               |
| WELLMASTER | Reliability data collection for well-completion equipment                                 |

## 4 Quality of data

### 4.1 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 is characterized by:

- completeness of data in relation to specification;
- compliance with definitions of reliability parameters, data types and formats;
- accurate input, transfer, handling and storage of data (manually or electronic).

### 4.2 Guidance for obtaining quality data

To obtain high quality data, the following measures shall be emphasized before the data collection process starts:

- investigate the data sources to make sure the required inventory data can be found and the operational data are complete;
- define the objective for collecting the data in order to collect relevant data 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);
- investigate the source(s) of the data to ensure that relevant data of sufficient quality is available;
- identify the installation date, population and operating period(s) for the equipment from which data may be collected;
- a pilot exercise of the data collection methods and tools (manual, electronic) is recommended to verify the feasibility of the planned data collection procedures;
- prepare a plan for the data collection process, e.g. schedules, milestones, sequence and number of equipment units, time periods to be covered, etc.;
- train, motivate and organize the data collection personnel;
- plan for quality assurance of the data collection process. This shall as a minimum include procedures for quality control of data and recording and correcting deviations. An example of a checklist is included in Annex C.

During and after the data collection exercise, analyse the data to check consistency, reasonable distributions, proper codes and correct interpretations. The quality control process shall be documented. When merging individual data bases it is imperative that each data record has a unique identification.

### 4.3 Data source systems

The facility maintenance management system constitutes the main source of RM data. The quality of the data which can be retrieved from this source is dependent on the way RM data is reported in the first place. Reporting of RM data according to this International Standard shall be allowed for in the facility maintenance management system, thereby providing a more consistent and sound basis for transferring RM data to equipment RM databases.

The level of detail of RM data reported and collected shall be closely linked to the production and safety importance of the equipment. Prioritization shall be based on regularity, safety and other criticality evaluations.

Those responsible for reporting RM data will derive benefit from the use of these data. Involvement of these staff in determining and communicating these benefits is a requirement for quality RM data.

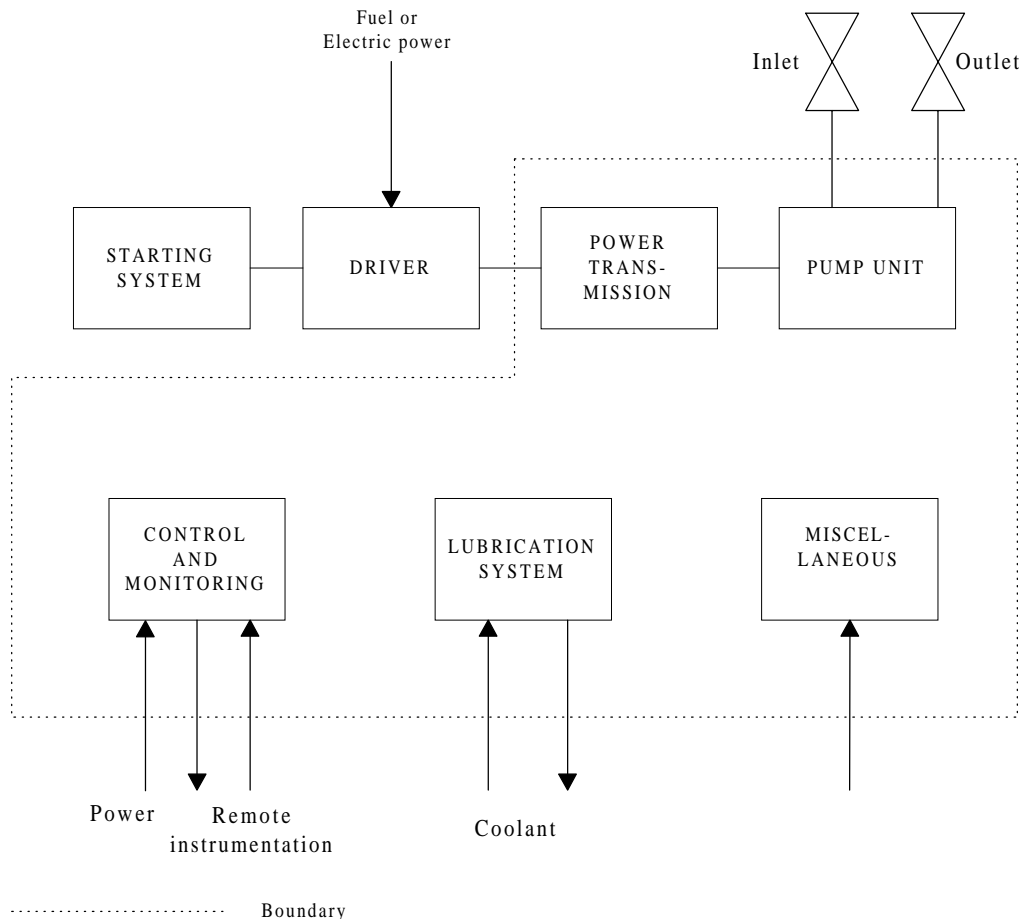
## 5 Equipment boundary and hierarchy

### 5.1 Boundary description

A clear boundary description is imperative for collecting, merging and analysing RM data from different industries, plants or sources. The merging and analysis will otherwise be based on incompatible data.

For each equipment class, a boundary shall be defined indicating what RM data are to be collected.

An example of a boundary diagram for a pump is shown in Figure 1.



**Figure 1 — Example of boundary diagram (pumps)**

The boundary diagram shall show the subunits 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.

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.

### 5.2 Guidance for defining an equipment hierarchy

Preparation of a hierarchy for the equipment is recommended. The highest level is the equipment unit class. The number of levels for subdivision will depend on the complexity of the equipment unit and the use of the data. Reliability data need to be related to a certain level within the equipment hierarchy in order to be meaningful and comparable. For example, the reliability data “severity class” shall be related to the equipment unit, while the failure cause shall be related to the lowest level in the equipment hierarchy.

A single instrument may need no further breakdown, while several levels are required for a compressor. For data used in availability analyses, the reliability at the equipment unit level may be the only desirable data needed, while an RCM analysis will need data on failure mechanism at maintainable item level.

A subdivision into three levels for an equipment unit will normally be sufficient. An example is shown in Figure 2, viz. equipment unit, subunit and maintainable items.

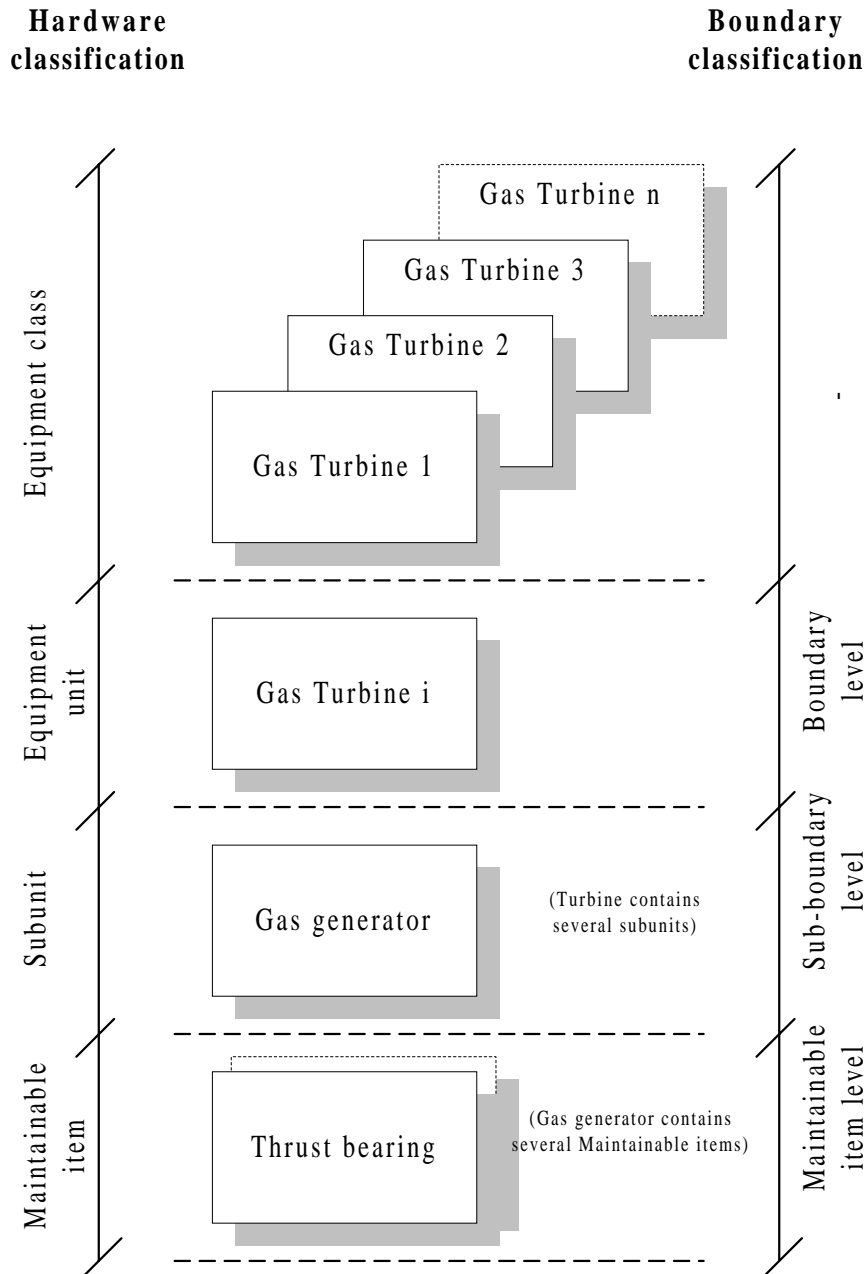


Figure 2 — Example of equipment hierarchy

## 6 Information structure

### 6.1 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 given below.

#### a) Equipment data

The description of equipment is characterized by:

- 1) identification data, e.g. equipment location, classification, installation data, equipment unit data;
- 2) design data, e.g. manufacturer's data, design characteristics;
- 3) application data, e.g. operation, environment.

These data categories shall be general for all equipment classes, e.g. type classification, and specific for each equipment unit, e.g. number of stages for a compressor. This shall be reflected in the database structure. For more details see Table 1.

#### b) Failure data

These data are characterized by:

- 1) identification data, failure record and equipment location;
- 2) failure data for characterizing a failure, e.g. failure date, maintainable items failed, severity class, failure mode, failure cause, method of observation.

For more details see Table 2.

#### c) Maintenance data

These data are characterized by:

- 1) identification data; e.g. maintenance record, equipment location, failure record;
- 2) maintenance data; parameters characterizing a maintenance, e.g. date of maintenance, maintenance category, maintenance activity, items maintained, maintenance man hours per discipline, active maintenance time, down time.

For more details see Table 3.

The type of failure and maintenance data shall normally be common for all equipment classes, with exceptions where specific data types need to be collected, 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.

### 6.2 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. the 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 pre-defined codes.

The range of pre-defined codes shall be optimized. A short range of codes may be too general to be useful. A long range of codes may give a more precise description, but will slow the input process and may not be used fully by the data acquirer. Examples of this are given in annex A and annex B for different equipment types and codes.

The disadvantage of a pre-defined list of codes versus free text is that some detailed information may be lost. It is recommended that free text be included to provide supplementary information. A free-text field with additional information is also useful for quality control of data.

**Table 1 — Equipment data**

| Main categories                                                                                                                                                                                                                                                                                                                                                 | Subcategories          | Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Identification                                                                                                                                                                                                                                                                                                                                                  | Equipment location     | Equipment tag number (*)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                 | Classification         | Equipment unit class, e.g. compressor (see annex A) (*)<br>Equipment type (see annex A) (*)<br>Application (see annex A)(*)                                                                                                                                                                                                                                                                                                                                                                                               |
|                                                                                                                                                                                                                                                                                                                                                                 | Installation data      | Installation code or name (*)<br>Installation category, e.g. platform, subsea, refinery (*)<br>Operation category, e.g. manned, remote controlled (*)<br>Geographic area, e.g. Southern North Sea, Adriatic Sea, Gulf of Mexico, continental Europe, Middle East                                                                                                                                                                                                                                                          |
|                                                                                                                                                                                                                                                                                                                                                                 | Equipment unit data    | Equipment unit description (nomenclature)<br>Unique number, e.g. serial number<br>Subunit redundancy, e.g. number of redundant subunits                                                                                                                                                                                                                                                                                                                                                                                   |
| Design                                                                                                                                                                                                                                                                                                                                                          | Manufacturer's data    | Manufacturer's name (*)<br>Manufacturer's model designation (*)                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|                                                                                                                                                                                                                                                                                                                                                                 | Design characteristics | Relevant for each equipment class, e.g. capacity, power, speed, pressure, see annex A (*)                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Application                                                                                                                                                                                                                                                                                                                                                     | Operation (normal use) | Equipment unit redundancy, e.g. 3 × 50 %<br>Mode while in the operating state, e.g. continuous running, standby, normally closed/open, intermittent<br>Date the equipment unit was installed or date of production start-up<br>Surveillance period (calendar time)(*)<br>The accumulated operating time during the surveillance period<br>Number of demands during the surveillance period as applicable<br>Operating parameters as relevant for each equipment class, e.g. operating power, operating speed, see annex A |
|                                                                                                                                                                                                                                                                                                                                                                 | Environmental factors  | Ambient conditions (severe, moderate, benign) <sup>a</sup><br>Interior environment (severe, moderate, benign) <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                |
| Remarks                                                                                                                                                                                                                                                                                                                                                         | Additional information | Additional information in free text as applicable<br>Source of data, e.g. process and instrumentation diagram, data sheet, maintenance system                                                                                                                                                                                                                                                                                                                                                                             |
| <sup>a</sup> Features to be considered, e.g. degree of protective enclosure, vibration, salt spray or other corrosive external fluids, dust, heat, humidity.<br><sup>b</sup> Features to be considered, e.g. for compressor, benign (gas - clean and dry), moderate (some droplets corrosion), severe (sour gas, high CO <sub>2</sub> , high particle content). |                        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |



Table 2 — Failure data

| Category       | Data                           | Description                                                                                                                 |
|----------------|--------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Identification | Failure record (*)             | Unique failure identification                                                                                               |
|                | Equipment location (*)         | Tag number                                                                                                                  |
| Failure data   | Failure date (*)               | Date of failure detection (year/month/day)                                                                                  |
|                | Failure mode (*)               | At equipment unit level (see annex A)                                                                                       |
|                | Impact of failure on operation | Zero, partial or total (safety consequences may also be included)                                                           |
|                | Severity class (*)             | Effect on equipment unit function: critical failure, non-critical failure                                                   |
|                | Failure descriptor             | The descriptor of the failure (see Table B.1)                                                                               |
|                | Failure cause                  | Cause of the failure (see Table B.2)                                                                                        |
|                | Subunit failed                 | Name of subunit that failed (see examples in annex A)                                                                       |
|                | Maintainable item(s) failed    | Specify the failed maintainable item(s) (see annex A)                                                                       |
|                | Method of observation          | How the failure was detected (see Table B.3)                                                                                |
| Remarks        | Additional information         | Give more details, if available, on the circumstances leading to the failure, additional information on failure cause, etc. |

Table 3 — Maintenance data

| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Data                                               | Description                                                                                                                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Identification                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Maintenance record (*)                             | Unique maintenance identification                                                                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Equipment location (*)                             | Tag number                                                                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Failure record (*)                                 | Corresponding failure identification (corrective maintenance only)                                                          |
| Maintenance data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Date of maintenance (*)                            | Date when maintenance action was undertaken                                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Maintenance category                               | Corrective maintenance or preventive maintenance                                                                            |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Maintenance activity                               | Description of maintenance activity (see Table B.4)                                                                         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Impact of maintenance on operation                 | Zero, partial or total, (safety consequences may also be included)                                                          |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Subunit maintained                                 | Name of subunit maintained (see annex A) <sup>a</sup>                                                                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Maintainable item(s) maintained                    | Specify the maintainable item(s) that were maintained (see annex A)                                                         |
| Maintenance resources <sup>b</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Maintenance man-hours, per discipline <sup>b</sup> | Maintenance man-hours per discipline (mechanical, electrical, instrument, others)                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Maintenance man-hours, total                       | Total maintenance man-hours                                                                                                 |
| Maintenance time                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Active maintenance time                            | Time duration for active maintenance work on the equipment <sup>c</sup>                                                     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Down time                                          | Time interval during which an item is in a down state                                                                       |
| Remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Additional information                             | Give more details, if available, on the maintenance action, e.g. abnormal waiting time, relation to other maintenance tasks |
| <p><sup>a</sup> For corrective maintenance, the subunit maintained will normally be identical with the one specified on the failure event report (see 7.2).</p> <p><sup>b</sup> For subsea equipment, the following apply:<br/> — type of main resource(s) and number of days used, e.g. drilling rig, diving vessel, service vessel (*);<br/> — type of supplementary resource(s) and number of hours used, e.g. divers, ROV/ROT, platform personnel.</p> <p><sup>c</sup> This information is desirable for RAM and RCM analyses. It is currently infrequently recorded in the maintenance management systems. The reporting of this information shall be improved.</p> |                                                    |                                                                                                                             |

### 6.3 Database structure

The data collected shall be organized and linked in a database to provide easy access for updates, queries and analysis, e.g. statistics, lifetime analysis. An example of how the information in the database may be logically structured is shown in Figure 3.

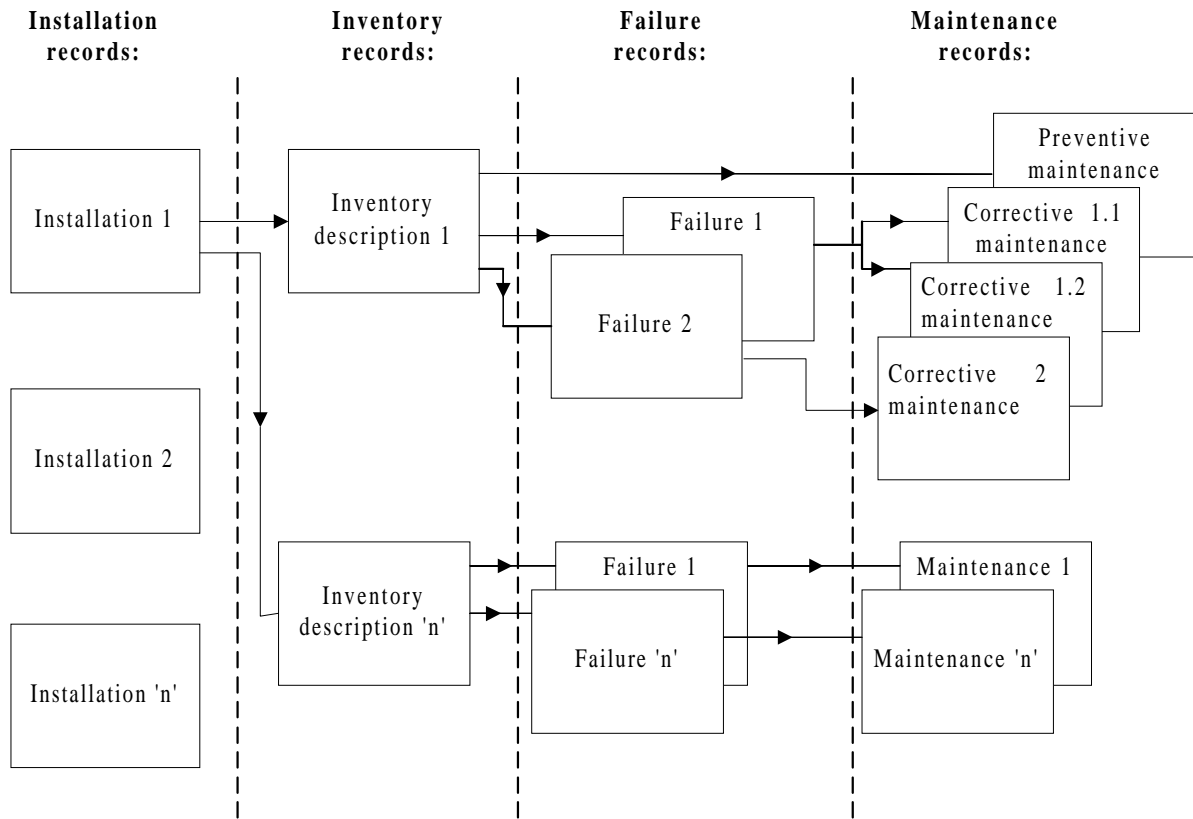


Figure 3 — Database structure

## 7 Equipment, failure and maintenance data

### 7.1 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 if the data are suitable or valid for various applications. There are some data which are common to all equipment classes and some data which are specific for each 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 1, 2 and 3.

Table 1 contains the data common to all equipment classes. In addition some data which are specific for each equipment class shall be reported. Annex A gives examples of such data for some equipment classes. In the examples in annex A, priority data are indicated.

The minimum data needed to meet the objectives of this International Standard are identified by (\*). However, certain additional data categories may significantly improve the potential uses for RM data, see annex D.

NOTE Some features under main category "Application" in Table 1 may vary with time. Some of this information is linked with information gathered from the production consequence upon failure or maintenance. This information has a significant bearing on the interpretation of down time.

## 7.2 Failure data

A uniform definition of failure and a method of classifying failures are essential when data from different sources (plants and operators) need to be combined in a common RM database.

A common report for all equipment classes shall be used for reporting failure data. The data are given in Table 2.

The minimum data needed to meet the objectives of this International Standard are identified by (\*). However, certain additional data categories may significantly improve the potential uses for RM data, see annex D.

## 7.3 Maintenance data

Maintenance is carried out:

- a) to correct a failure (corrective maintenance). The failure shall be reported as described in 7.2;
- 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 3.

The minimum data needed to meet the objectives of this International Standard are identified by (\*). However, certain additional data categories may significantly improve the potential uses for RM data, see annex D.

## Annex A (informative)

### Equipment class attributes

#### A.1 Advisory notes

##### A.1.1 General

Annex A gives examples in Tables A.1 to A.66 on how some typical oil and gas equipment may be categorized as to taxonomy, boundary definition, inventory data and failure modes. These data are specific for each equipment unit. Data common for all equipment units are shown in annex B.

In this categorization, a standardization approach has been applied to classification and subdivision of units. This means that the total number of different data categories and definitions are reduced, while 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 which are applicable to the specific equipment unit for which data are being collected. For equipment units of special design, a more tailor-made categorization than that shown in these examples may be required.

In the tables in which equipment is broken down into “subunit” and “maintainable items” (e.g. Table A.2), it is recommended to include additional “maintainable items”, as needed, to cover instrumentation, and an “unknown” category in case information is not available.

##### A.1.2 Boundary definitions

The purpose of the boundary definition is to ensure a common understanding of what equipment is to be included within the boundary of a particular system, and hence which failures and maintenance to record. For definition of the boundaries, the following rules are recommended:

- a) exclude connected items from the equipment unit boundary, unless specifically included by the boundary specification. Failures that occur in a connection (e.g. leak), and which cannot be solely related to the *connected item*, should be included within the boundary definition;
- b) when a driver and the driven unit use a common subunit (e.g. lubrication system), relate failure on this subunit, as a general rule, to the *driven unit*;
- c) 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.

##### A.1.3 Failure modes

In annex A, a list of relevant failure modes is given for each equipment unit. The failure modes should be related to the equipment unit level in the hierarchy. The failure modes used can be categorized in three types:

- a) the desired *function is not obtained* (e.g. fail to start);
- b) there is a deviation in a specified *function outside accepted limits* (e.g. high output);
- c) there is a *failure indication* observed, but there is no immediate and critical impact on equipment unit function (e.g. leakage).

For the latter category the failure mode should describe the *failure indication on equipment unit level*, while the failure descriptor should describe the *cause of failure on the lowest level within the equipment hierarchy* for which this information is known.

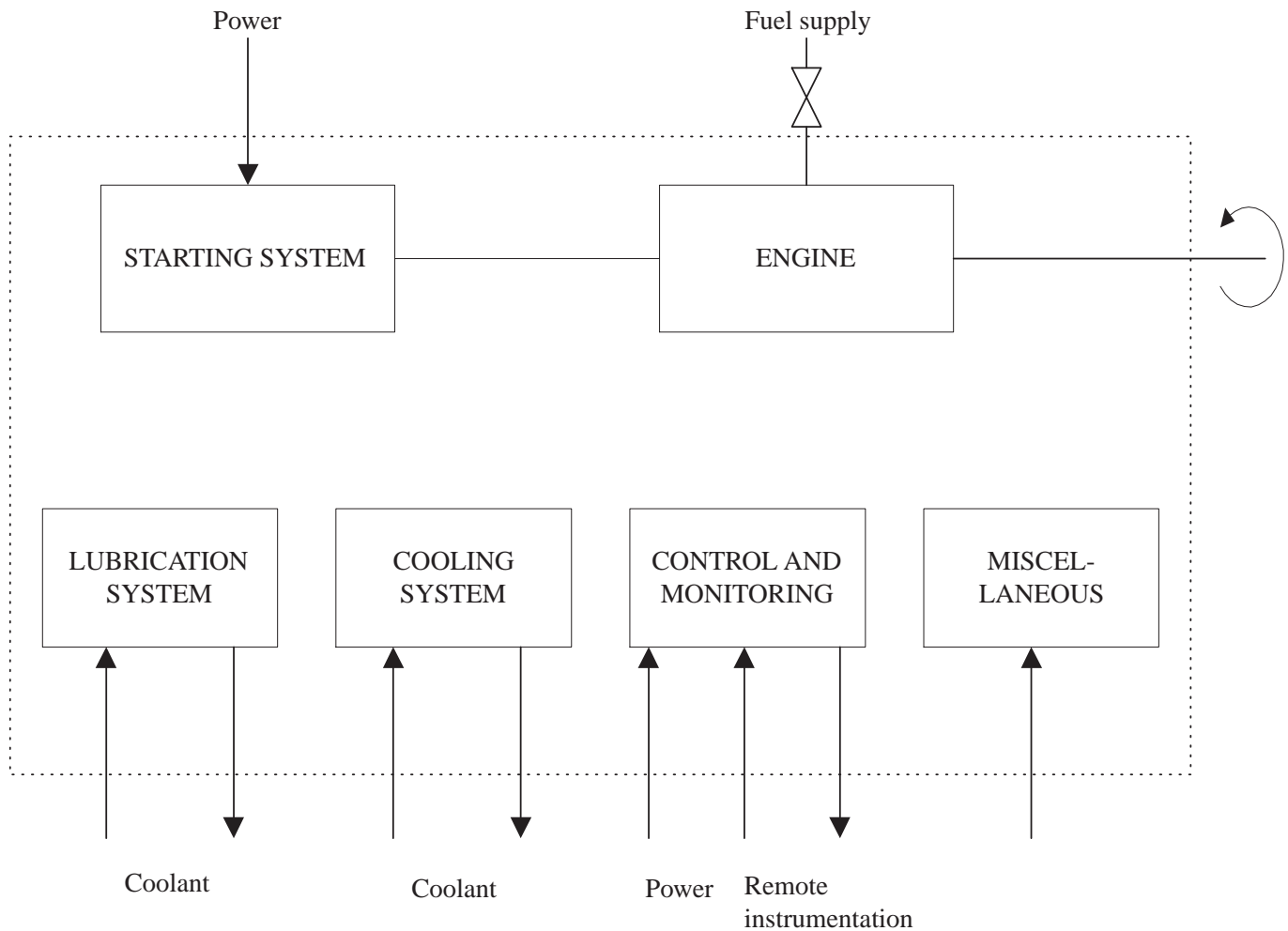
## A.2 Process equipment

### A.2.1 Combustion engines (piston)

**Table A.1 — Taxonomy classification — Combustion engines**

| Equipment class                                  |      | Type          |      | Application         |      |
|--------------------------------------------------|------|---------------|------|---------------------|------|
| Description                                      | Code | Description   | Code | Description         | Code |
| Combustion engines - piston (diesel/gas engines) | CE   | Diesel engine | DE   | Main power          | MP   |
|                                                  |      | Gas engine    | GE   | Essential power     | EP   |
|                                                  |      |               |      | Emergency power     | EM   |
|                                                  |      |               |      | Water injection     | WI   |
|                                                  |      |               |      | Oil handling        | OH   |
|                                                  |      |               |      | Gas handling        | GH   |
|                                                  |      |               |      | Water fire-fighting | FF   |
|                                                  |      |               |      | Material handling   | MH   |

NOTE In Table A.1 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.



..... Boundary

**Figure A.1 — Equipment boundary — Combustion engines**

Table A.2 — Equipment unit subdivision — Combustion engines

| Equipment unit     | Combustion engines                                            |                                                                                                                                                                                   |                                                                              |                                                                                                 |                                                                                              |                                 |
|--------------------|---------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|---------------------------------|
| Subunit            | Start system                                                  | Combustion engine unit                                                                                                                                                            | Control and monitoring                                                       | Lubrication system                                                                              | Cooling system                                                                               | Miscellaneous                   |
| Maintainable items | Start energy (battery, air)<br>Starting unit<br>Start control | Air inlet<br>Turbocharger<br>Fuel pumps<br>Injectors<br>Fuel filters<br>Exhaust<br>Cylinders<br>Pistons<br>Shaft<br>Thrust bearing<br>Radial bearing<br>Seals<br>Piping<br>Valves | Control<br>Actuating device<br>Monitoring<br>Valves<br>Internal power supply | Reservoir<br>Pump w/motor<br>Filter<br>Cooler<br>Valves<br>Piping<br>Oil<br>Temperature control | Heat exchanger<br>Fan and motor<br>Filter<br>Valves<br>Piping<br>Pump<br>Temperature control | Hood<br>Others<br>Flange joints |

Table A.3 — Equipment unit specific data — Combustion engines

| Name                                     | Description                                                                                     | Unit or code list                           |
|------------------------------------------|-------------------------------------------------------------------------------------------------|---------------------------------------------|
| Driver application (*)                   | Name of driven unit                                                                             | Pump, generator, compressor                 |
| Corresponding driven unit                | Specify identification number of driven unit                                                    | Numeric                                     |
| Power- design (*)                        | Max. rated output (design)                                                                      | kW                                          |
| Power - operating (*)                    | Specify the approximate power at which the unit has been operated for most of surveillance time | kW                                          |
| Speed (*)                                | Design speed                                                                                    | r/min                                       |
| Number of cylinders                      | Specify number of cylinders                                                                     | Integer                                     |
| Cylinder configuration                   | Type                                                                                            | Inline, vee, flat                           |
| Starting system (*)                      | Type                                                                                            | Electric, hydraulic, pneumatic              |
| Fuel                                     | Type                                                                                            | Gas, light oil, medium oil, heavy oil, dual |
| Air inlet filtration type                | Type                                                                                            | Free text                                   |
| Engine aspiration type (*)               | Type of engine aspiration                                                                       | Turbo, natural                              |
| (*) Indicates high-priority information. |                                                                                                 |                                             |

Table A.4 — Failure modes — Combustion engines

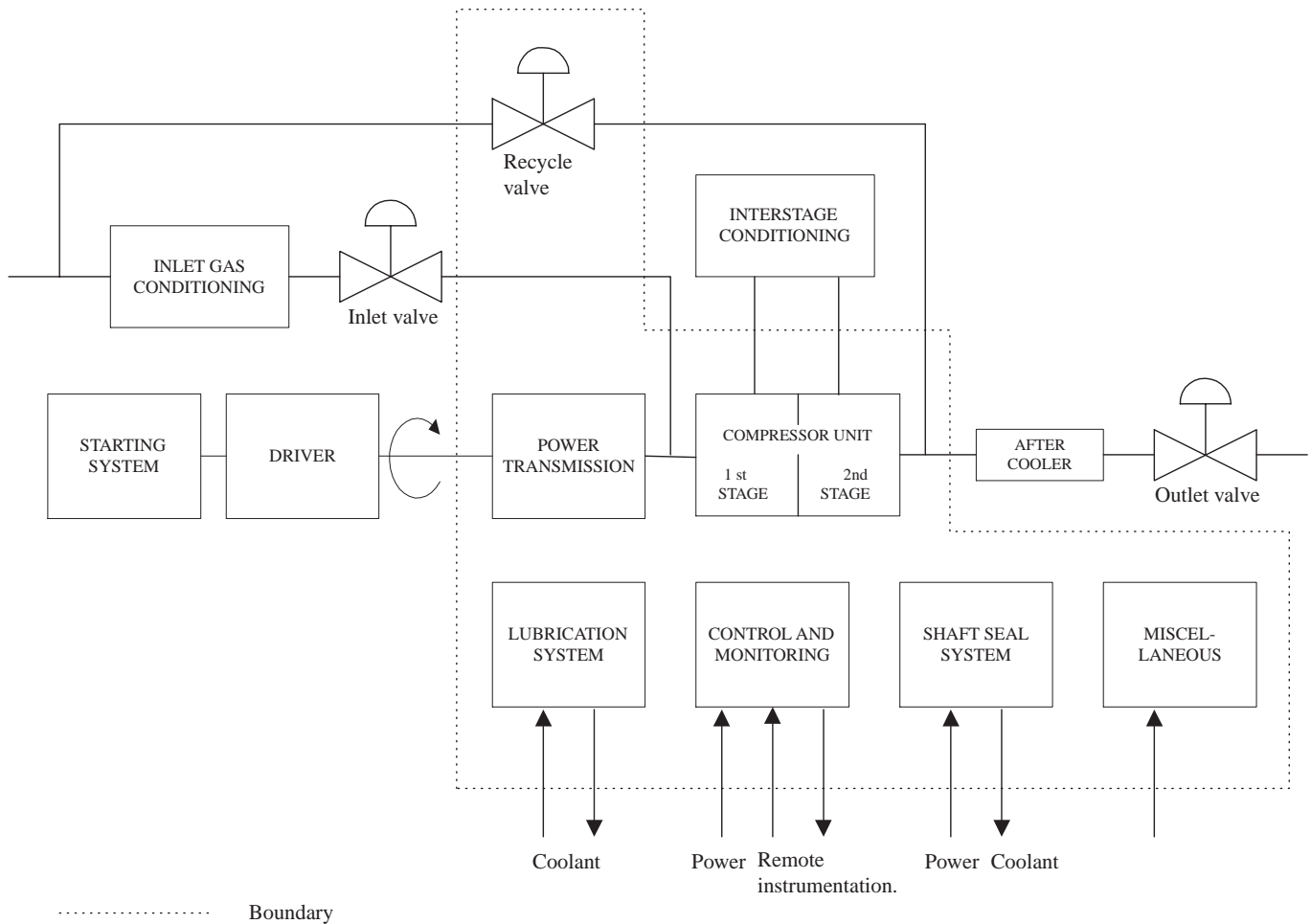
| Equipment unit    | Code    | Definition                      | Description                                         |
|-------------------|---------|---------------------------------|-----------------------------------------------------|
| Combustion engine | FTS     | Fail to start on demand         | Unable to start the engine                          |
|                   | STP     | Fail to stop on demand          | Unable to stop or incorrect shutdown process        |
|                   | SPS     | Spurious stop                   | Unexpected shutdown of engine                       |
|                   | OWD     | Operation without demand        | Undesired start                                     |
|                   | BRD     | Breakdown                       | Serious damage (seizure, breakage, explosion, etc.) |
|                   | HIO     | High output                     | Overspeed/output above specification                |
|                   | LOO     | Low output                      | Output below desired specification                  |
|                   | ERO     | Erratic output                  | Oscillating or hunting                              |
|                   | ELF     | External leakage - fuel         | Fuel gas or diesel leak                             |
|                   | ELU     | External leakage utility medium | Lube oil, coolant, etc.                             |
|                   | INL     | Internal leakage                | E.g. internal cooling water leakage                 |
|                   | VIB     | Vibration                       | Excessive vibration                                 |
|                   | NOI     | Noise                           | Excessive noise                                     |
|                   | OHE     | Overheating                     | Excessive temperature                               |
|                   | PDE     | Parameter deviation             | Monitored parameter exceeding tolerances            |
|                   | AIR     | Abnormal instrument reading     | E.g. false alarm, faulty reading                    |
|                   | STD     | Structural deficiency           | E.g. cracks in cylinder head, support               |
|                   | SER     | Minor in-service problems       | Loose items, discoloration, dirt, etc.              |
| OTH               | Other   | Specify in comment field        |                                                     |
| UNK               | Unknown | Inadequate/missing information  |                                                     |

## A.2.2 Compressors

Table A.5 — Taxonomy classification — Compressors

| Equipment class |      | Type          |      | Application          |      |
|-----------------|------|---------------|------|----------------------|------|
| Description     | Code | Description   | Code | Description          | Code |
| Compressor      | CO   | Centrifugal   | CE   | Gas processing       | GP   |
|                 |      | Reciprocating | RE   | Gas export           | GE   |
|                 |      | Screw         | SC   | Gas injection        | GI   |
|                 |      | Blowers/fans  | BL   | Lift gas compression | GL   |
|                 |      | Axial         | AX   | Compressed air       | AI   |
|                 |      |               |      | Refrigeration        | RE   |

NOTE In Table A.5 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.



**Figure A.2 — Equipment boundary — Compressors**

**Table A.6 — Equipment unit subdivision — Compressors**

| Equipment unit     | Compressors                                                                                                         |                                                                                                                                                                                                                                                         |                                                                              |                                                                                                                       |                                                                                                                                                   |                                                                                                                                                                                         |
|--------------------|---------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Subunit            | Power transmission                                                                                                  | Compressor                                                                                                                                                                                                                                              | Control and monitoring                                                       | Lubrication system                                                                                                    | Shaft seal system                                                                                                                                 | Miscellaneous                                                                                                                                                                           |
| Maintainable items | Gearbox/variable drive<br>Bearings<br>Coupling to the driver<br>Lubrication<br>Seals<br>Coupling to the driven unit | Casing<br>Rotor with impellers<br>Balance piston<br>Interstage seals<br>Radial bearing<br>Thrust bearing<br>Shaft seals<br>Internal piping<br>Valves<br>Antisurge system including recycle valve and controllers<br>Piston<br>Cylinder liner<br>Packing | Control<br>Actuating device<br>Monitoring<br>Valves<br>Internal power supply | Oil tank with heating system<br>Pump with motor<br>Check valves<br>Coolers<br>Filters<br>Piping<br>Valves<br>Lube oil | Oil tank with heating<br>Reservoir<br>Pump with motor/gear<br>Filters<br>Valves<br>Buffer gas<br>Seal oil<br>Dry gas seal<br>Seal gas<br>Scrubber | Base frame<br>Piping, pipe support and bellows<br>Control-isolation and check valves<br>Coolers<br>Silencers<br>Purge air<br>Magnetic bearing control system<br>Flange joints<br>Others |

NOTE The maintainable Items listed in Table A.6 should be applied as relevant for the compressor type.



Table A.7 — Equipment unit specific data — Compressors

| Name                                     | Description                                                                              | Unit or code list                                                                                                   |
|------------------------------------------|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Corresponding driver (*)                 | Specify unique record identification number when relevant                                | Numeric                                                                                                             |
| Gas handled (*)                          | Average molar mass<br>(specific gravity × 28,96)                                         | g/mol                                                                                                               |
| Suction pressure - design (*)            | First stage                                                                              | pascal (bar)                                                                                                        |
| Suction pressure - operating             | First stage                                                                              | pascal (bar)                                                                                                        |
| Discharge pressure - design (*)          | Last stage                                                                               | pascal (bar)                                                                                                        |
| Discharge pressure - operating (*)       | Last stage                                                                               | pascal (bar)                                                                                                        |
| Flowrate - design (*)                    |                                                                                          | m <sup>3</sup> /h                                                                                                   |
| Flowrate - operating                     |                                                                                          | m <sup>3</sup> /h                                                                                                   |
| Discharge temperature - design (*)       |                                                                                          | °C                                                                                                                  |
| Discharge temperature - operating        |                                                                                          | °C                                                                                                                  |
| Power - design (*)                       | Design power                                                                             | kW                                                                                                                  |
| Utilization (*)                          | % utilization compared to design                                                         | %                                                                                                                   |
| Polytrophic head                         |                                                                                          | kJ/kg                                                                                                               |
| Number of casings (*)                    | Number of casings in the train                                                           | Integer                                                                                                             |
| Number of stages (*)                     | Number of compressor stages<br>(not impellers) in this train                             | Integer                                                                                                             |
| Body type                                | Type                                                                                     | Vertical split case (barrel type),<br>axial split case                                                              |
| Shaft sealing                            | Type                                                                                     | Mechanical, oil, dry gas-packed,<br>dry gland, labyrinth, combined                                                  |
| Inter cooler fitted                      | Specify if cooler is fitted                                                              | Yes/no                                                                                                              |
| Shaft seal system (*)                    | Separate, combined, dry, etc.                                                            | Separate, combined, dry                                                                                             |
| Radial bearing (*)<br>Thrust bearing (*) | Type (specify in comment field whether<br>any thrust pressure regulator is<br>installed) | Antifrictional, journal, magnetic                                                                                   |
| Speed                                    | Design speed                                                                             | r/min                                                                                                               |
| Type of driver (*)                       | Type                                                                                     | Electric motor, gas turbine, steam<br>turbine, diesel engine, gas en-<br>gine, turboexpander, integral gas<br>motor |
| Coupling                                 | Type                                                                                     | Fixed, flexible, hydraulic,<br>disconnect                                                                           |
| <i>Reciprocating compressors only:</i>   |                                                                                          |                                                                                                                     |
| Cylinder configuration                   |                                                                                          | Inline, opposed, V, W                                                                                               |
| Cylinder orientation                     |                                                                                          | Horizontal, vertical, inclined                                                                                      |
| Working principle (*)                    |                                                                                          | Single-acting, double-acting                                                                                        |
| Packing type (*)                         |                                                                                          | Lubricated, dry                                                                                                     |
| (*) Indicates high priority information. |                                                                                          |                                                                                                                     |

**Table A.8 — Failure modes — Compressors**

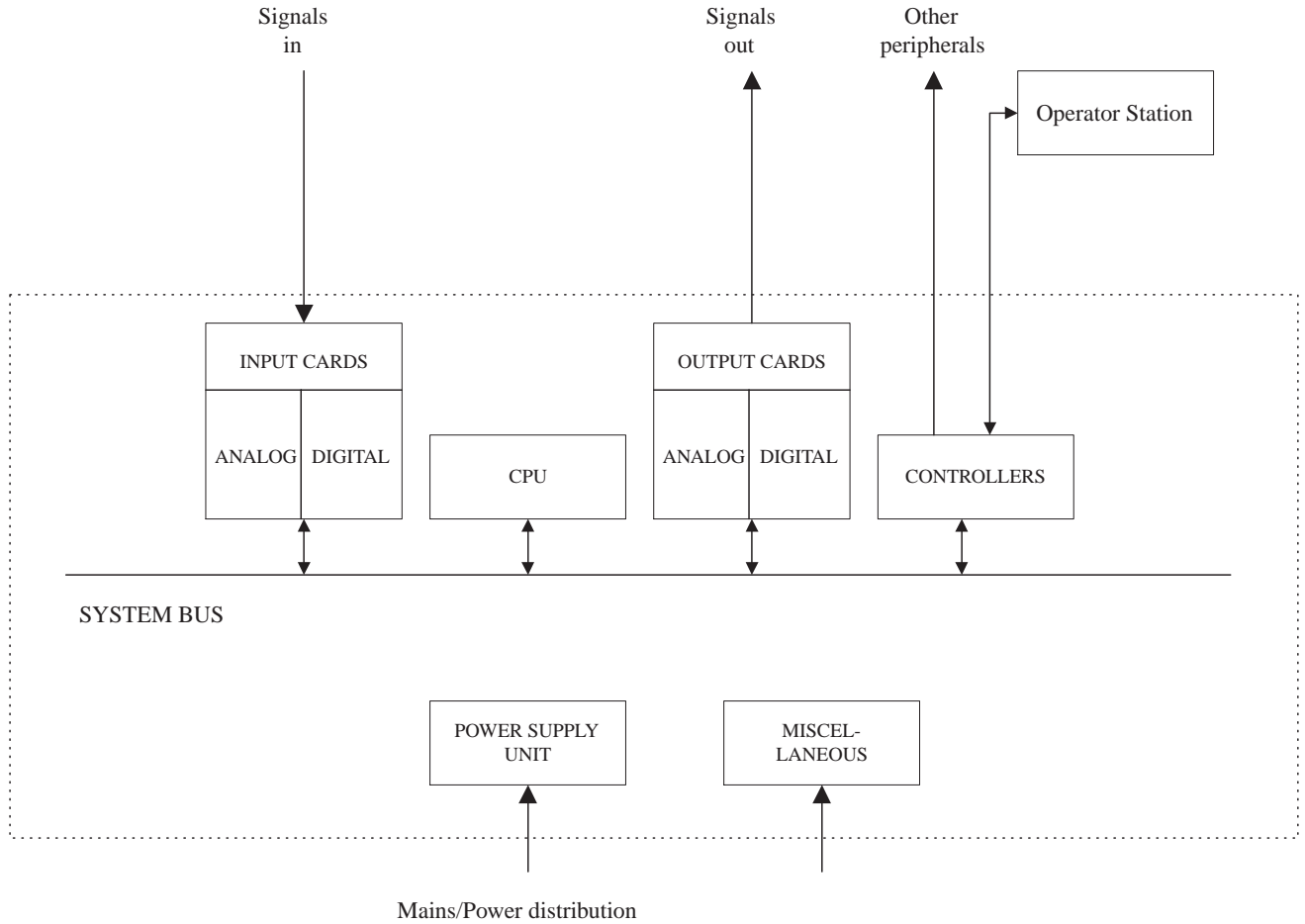
| Equipment unit | Code    | Definition                                    | Description                                         |
|----------------|---------|-----------------------------------------------|-----------------------------------------------------|
| Compressor     | FTS     | Fail to start on demand                       | Unable to activate compressor                       |
|                | STP     | Fail to stop on demand                        | Unable to stop or incorrect shutdown action         |
|                | SPS     | Spurious stop                                 | Unexpected shutdown of compressor                   |
|                | BRD     | Breakdown                                     | Serious damage (seizure, breakage, explosion, etc.) |
|                | HIO     | High output                                   | Output pressure/flow above specification            |
|                | LOO     | Low output                                    | Output pressure/flow below specification            |
|                | ERO     | Erratic output                                | Oscillating or unstable pressure/flow               |
|                | ELP     | External leakage process medium               | Process medium escape to environment                |
|                | ELU     | External leakage utility medium               | Lube/seal oil, coolant, etc.                        |
|                | INL     | Internal leakage                              | E.g. process medium in lube oil                     |
|                | VIB     | Vibration                                     | Excessive vibration                                 |
|                | NOI     | Noise                                         | Excessive noise                                     |
|                | OHE     | Overheating                                   | Excessive temperature                               |
|                | PDE     | Parameter deviation                           | Monitored parameter exceeding tolerances            |
|                | AIR     | Abnormal instrument reading                   | E.g. false alarm, faulty reading                    |
|                | STD     | Structural deficiency                         | E.g. cracks in support or suspension                |
|                | SER     | Minor in-service problems                     | Loose items, discoloration, contamination, etc.     |
| OTH            | Other   | None of above apply. Specify in comment field |                                                     |
| UNK            | Unknown | Inadequate/missing information                |                                                     |

**A.2.3 Control logic units**

**Table A.9 — Taxonomy classification — Control logic units**

| Equipment class     |      | Type                       |      | Application              |      |
|---------------------|------|----------------------------|------|--------------------------|------|
| Description         | Code | Description                | Code | Description              | Code |
| Control logic units | CL   | PLC                        | LC   | Fire and gas detection   | FG   |
|                     |      | Computer                   | PC   | Process shutdown         | PS   |
|                     |      | Distributed control system | DC   | Emergency shutdown       | ES   |
|                     |      | Relay                      | RL   | Process shutdown and ESD | CS   |
|                     |      | Solid state                | SS   | Process control          | PC   |
|                     |      | Single loop controller     | SL   |                          |      |

NOTE In Table A.9 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.



..... Boundary

**Figure A.3 — Equipment boundary — Control logic units**

**Table A.10 — Equipment unit subdivision — Control logic units**

| Equipment unit     | Control logic units                                                                                                      |                               |                                         |                                         |                                                                                                |
|--------------------|--------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------|-----------------------------------------|------------------------------------------------------------------------------------------------|
| Subunit            | Analog input cards                                                                                                       | Digital input cards           | Analog output cards                     | Digital output cards                    | Central processor unit                                                                         |
| Maintainable items | Input card<br>Connection unit                                                                                            | Input card<br>Connection unit | Output card<br>Connection unit<br>Relay | Output card<br>Connection unit<br>Relay | Central processor unit (CPU)<br>Random access memory (RAM)<br>Watchdog/diagnostics<br>Software |
| Subunit            | Controllers                                                                                                              |                               | System bus                              | Power supply                            | Miscellaneous                                                                                  |
| Maintainable items | Internal bus controller<br>Visual display unit control (VDU)<br>Communication control<br>Disk control<br>Printer control |                               | (No subdivision)                        | (No subdivision)                        | Others                                                                                         |

**Table A.11 — Equipment unit specific data — Control logic units**

| Name                                     | Description                                                                                                                       | Unit or code list                                                                         |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|
| Application - control logic (*)          | Where used                                                                                                                        | Fire and gas detection, process shutdown, emergency shutdown, process control, monitoring |
| Central process unit voting (*)          | At least <i>k</i> out of <i>n</i> sensors shall provide signal to initiate safety action - <i>k</i> and <i>n</i> shall be entered | <i>k</i> = 'nn' (integer)<br><i>n</i> = 'nn' (integer)                                    |
| (*) Indicates high priority information. |                                                                                                                                   |                                                                                           |

**Table A.12 — Failure modes — Control logic units**

| Equipment unit      | Code | Definition                 | Description                                       |
|---------------------|------|----------------------------|---------------------------------------------------|
| Control logic units | FTF  | Fail to function on demand | Fail to activate output function                  |
|                     | OWD  | Operates without demand    | False alarm                                       |
|                     | AOL  | Abnormal output - Low      | Trend toward FTF failure, e.g. low output         |
|                     | AOH  | Abnormal output - High     | Trend toward OWD failure, e.g. high output        |
|                     | ERO  | Erratic output             | Reading not intelligible, e.g. oscillating        |
|                     | SER  | Minor in-service problems  | Some minor repair required                        |
|                     | UNK  | Unknown                    | Inadequate/missing information                    |
|                     | OTH  | Other                      | None of the above apply. Specify in comment field |

**A.2.4 Electric generators**

**Table A.13 — Taxonomy classification — Electric generators**

| Equipment class    |      | Type                                          |      | Application     |      |
|--------------------|------|-----------------------------------------------|------|-----------------|------|
| Description        | Code | Description                                   | Code | Description     | Code |
| Electric generator | EG   | Gas turbine driven                            | TD   | Main power      | MP   |
|                    |      | Steam turbine driven                          | SD   | Essential power | EP   |
|                    |      | Engine driven, e.g. diesel engine, gas engine | MD   | Emergency power | EM   |

NOTE In Table A.13 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.

**Table A.14 — Equipment unit subdivision — Electric generators**

| Equipment unit     | Electric generators     |                    |                        |                    |                 |               |
|--------------------|-------------------------|--------------------|------------------------|--------------------|-----------------|---------------|
| Subunit            | Power transmission      | Electric generator | Control and monitoring | Lubrication system | Cooling system  | Miscellaneous |
| Maintainable items | Gearbox                 | Stator             | Control                | Reservoir          | Heat exchanger  | Hood          |
|                    | Bearing                 | Rotor              | Actuating device       | Pump with motor    | Fan with motor  | Purge air     |
|                    | Seals                   | Excitation         | Monitoring             | Filter             | Filter          | Others        |
|                    | Lubrication             | Radial bearing     | Valves                 | Cooler             | Valves          |               |
|                    | Coupling to driver      | bearing            | Internal power supply  | Valves             | Piping          |               |
|                    | Coupling to driven unit | Thrust bearing     |                        | Piping             | Pump with motor |               |
|                    |                         |                    |                        | Oil                |                 |               |

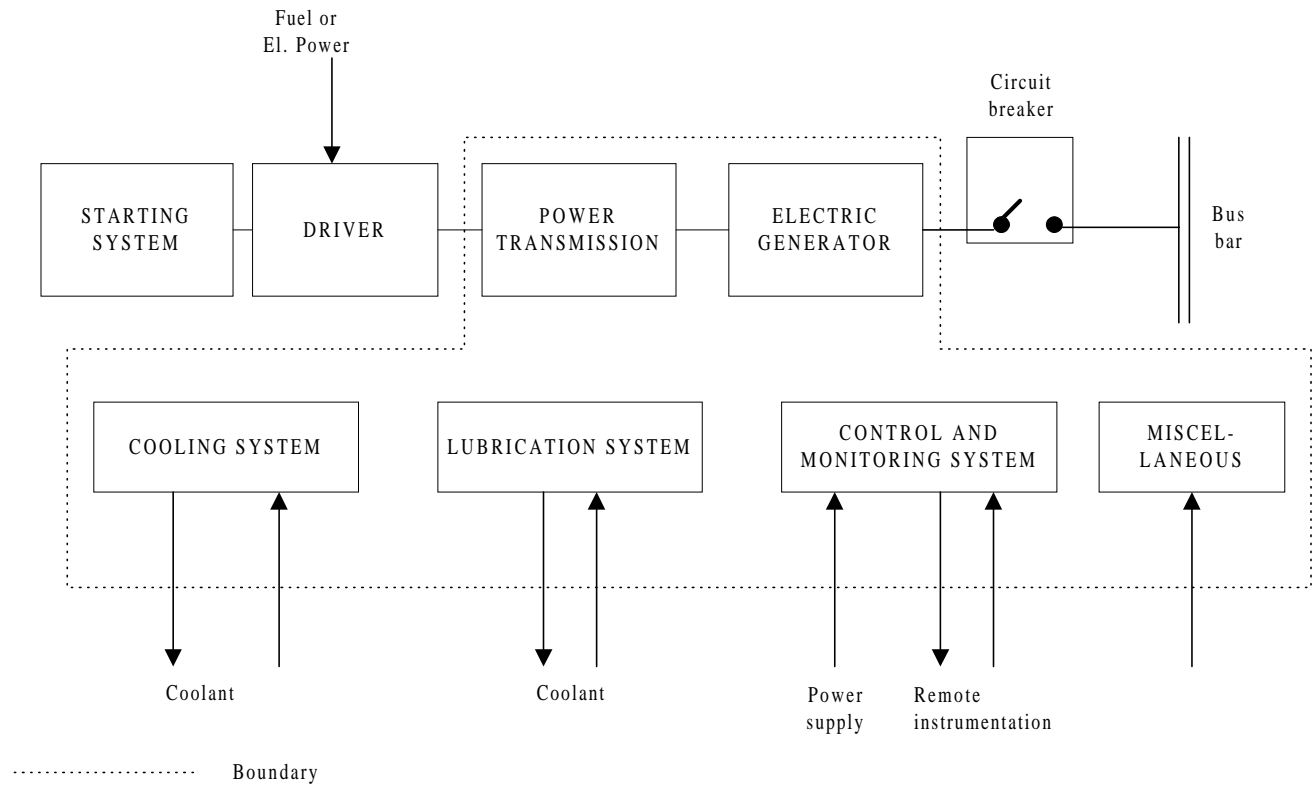


Figure A.4 — Equipment boundary — Electric generators

Table A.15 — Equipment unit specific data — Electric generators

| Name                                | Description                                        | Unit or code list                                                     |
|-------------------------------------|----------------------------------------------------|-----------------------------------------------------------------------|
| Corresponding driver (*)            | Specify driver identification number when relevant | Numeric                                                               |
| Type of driver (*)                  | Type                                               | Electric motor, gas turbine, steam turbine, diesel engine, gas engine |
| Coupling                            | Specify (fixed, flexible, etc.)                    | Fixed, flexible, hydraulic, disconnect                                |
| Synchronous speed (*)               |                                                    | r/min                                                                 |
| Frequency                           | Design frequency                                   | Hz                                                                    |
| Voltage (*)                         | Design voltage                                     | kV                                                                    |
| Power - design                      | Design power                                       | kW                                                                    |
| Power factor                        | cos φ                                              | Numeric                                                               |
| Excitation control (*)              | Type                                               | Automatic, manual                                                     |
| Excitation type (*)                 | Brushless/slip-ring                                | Brushless, slip-ring                                                  |
| Degree of protection                | Protection class according to IEC 60529            |                                                                       |
| Insulation class - stator (*)       | Insulation class according to IEC 60085            | Y, A, E, B, F, H, 200, 220, 250                                       |
| Temperature rise - stator           |                                                    | °C                                                                    |
| Insulation class - rotor            | Insulation class according to IEC 60085            | Y, A, E, B, F, H, 200, 220, 250                                       |
| Temperature rise - rotor            |                                                    | °C                                                                    |
| Radial bearing(*)<br>Thrust bearing | Type                                               | Antifrictional, journal, magnetic                                     |
| Lubrication of bearings             | Type of bearing lubrication                        | Grease, oil bath, pressurized oil, oil ring                           |
| Generator cooling (*)               | Type                                               | Air/air, air/water, open ventilated                                   |

(\*) Indicates high-priority information.

Table A.16 — Failure modes — Electric generators

| Equipment unit      | Code    | Definition                      | Description                                         |
|---------------------|---------|---------------------------------|-----------------------------------------------------|
| Electric generators | FTS     | Fail to start on demand         | Unable to activate generator                        |
|                     | STP     | Fail to stop on demand          | Unable to stop or incorrect shutdown process        |
|                     | SPS     | Spurious stop                   | Unexpected shutdown of generator                    |
|                     | BRD     | Breakdown                       | Serious damage (seizure, breakage, explosion, etc.) |
|                     | SYN     | Fail to synchronise             | Unable to synchronise generator                     |
|                     | FOF     | Faulty output frequency         |                                                     |
|                     | FOV     | Faulty output voltage           |                                                     |
|                     | LOO     | Low output                      | Reduced power delivery                              |
|                     | VIB     | Vibration                       | Excessive vibration                                 |
|                     | NOI     | Noise                           | Excessive noise                                     |
|                     | ELU     | External leakage utility medium | Lube oil, coolant, etc.                             |
|                     | OHE     | Overheating                     | Excessive temperature                               |
|                     | PDE     | Parameter deviation             | Monitored parameter exceeding tolerances            |
|                     | AIR     | Abnormal instrument reading     | E.g. false alarm, faulty reading                    |
|                     | STD     | Structural deficiency           | E.g. cracks in support or suspension                |
|                     | SER     | Minor in-service problems       | Loose items, discoloration, dirt, etc.              |
|                     | OTH     | Other                           | Specify in comment field                            |
| UNK                 | Unknown | Inadequate/missing information  |                                                     |

### A.2.5 Electric motors

Table A.17 — Taxonomy classification — Electric motors

| Equipment class |      | Type                |      | Application         |      |
|-----------------|------|---------------------|------|---------------------|------|
| Description     | Code | Description         | Code | Description         | Code |
| Electric motor  | EM   | Alternating current | AC   | Water fire-fighting | FF   |
|                 |      | Direct current      | DC   | Water injection     | WI   |
|                 |      |                     |      | Oil handling        | OH   |
|                 |      |                     |      | Gas handling        | GH   |
|                 |      |                     |      | Gas processing      | GP   |
|                 |      |                     |      | Chemical injection  | CI   |
|                 |      |                     |      | Sea-water lift      | SL   |

NOTE In Table A.17 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.

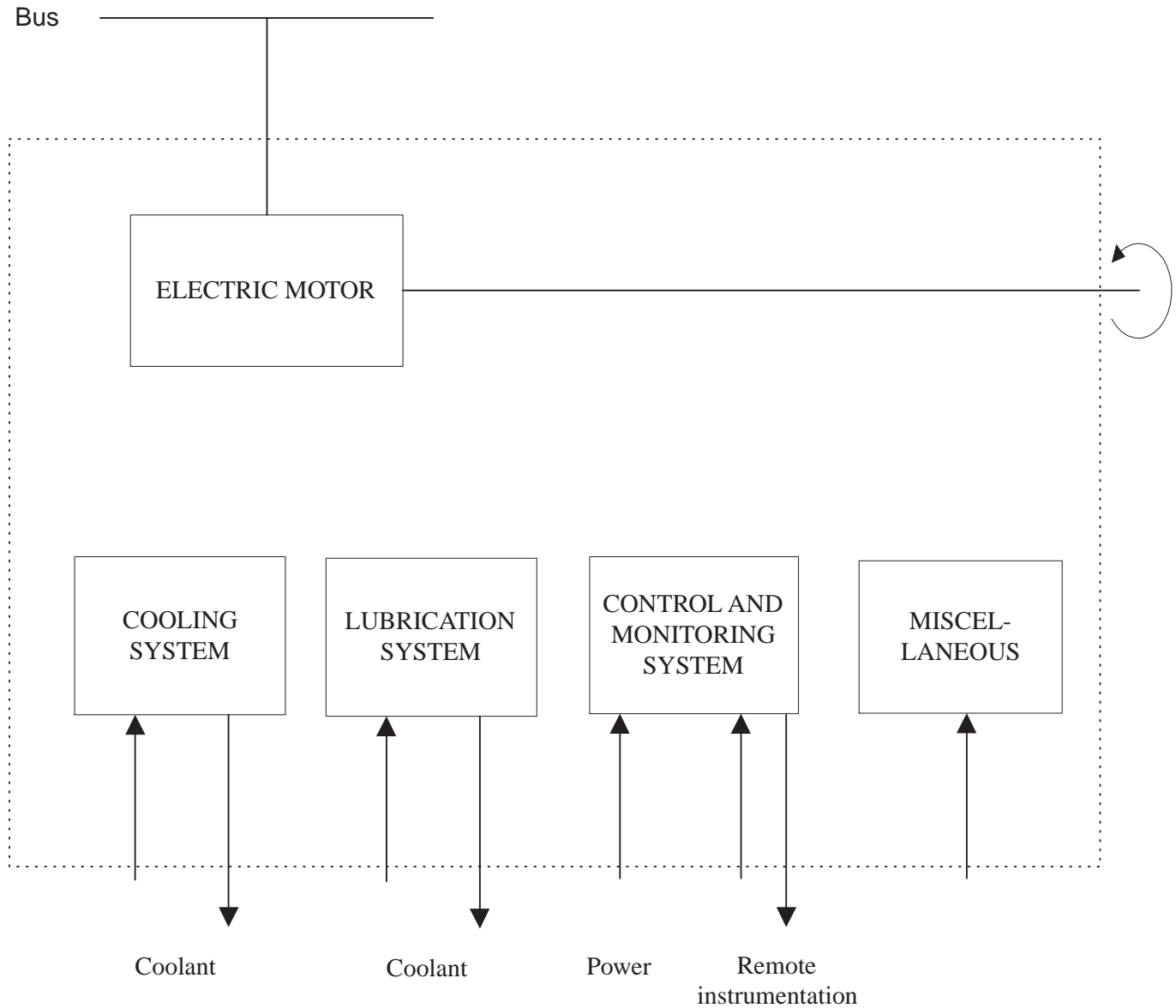


Figure A.5 — Equipment boundary — Electric motors

Table A.18 — Equipment unit subdivision — Electric motors

| Subunit            | Electric motor                                                                | Control and monitoring <sup>a</sup>                                          | Lubrication system                                                          | Cooling system                                                                    | Miscellaneous  |
|--------------------|-------------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------|
| Maintainable items | Stator<br>Rotor<br>Excitation<br>Radial bearing<br>Thrust bearing<br>Coupling | Control<br>Actuating device<br>Monitoring<br>Valves<br>Internal power supply | Reservoir<br>Pump with motor<br>Filter<br>Cooler<br>Valves<br>Piping<br>Oil | Heat exchanger<br>Filter<br>Valves<br>Piping<br>Pump with motor<br>Fan with motor | Hood<br>Others |

<sup>a</sup> Normally no extra control system for motors. For motors of Ex(p) class (pressurized) the internal pressure is monitored. Temperature may be monitored on large motors.

Table A.19 — Equipment unit specific data — Electric motors

| Name                                     | Description                                                                                     | Unit or code list                         |
|------------------------------------------|-------------------------------------------------------------------------------------------------|-------------------------------------------|
| Corresponding driven unit                | Specify driver identification number when relevant                                              | Numeric                                   |
| Driver application (*)                   | Type of driven unit                                                                             | Pump, compressor                          |
| Power - design (*)                       | Max. output (design)                                                                            | kW                                        |
| Power - operating                        | Specify the approximate power at which the unit has been operated for most of surveillance time | kW                                        |
| Variable speed                           | Specify if installed or not                                                                     | Yes/No                                    |
| Speed (*)                                | Design speed                                                                                    | r/min                                     |
| Voltage (*)                              | Design voltage                                                                                  | V                                         |
| Motor type (*)                           | Type                                                                                            | Induction, commutator (d.c.), synchronous |
| Radial bearing (*)<br>Thrust bearing     | Type                                                                                            | Antifrictional, journal, magnetic         |
| Degree of protection (*)                 | Protection class according to IEC 60529                                                         |                                           |
| Safety class (*)                         | Explosion/fire classification category, e.g. Ex(d), Ex(e)                                       | e.g.: Ex(d), Ex(e)                        |
| (*) Indicates high-priority information. |                                                                                                 |                                           |

Table A.20 — Failure modes — Electric motors

| Equipment unit  | Code | Definition                      | Description                                   |
|-----------------|------|---------------------------------|-----------------------------------------------|
| Electric motors | FTS  | Fail to start on demand         | Unable to activate motor                      |
|                 | STP  | Fail to stop on demand          | Unable to stop or incorrect shutdown process  |
|                 | SPS  | Spurious stop                   | Unexpected stop of motor                      |
|                 | OWD  | Operation without demand        | Undesired start                               |
|                 | BRD  | Breakdown                       | Serious damage (seizure, breakage, explosion) |
|                 | HIO  | High output                     | Output above specification                    |
|                 | LOO  | Low output                      | Reduced power delivery                        |
|                 | ERO  | Erratic output                  | Oscillating                                   |
|                 | VIB  | Vibration                       | Excessive vibration                           |
|                 | NOI  | Noise                           | Excessive noise                               |
|                 | ELU  | External leakage utility medium | Lube oil, coolant, etc.                       |
|                 | OHE  | Overheating                     | Excessive temperature                         |
|                 | PDE  | Parameter deviation             | Monitored parameter exceeding tolerances      |
|                 | AIR  | Abnormal instrument reading     | E.g. false alarm, faulty reading              |
|                 | STD  | Structural deficiency           | E.g. cracks, wear, fracture                   |
|                 | SER  | Minor in-service problems       | Loose items, discoloration, dirt, etc.        |
|                 | OTH  | Other                           | Specify in comment field                      |
|                 | UNK  | Unknown                         | Inadequate/missing information                |

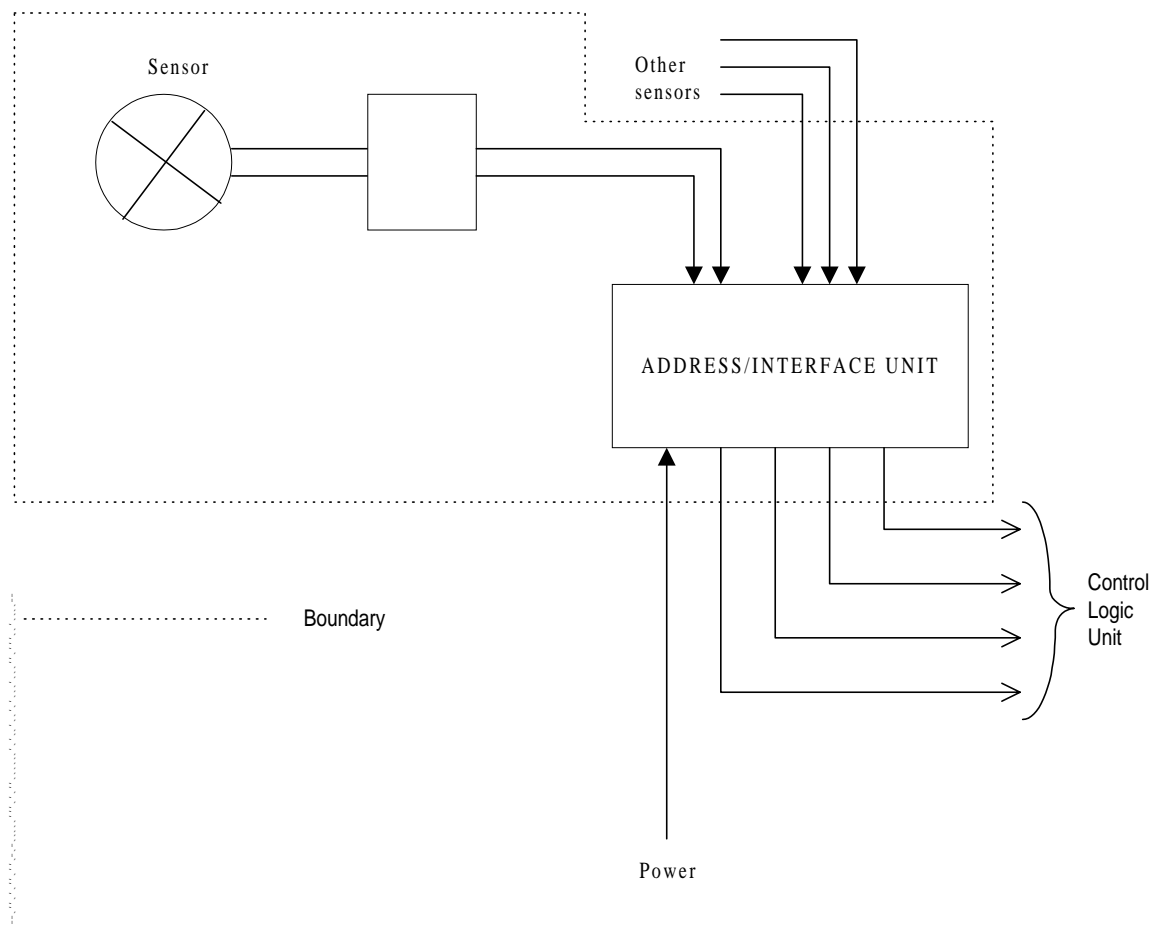


**A.2.6 Fire and gas detectors**

**Table A.21 — Taxonomy classification — Fire and gas detectors**

| Equipment class        |      | Type             |      | Application    |      |
|------------------------|------|------------------|------|----------------|------|
| Description            | Code | Description      | Code | Description    | Code |
| Fire and gas detectors | FG   | Smoke/Combustion | BS   | Fire detection | FD   |
|                        |      | Heat             | BH   |                |      |
|                        |      | Flame            | BF   |                |      |
|                        |      | Hydrocarbon      | AB   | Gas detection  | GD   |
| H <sub>2</sub> S       | AS   |                  |      |                |      |

NOTE In Table A.21 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.



**Figure A.6 — Equipment boundary — Fire and gas detectors**

**Table A.22 — Equipment unit subdivision — Fire and gas detectors**

| Equipment unit     | Fire and gas detectors                    |                                               |               |
|--------------------|-------------------------------------------|-----------------------------------------------|---------------|
| Subunit            | Sensor                                    | Interface unit                                | Miscellaneous |
| Maintainable items | Mounting socket<br>Detector head<br>Cover | Control card<br>Display<br>Cabinet<br>Cabling | Others        |

**Table A.23 — Equipment unit specific data — Fire and gas detectors**

| Name                                     | Description                                                                                                                                               | Unit or code list                                                                                                                                                                                                                                                                                                                                                       |
|------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Location on installation (*)             | Where installed                                                                                                                                           | Wellhead, christmas tree, wellhead flow line, wellhead injection line, pump, turbine, electric generator, separator, heat exchanger, vessel, header, electric motor, turboexpander, drilling, pipeline, mud processing, utility, living quarter, air inlet, alkylation unit, isomerization units, catalytic crackers, control room, auxiliary room, MCC and switch room |
| Sensor voting, $k$ out of $n$            | At least $k$ out of $n$ sensors shall provide signal to initiate safety action - $k$ and $n$ shall be entered                                             | $k = 'nn'$ (integer)<br>$n = 'nn'$ (integer)                                                                                                                                                                                                                                                                                                                            |
| Loop voting, $i$ out of $j$              | At least $i$ out of $j$ loops shall provide signal to carry out safety action - $i$ and $j$ shall be entered. If there is no voting on loops, leave blank | $i = 'nn'$ (integer)<br>$j = 'nn'$ (integer)                                                                                                                                                                                                                                                                                                                            |
| Sensing principle (*)                    | Type                                                                                                                                                      | Catalytic, electrochemical, ionization, photoelectrochemical, photoelectric beam, IR, UV, IR/UV, rate rise, rate comp, fixed temp, fusible plug                                                                                                                                                                                                                         |
| Fail-safe principle (*)                  | Normally energized, normally de-energized. Normally not applicable for analog equipment                                                                   | Energized, de-energized                                                                                                                                                                                                                                                                                                                                                 |
| Detector communication†(*)               | Type                                                                                                                                                      | Conventional, addressable (one-way), smart (two-way)                                                                                                                                                                                                                                                                                                                    |
| Self-test feature (*)                    | Degree of self-testing                                                                                                                                    | No self-test, automatic loop test, built-in test                                                                                                                                                                                                                                                                                                                        |
| Detailed operational time                | Reflects completeness of source material                                                                                                                  | Additional comments for the collection of operating time on fire and gas detectors and process sensors                                                                                                                                                                                                                                                                  |
| Safety class                             | Ex standard                                                                                                                                               | Ex(d), Ex(e), None                                                                                                                                                                                                                                                                                                                                                      |
| (*) Indicates high-priority information. |                                                                                                                                                           |                                                                                                                                                                                                                                                                                                                                                                         |

This set of data fields is included in the specific inventory report for fire and gas detectors and process sensors to keep track of the large variations in the use and the level of detail in the data reported into the facility information management. The data fields in Table A.24 indicate the total time during the surveillance period during which different failure categories have been available. This time is recorded in hours as for surveillance time, and will always be less than or equal to the surveillance time.

The data fields are organized in a matrix as shown in Table A.24.

The data fields should be filled in, based on what is *actually* available and not what *should* be available according to operator procedures.

Without this information, analysis of the data may lead to the overall conclusion that the operator which has the most comprehensive history reports, also has the highest estimated failure rate for detectors/sensors. For instance, one operator may not record replacement of a detector head if this is carried out as part of the preventive maintenance. Comparing the failure rate of this operator with the failure rate of another operator that records any replacement would be misleading.

Thus, in order to compare like with like, the part of the total surveillance period during which data on each Restoration Activity/Failure Mode combination has been recorded, should be specified. The various combinations are indicated in the matrix given below; e.g.: If the surveillance period is 10 000 h and  $t_R$  is 5 000 h, this means that in half of the surveillance period, data on *replacement* (including all failure modes) have been recorded and are available for the data acquirer(s).

**Table A.24 — Data recording times for combinations of repair type/ failure mode for fire and gas detectors and process sensors**

| Maintenance activity                                                                                                                                                    | Failure mode                                 |                |                               |           |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|----------------|-------------------------------|-----------|
|                                                                                                                                                                         | FTF <sup>a</sup><br>NOO/<br>VLO <sup>b</sup> | SPO<br>SLL/SHH | HIO/LOO/<br>SER/OVH<br>OTHERS | ALL MODES |
| Replace<br>(by maintenance personnel)                                                                                                                                   | $t_R^F$                                      | $t_R^S$        | $t_R^O$                       | $t_R$     |
| Adjust/Repair/Refit<br>(by maintenance personnel)                                                                                                                       | $t_A^F$                                      | $t_A^S$        | $t_A^O$                       | $t_A$     |
| Check (Restart)<br>(by operations personnel)                                                                                                                            | $t_C^F$                                      | $t_C^S$        |                               | $t_C$     |
| All repair activities                                                                                                                                                   | $t^F$                                        | $t^S$          | $t^O$                         | $t$       |
| <p><sup>a</sup> Failure mode applicable for fire detectors, process sensors and control logic units.</p> <p><sup>b</sup> Failure mode applicable for gas detectors.</p> |                                              |                |                               |           |

The failure categories are defined as:

- a)  $t_R$  Failure events in which the detector subunit has been *replaced*.
- b)  $t_R^F$  Failure events in which the detector subunit has been replaced due to zero or very low detector output upon test condition (generally recorded in preventive maintenance reports).
- c)  $T_R^S$  Failure events in which the detector subunit has been replaced due to false alarm signal (generally recorded in corrective maintenance reports).
- d)  $T_R^O$  Failure events in which the detector subunit has been replaced due to failure modes other than FTF/SPO failure (generally recorded in preventive or corrective maintenance reports).
- e)  $T_A$  Failure events in which the detector subunit has been repaired/adjusted/refitted.
- f)  $t_A^F$  Failure events in which the detector subunit has been repaired/adjusted/refitted due to zero or very low detector output upon test condition (generally recorded in preventive maintenance reports).
- g)  $T_A^S$  Failure events in which the detector subunit has been repaired/adjusted/refitted due to false alarm signal (generally recorded in corrective maintenance reports).
- h)  $T_A^O$  Failure events in which the detector subunit has been repaired/adjusted/refitted due to failure modes other than FTF/ SPO failure (generally recorded in preventive/corrective maintenance reports or in detailed technical log books).
- i)  $T_C$  Failure events in which the detector has not responded to a real fire condition or provided false alarm; restart only required to continue operation.
- j)  $t_C^F$  Failure events in which the detector has not responded to a real fire condition; restart only required to continue operation (generally recorded in dedicated fire (near-miss) reports).
- k)  $T_C^S$  Failure events in which the detector has provided a false alarm signal; restart only required to continue operation (generally recorded in control room log books or daily activity reports).
- l)  $t^F, t^S, t^O, t$  Summary of times within each Failure mode category.

Table A.25 — Failure modes — Fire and gas detectors

| Equipment unit | Code | Definition                       | Description                                                                      |
|----------------|------|----------------------------------|----------------------------------------------------------------------------------|
| Fire detectors | FTF  | Fail to function on demand       | Unable to activate detector                                                      |
|                | OWD  | Operates without demand          | False alarm                                                                      |
|                | AOL  | Abnormal output - Low            | Trend toward FTF failure, e.g. low output                                        |
|                | AOH  | Abnormal output - High           | Trend toward OWD failure, e.g. high output                                       |
|                | ERO  | Erratic output                   | Reading not intelligible, e.g. oscillating                                       |
|                | SER  | Minor in-service problems        | Some minor repair required                                                       |
|                | UNK  | Unknown                          | Inadequate/missing information                                                   |
|                | OTH  | Other                            | Specify in comment field                                                         |
| Gas detectors  | SHH  | Spurious high level alarm signal | E.g. 60 % LEL                                                                    |
|                | SLL  | Spurious low level alarm signal  | E.g. 20 % LEL                                                                    |
|                | HIO  | High output                      | E.g. reading 10 % - 20 % LEL without test gas/reading above 80 % LEL on test gas |
|                | HIU  | High output, unknown reading     | —                                                                                |
|                | LOO  | Low output                       | E.g. reading between 31 % - 50 % LEL upon test gas <sup>a</sup>                  |
|                | LOU  | Low output, unknown reading      | —                                                                                |
|                | VLO  | Very low output                  | E.g. reading between 11 % - 30 % LEL upon test gas                               |
|                | NOO  | No output                        | E.g. reading less than 10 % LEL upon test gas                                    |
|                | ERO  | Erratic output                   | Reading not intelligible (e.g. oscillating)                                      |
|                | SER  | Minor in-service problems        | Some minor repair required                                                       |

<sup>a</sup> Assuming a nominal set point of 65 % LEL.

## A.2.7 Gas turbines

Table A.26 — Taxonomy classification — Gas turbines

| Equipment class |      | Type             |      | Application          |      |
|-----------------|------|------------------|------|----------------------|------|
| Description     | Code | Description      | Code | Description          | Code |
| Gas turbine     | GT   | Industrial       | IN   | Oil handling         | OH   |
|                 |      | Aeroderivative   | AD   | Gas processing       | GP   |
|                 |      | Light industrial | LI   | Gas export           | GE   |
|                 |      |                  |      | Gas injection        | GI   |
|                 |      |                  |      | Lift gas compression | GL   |
|                 |      |                  |      | Main power           | MP   |
|                 |      |                  |      | Essential power      | EP   |
|                 |      |                  |      | Emergency power      | EM   |
|                 |      |                  |      | Water injection      | WI   |
|                 |      |                  |      | Refrigeration        | RE   |

NOTE In Table A.26 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.

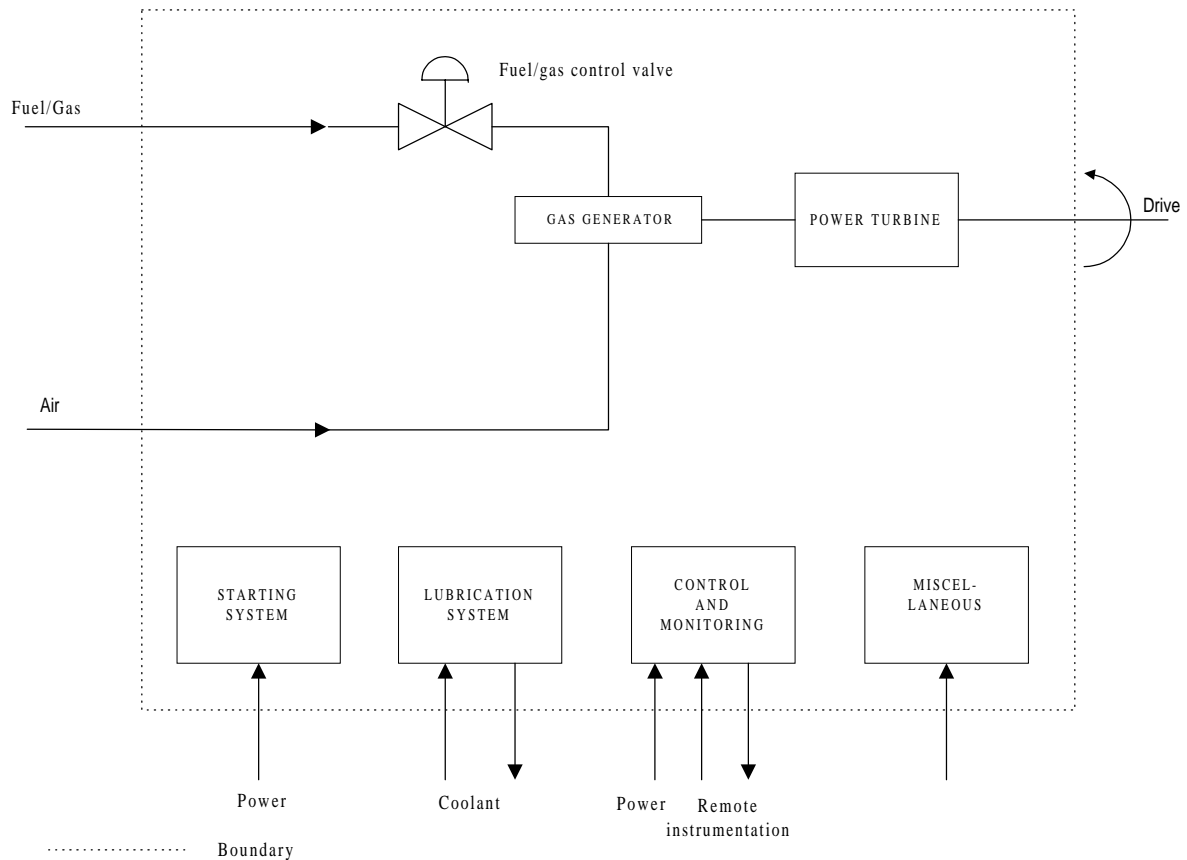


Figure A.7 — Equipment boundary — Gas turbines

Table A.27 — Equipment unit subdivision — Gas turbines

| Equipment unit     | Gas turbines                                                  |                                                                                                                                                                                                                    |                                                                                                       |                                                                              |                                                                             |                                                                   |
|--------------------|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------|
| Subunit            | Starting system                                               | Gas generator                                                                                                                                                                                                      | Power turbine                                                                                         | Control and monitoring                                                       | Lubrication system                                                          | Miscellaneous                                                     |
| Maintainable items | Start energy (battery, air)<br>Starting unit<br>Start control | Air inlet<br>Compressor rotor<br>Compressor stator<br>Combustion chambers<br>Burners<br>Fuel control<br>Turbine rotor<br>Turbine stator<br>Casing<br>Thrust bearing<br>Radial bearing<br>Seals<br>Valves<br>Piping | Rotor<br>Stator<br>Casing<br>Radial bearing<br>Thrust bearing<br>Seals<br>Exhaust<br>Valves<br>Piping | Control<br>Actuating device<br>Monitoring<br>Valves<br>Internal power supply | Reservoir<br>Pump with motor<br>Filter<br>Cooler<br>Valves<br>Piping<br>Oil | Hood<br>Purge air<br>Flange joints<br>Others<br>Water wash system |

Table A.28 — Equipment unit specific data — Gas turbines

| Name                                     | Description                                                                                         | Unit or code list                           |
|------------------------------------------|-----------------------------------------------------------------------------------------------------|---------------------------------------------|
| Power - design (*)                       | ISO power rating                                                                                    | kW                                          |
| Power - operating (*)                    | Specify the approximate power at which the unit has been operated for most of the surveillance time | kW                                          |
| Speed (*)                                | Design speed (power shaft)                                                                          | r/min                                       |
| No. of shafts (*)                        | Specify number                                                                                      | Number off                                  |
| Starting system (*)                      | Specify main starting system                                                                        | Electric, hydraulic, pneumatic              |
| Backup starting system                   | Specify if relevant                                                                                 | Electric, hydraulic, pneumatic              |
| Fuel (*)                                 | Fuel type                                                                                           | Gas, oil-light, oil-medium, oil-heavy, dual |
| Driver application (*)                   | Type of driven unit                                                                                 | Pump, electric generator, compressor        |
| Corresponding driven unit                | Specify driver identification number when relevant                                                  | Numeric                                     |
| Air inlet filtration type                | Type                                                                                                | Free text                                   |
| (*) Indicates high-priority information. |                                                                                                     |                                             |

Table A.29 — Failure modes — Gas turbines

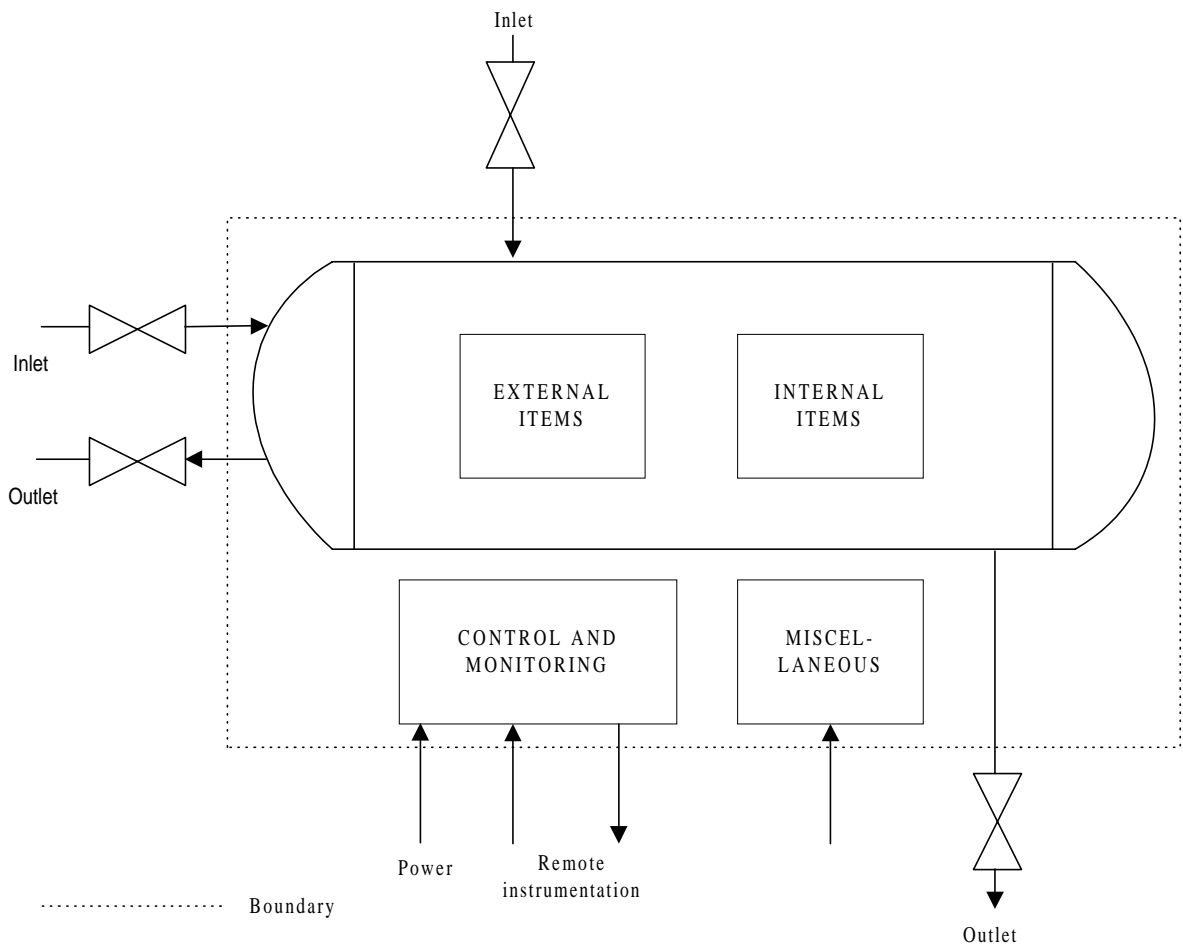
| Equipment unit | Code    | Definition                       | Description                                                     |
|----------------|---------|----------------------------------|-----------------------------------------------------------------|
| Gas turbines   | FTS     | Fail to start on demand          | Unable to activate turbine                                      |
|                | STP     | Fail to stop on demand           | Unable to stop or incorrect shutdown process                    |
|                | SPS     | Spurious stop                    | Unexpected shutdown of turbine                                  |
|                | OWD     | Operation without demand         | Undesired start                                                 |
|                | FCH     | Fail to change between fuel type | Dual fuel engines: Fail to switch from one fuel type to another |
|                | BRD     | Breakdown                        | Serious damage (seizure, breakage, explosion, etc.)             |
|                | HIO     | High output                      | E.g. overspeed                                                  |
|                | LOO     | Low output                       | Efficiency/power below specification                            |
|                | ERO     | Erratic output                   | Unstable operation/rpm hunting                                  |
|                | ELF     | External leakage - fuel          | Fuel gas or diesel leakage                                      |
|                | ELU     | External leakage utility medium  | Lube/seal oil, coolant, etc.                                    |
|                | INL     | Internal leakage                 | E.g. process medium in lube oil                                 |
|                | VIB     | Vibration                        | Excessive vibration                                             |
|                | NOI     | Noise                            | Excessive noise                                                 |
|                | OHE     | Overheating                      | Excessive temperature                                           |
|                | PDE     | Parameter deviation              | Monitored parameter exceeding tolerances                        |
|                | AIR     | Abnormal instrument reading      | E.g. false alarm, faulty reading                                |
|                | STD     | Structural deficiency            | E.g. cracks in support or suspension                            |
|                | SER     | Minor in-service problems        | Loose items, discoloration, dirt, etc.                          |
|                | OTH     | Other                            | Specify in comment field                                        |
| UNK            | Unknown | Inadequate/missing information   |                                                                 |

**A.2.8 Heat exchangers**

**Table A.30 — Taxonomy classification — Heat exchangers**

| Equipment class |      | Type            |      | Application    |      |
|-----------------|------|-----------------|------|----------------|------|
| Description     | Code | Description     | Code | Description    | Code |
| Heat exchanger  | HE   | Shell and tube  | ST   | Oil processing | OP   |
|                 |      | Plate           | PL   | Gas processing | GP   |
|                 |      | Double pipe     | DP   | Gas export     | GE   |
|                 |      | Bayonet         | BY   | Cooling system | CW   |
|                 |      | Printed circuit | CI   | Condensing     | CO   |
|                 |      | Air cooled      | AC   |                |      |

NOTE In Table A.30 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.



**Figure A.8 — Equipment boundary — Heat exchangers**

Table A.31 — Equipment unit subdivision — Heat exchangers

| Equipment unit                                               | Heat exchangers                           |                                                  |                                                                              |                                         |
|--------------------------------------------------------------|-------------------------------------------|--------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------------|
| Subunit                                                      | External                                  | Internal                                         | Control and monitoring                                                       | Miscellaneous                           |
| Maintainable items                                           | Support<br>Body/shell<br>Valves<br>Piping | Body/shell<br>Tubes<br>Plates<br>Seals (gaskets) | Control<br>Actuating device<br>Monitoring<br>Valves<br>Internal power supply | Fan <sup>a</sup><br>Fan motor<br>Others |
| <sup>a</sup> Applicable for air cooled heat exchangers only. |                                           |                                                  |                                                                              |                                         |

Table A.32 — Equipment unit specific data — Heat exchangers

| Name                                     | Description                           | Unit or code list                                                                                                                                        |
|------------------------------------------|---------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fluid, hot side (*)                      | Fluid type                            | E.g. oil, gas, condensate, freshwater, steam, sea water, crude oil, oily water, flare gas, water/glycol, methanol, nitrogen, chemicals, hydrocarbon, air |
| Fluid, cold side (*)                     | Fluid type                            | E.g. oil, gas, condensate, freshwater, steam, sea water, crude oil, oily water, flare gas, water/glycol, methanol, nitrogen, chemicals, hydrocarbon, air |
| Rated heat transfer (*)                  | Design value                          | kW                                                                                                                                                       |
| Utilisation (*)                          | Used/rated heat transfer              | %                                                                                                                                                        |
| Pressure, hot side (*)                   | Design pressure                       | pascal (bar)                                                                                                                                             |
| Pressure, cold side (*)                  | Design pressure                       | pascal (bar)                                                                                                                                             |
| Temperature drop, hot side               | Operating                             | °C                                                                                                                                                       |
| Temperature rise, cold side              | Operating                             | °C                                                                                                                                                       |
| Size - diameter (*)                      | External                              | mm                                                                                                                                                       |
| Size - length (*)                        | External                              | mm                                                                                                                                                       |
| Number of tubes/plates                   |                                       | Numeric                                                                                                                                                  |
| Tube/plate material (*)                  | Specify material type in tubes/plates | Free text                                                                                                                                                |
| (*) Indicates high-priority information. |                                       |                                                                                                                                                          |

Table A.33 — Failure modes — Heat exchangers

| Equipment unit  | Code | Definition                      | Description                                                          |
|-----------------|------|---------------------------------|----------------------------------------------------------------------|
| Heat exchangers | IHT  | Insufficient heat transfer      | Insufficient heating/cooling                                         |
|                 | ELP  | External leakage process medium | Process medium escape to environment                                 |
|                 | ELU  | External leakage utility medium | Coolant escape to environment                                        |
|                 | INL  | Internal leakage                | Hot/cold side communication                                          |
|                 | PLU  | Plugged/choked                  | Partial or full flow restriction due to hydrate, wax, scale, etc.    |
|                 | STD  | Structural deficiency           | Reduced strength due to impact, unacceptable corrosion, cracks, etc. |
|                 | PDE  | Parameter deviation             | Monitored parameter exceeding tolerances                             |
|                 | AIR  | Abnormal instrument reading     | E.g. false alarm, faulty reading                                     |
|                 | SER  | Minor in-service problems       | Loose items, discoloration, dirt, etc.                               |
|                 | OTH  | Other                           | Specify in comment field                                             |
|                 | UNK  | Unknown                         | Inadequate/missing information                                       |



A.2.9 Process sensors

Table A.34 — Taxonomy classification — Process sensors

| Equipment class |      | Type         |      | Application           |      |
|-----------------|------|--------------|------|-----------------------|------|
| Description     | Code | Description  | Code | Description           | Code |
| Process sensors | PS   | Pressure     | PS   | Oil processing        | OP   |
|                 |      | Level        | LS   | Gas processing        | GP   |
|                 |      | Temperature  | TS   | Condensate processing | CP   |
|                 |      | Flow         | FS   | Cooling system        | CW   |
|                 |      | Speed        | SP   | Water fire-fighting   | FF   |
|                 |      | Vibration    | VI   | Water injection       | WI   |
|                 |      | Displacement | DI   | Oily water treatment  | OW   |
|                 |      | Analyser     | AN   | Chemical injection    | CI   |
|                 |      | Weight       | WE   | Completion fluid      | CF   |

NOTE In Table A.34 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.

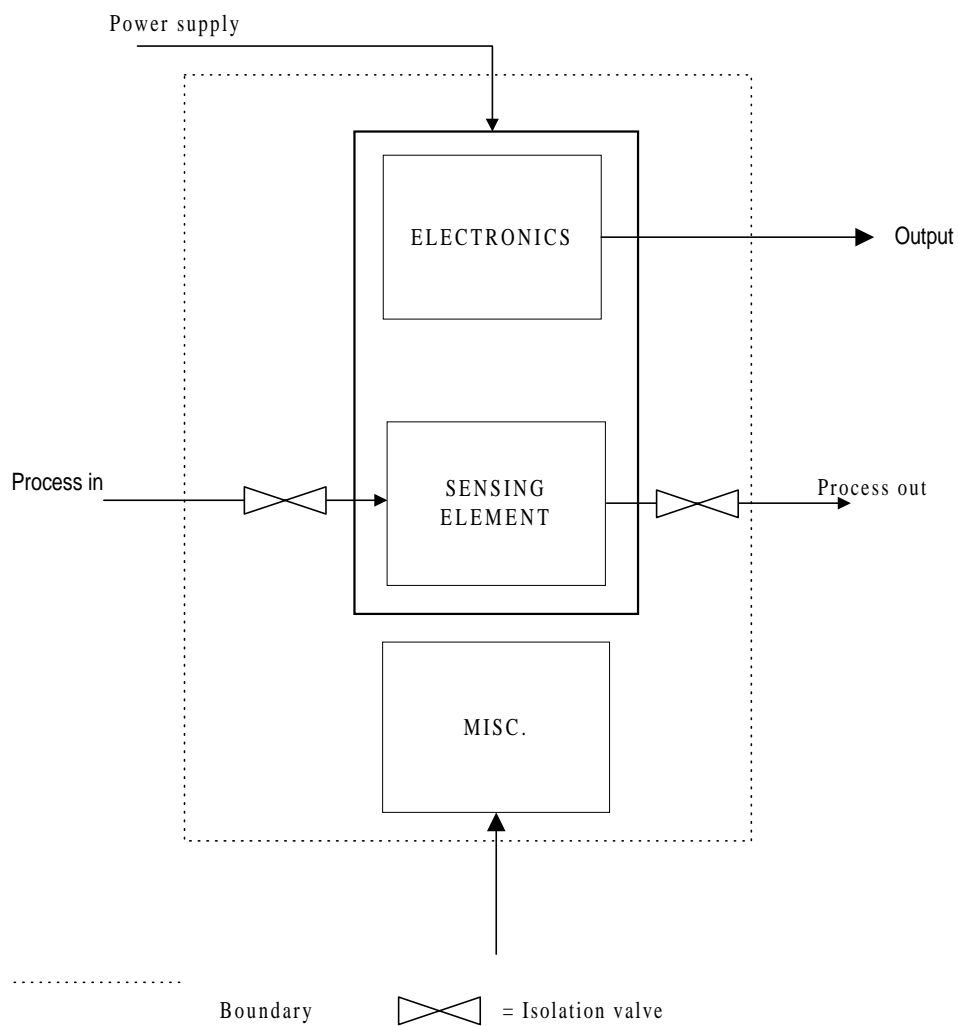


Figure A.9 — Equipment boundary — Process sensors

Table A.35 — Equipment unit subdivision, process sensors

| Equipment unit     | Process sensors                |                                     |
|--------------------|--------------------------------|-------------------------------------|
| Subunit            | Sensor and electronics         | Miscellaneous                       |
| Maintainable items | Sensing element<br>Electronics | Isolation valve<br>Piping<br>Others |

Table A.36 — Equipment unit specific data — Process sensors

| Name                              | Description                                                                                                                                                                                                                                                                                                                                                   | Unit or code list                                                                                                                                                                                                                                                                                                    |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Location on installation (*)      | Where installed                                                                                                                                                                                                                                                                                                                                               | Wellhead, christmas tree, wellhead flow line, wellhead injection line, pump, turbine, electric generator, separator, heat exchanger, vessel, header, electric motor, turboexpander, drilling, pipeline, mud processing, utility, living quarter, air inlet, alkylation unit, isomerization units, catalytic crackers |
| Application (*)                   | Where applied                                                                                                                                                                                                                                                                                                                                                 | Shut-off, process control, emergency shutdown, process shutdown, fire and gas detection, non-return, relief, pressure reduction, by-pass, blowdown, monitoring, combined                                                                                                                                             |
| Pressure - operating              | Normal operating pressure                                                                                                                                                                                                                                                                                                                                     | pascal (bar)                                                                                                                                                                                                                                                                                                         |
| Temperature - operating           | Normal operating temperature                                                                                                                                                                                                                                                                                                                                  | °C                                                                                                                                                                                                                                                                                                                   |
| Sensor voting, $k$ out of $n$     | At least $k$ out of $n$ sensors shall provide signal to initiate control/safety action. $k$ and $n$ shall be entered; if no voting, leave blank                                                                                                                                                                                                               | $k = 'nn'$ (integer)<br>$n = 'nn'$ (integer)                                                                                                                                                                                                                                                                         |
| Pressure - reference (*)          | Applicable only for pressure sensors                                                                                                                                                                                                                                                                                                                          | Differential, absolute, gauge                                                                                                                                                                                                                                                                                        |
| Pressure-sensing principle (*)    | Applicable for pressure sensors only                                                                                                                                                                                                                                                                                                                          | Bonded strain, semiconductor, strain, piezoelectric, electromechanical, capacitance, reluctance                                                                                                                                                                                                                      |
| Level-sensing principle (*)       | Applicable for level sensors only                                                                                                                                                                                                                                                                                                                             | Differential pressure cell, capacitance, conductive, displacement, diaphragm, sonic, optical, microwave, radio frequency, nuclear                                                                                                                                                                                    |
| Temperature-sensing principle (*) | Applicable for temperature sensors only                                                                                                                                                                                                                                                                                                                       | Resistance temperature detector (PT), thermocouple, capillary                                                                                                                                                                                                                                                        |
| Flow-sensing principle (*)        | Applicable for flow sensors only                                                                                                                                                                                                                                                                                                                              | Displacement, differential head (closed conduit/pipe, open channel), velocity, mass                                                                                                                                                                                                                                  |
| Type - process sensor (*)         | Transmitter (converts process parameter, e.g. pressure, into proportional electrical signals - 4 mA to 20 mA or 0 V to 10 V (ref. IEC 60381-2);<br>Transducer (converts process parameters, e.g. pressure, into proportional electrical signals - unamplified output);<br>Switch (converts process parameters, e.g. pressure, into on/off electrical signals) | Transmitter, transducer, switch                                                                                                                                                                                                                                                                                      |
| Fail-safe principle (*)           | Type                                                                                                                                                                                                                                                                                                                                                          | Normally energized, normally de-energized.<br>Normally not applicable for analog equipment                                                                                                                                                                                                                           |
| Detector communication (*)        | Type                                                                                                                                                                                                                                                                                                                                                          | Conventional, addressable (one-way), smart (two-way)                                                                                                                                                                                                                                                                 |
| Self-test feature (*)             | Same as for fire and gas detectors                                                                                                                                                                                                                                                                                                                            | None, auto-loop, built-in, combination of automatic loop test/built-in test                                                                                                                                                                                                                                          |
| Detailed operational time         | Same as for fire and gas detectors                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                      |
| Safety class                      | Ex standard                                                                                                                                                                                                                                                                                                                                                   | Ex(d), Ex(e), None                                                                                                                                                                                                                                                                                                   |

(\*) Indicates high-priority information.

Table A.37 — Failure modes — Process sensors

| Equipment unit  | Code | Definition                 | Description                                |
|-----------------|------|----------------------------|--------------------------------------------|
| Process sensors | FTF  | Fail to function on demand | "Stuck" sensor                             |
|                 | OWD  | Operates without demand    | False alarm                                |
|                 | AOL  | Abnormal output - Low      | Trend toward FTF failure, e.g. low output  |
|                 | AOH  | Abnormal output - High     | Trend toward OWD failure, e.g. high output |
|                 | ERO  | Erratic output             | Reading not intelligible, e.g. oscillating |
|                 | SER  | Minor in-service problems  | Some minor repair required                 |
|                 | OTH  | Other                      | Specify in comment field                   |
|                 | UNK  | Unknown                    | Inadequate/missing information             |

## A.2.10 Pumps

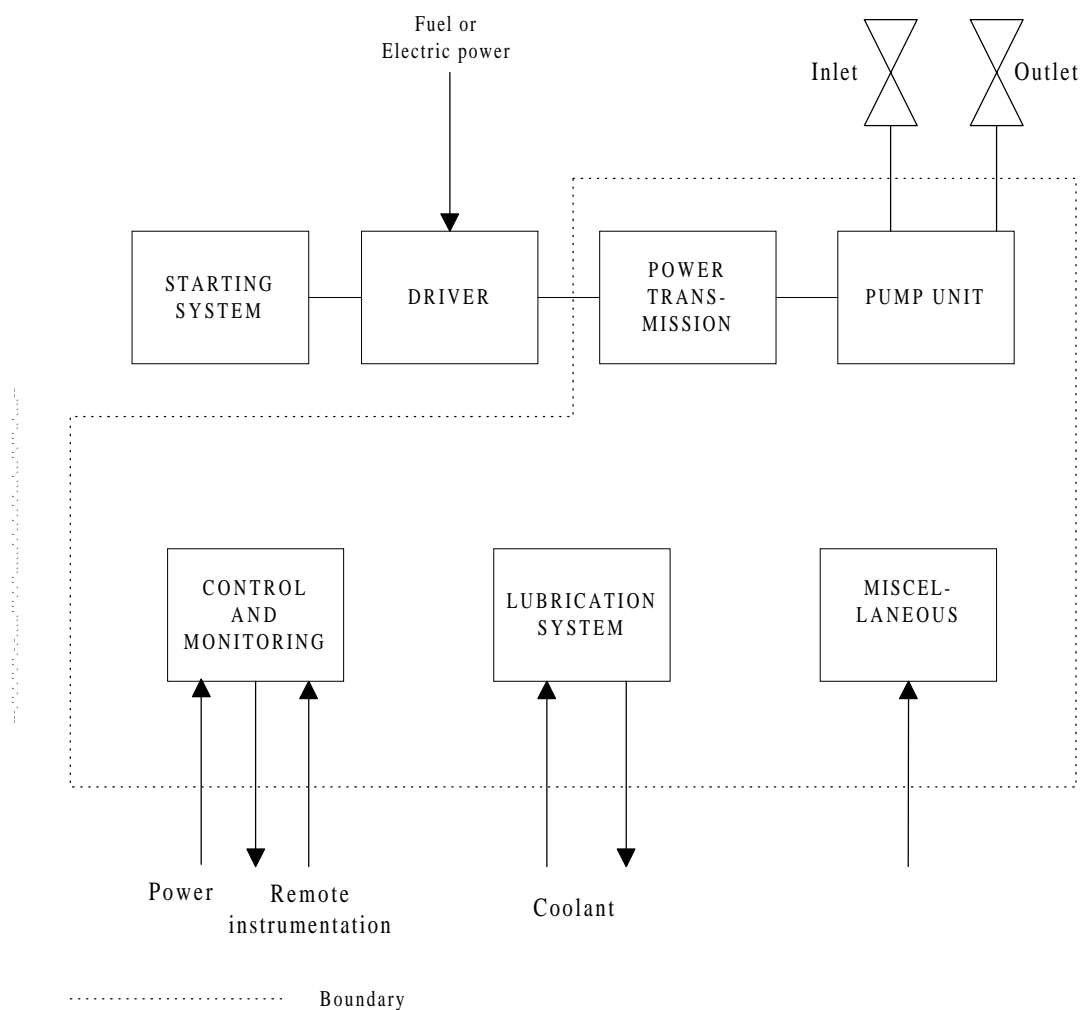
Table A.38 — Taxonomy classification — Pumps

| Equipment class |      | Type          |      | Application         |      |
|-----------------|------|---------------|------|---------------------|------|
| Description     | Code | Description   | Code | Description         | Code |
| Pump            | PU   | Centrifugal   | CE   | Water fire-fighting | FF   |
|                 |      | Reciprocating | RE   | Water injection     | WI   |
|                 |      | Rotary        | RO   | Oil handling        | OH   |
|                 |      |               |      | Gas treatment       | GT   |
|                 |      |               |      | Gas processing      | GP   |
|                 |      |               |      | Chemical injection  | CI   |
|                 |      |               |      | Sea-water lift      | SL   |
|                 |      |               |      | NGL export          | NE   |
|                 |      | Utility       | UT   |                     |      |

NOTE In Table A.38 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.

Table A.39 — Equipment unit subdivision — Pumps

| Equipment unit     | Pumps                                                                                                      |                                                                                                                                                  |                                                                              |                                                                             |                                                                                                       |
|--------------------|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| Subunit            | Power transmission                                                                                         | Pump unit                                                                                                                                        | Control and monitoring                                                       | Lubrication system                                                          | Miscellaneous                                                                                         |
| Maintainable items | Gearbox/variable drive<br>Bearing<br>Seals<br>Lubrication<br>Coupling to driver<br>Coupling to driven unit | Support<br>Casing<br>Impeller<br>Shaft<br>Radial bearing<br>Thrust bearing<br>Seals<br>Valves<br>Piping<br>Cylinder liner<br>Piston<br>Diaphragm | Control<br>Actuating device<br>Monitoring<br>Valves<br>Internal power supply | Reservoir<br>Pump with motor<br>Filter<br>Cooler<br>Valves<br>Piping<br>Oil | Purge air<br>Cooling/heating system<br>Filter, cyclone<br>Pulsation damper<br>Flange joints<br>Others |



**Figure A.10 — Equipment boundary — Pumps**

Table A.40 — Equipment unit specific data — Pumps

| Name                                     | Description                                                                                                                                                                                                                                                      | Unit or code list                                                                                                                                                                                                    |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Corresponding driver (*)                 | Specify driver identification number when relevant. Compulsory for fire pumps                                                                                                                                                                                    |                                                                                                                                                                                                                      |
| Type of driver (*)                       | Type                                                                                                                                                                                                                                                             | Electric, turbine, diesel, gas engine                                                                                                                                                                                |
| Fluid handled (*)                        | Type                                                                                                                                                                                                                                                             | Oil, gas, condensate, freshwater, steam, sea water, crude oil, oily water, flare gas, fuel gas, water/glycol, methanol, nitrogen, chemicals, hydrocarbon-combined, gas/oil, gas/condensate, oil/water, gas/oil/water |
| Fluid corrosive/erosive (*)              | Benign (clean fluids, e.g. air, water, nitrogen)<br>Moderately corrosive/erosive (oil/gas not defined as severe, sea water, occasionally particles)<br>Severe corrosive/erosive [sour gas/oil (high H <sub>2</sub> S), high CO <sub>2</sub> , high sand content] | Benign, moderate, severe                                                                                                                                                                                             |
| Application - pump (*)                   | Where applied                                                                                                                                                                                                                                                    | Booster, supply, injection, transfer, lift, dosage, disperse                                                                                                                                                         |
| Pump design                              | Design characteristic                                                                                                                                                                                                                                            | Axial, radial, composite, diaphragm, plunger, piston, screw, vane, gear, lobe                                                                                                                                        |
| Power - design (*)                       | Design/rated power of pump                                                                                                                                                                                                                                       | kW                                                                                                                                                                                                                   |
| Utilization of capacity (*)              | Normal operating/design capacity                                                                                                                                                                                                                                 | %                                                                                                                                                                                                                    |
| Suction pressure - design (*)            | Design pressure                                                                                                                                                                                                                                                  | pascal (bar)                                                                                                                                                                                                         |
| Discharge pressure - design (*)          | Design pressure                                                                                                                                                                                                                                                  | pascal (bar)                                                                                                                                                                                                         |
| Speed                                    | Design speed                                                                                                                                                                                                                                                     | r/min or strokes/min                                                                                                                                                                                                 |
| Number of stages                         | Centrifugal:<br>Number of impellers (in all stages)<br>Reciprocating:<br>Number of cylinders<br>Rotary:<br>Number of rotors                                                                                                                                      | Numeric                                                                                                                                                                                                              |
| Body type                                | Barrel, split casing, etc.                                                                                                                                                                                                                                       | Barrel, split case, axial split, cartridge,                                                                                                                                                                          |
| Shaft orientation                        |                                                                                                                                                                                                                                                                  | Horizontal, vertical                                                                                                                                                                                                 |
| Shaft sealing                            | Type                                                                                                                                                                                                                                                             | Mechanical, oil seal, dry gas, packed, gland, dry seal, labyrinth, combined                                                                                                                                          |
| Transmission type                        | Type                                                                                                                                                                                                                                                             | Direct, gear, integral,                                                                                                                                                                                              |
| Coupling                                 | Coupling                                                                                                                                                                                                                                                         | Fixed, flexible, hydraulic, magnetic, disconnect                                                                                                                                                                     |
| Environment (*)                          | Submerged or dry-mounted                                                                                                                                                                                                                                         |                                                                                                                                                                                                                      |
| Pump cooling                             | Specify if separate cooling system is installed                                                                                                                                                                                                                  | Yes/No                                                                                                                                                                                                               |
| Radial bearing<br>Thrust bearing         | Type<br>Specify in comment field if thrust pressure regulator installed                                                                                                                                                                                          | Antifrictional, journal, magnetic                                                                                                                                                                                    |
| Bearing support                          | Type                                                                                                                                                                                                                                                             | Overhung, between bearings, pump casing, split sleeve                                                                                                                                                                |
| (*) Indicates high-priority information. |                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                      |

**Table A.41 — Failure modes — Pumps**

| Equipment unit | Code    | Definition                      | Description                                         |
|----------------|---------|---------------------------------|-----------------------------------------------------|
| Pumps          | FTS     | Fail to start on demand         | Unable to activate pump                             |
|                | STP     | Fail to stop on demand          | Unable to stop or incorrect shutdown process        |
|                | SPS     | Spurious stop                   | Unexpected shutdown of pump                         |
|                | BRD     | Breakdown                       | Serious damage (seizure, breakage, explosion, etc.) |
|                | HIO     | High output                     | Output pressure/flow above specification            |
|                | LOO     | Low output                      | Output pressure/flow below specification            |
|                | ERO     | Erratic output                  | Oscillating or unstable pressure/flow               |
|                | ELP     | External leakage process medium | Process medium escape to environment                |
|                | ELU     | External leakage utility medium | Lube/seal oil, coolant, etc.                        |
|                | INL     | Internal leakage                | E.g. process medium in lube oil                     |
|                | VIB     | Vibration                       | Excessive vibration                                 |
|                | NOI     | Noise                           | Excessive noise                                     |
|                | OHE     | Overheating                     | Excessive temperature                               |
|                | PDE     | Parameter deviation             | Monitored parameter exceeding tolerances            |
|                | AIR     | Abnormal instrument reading     | E.g. false alarm, faulty reading                    |
|                | STD     | Structural deficiency           | E.g. cracks in support or suspension                |
|                | SER     | Minor in-service problems       | Loose items, discoloration, dirt, etc.              |
| OTH            | Other   | Specify in comment field        |                                                     |
| UNK            | Unknown | Inadequate/missing information  |                                                     |

**A.2.11 Turboexpanders**

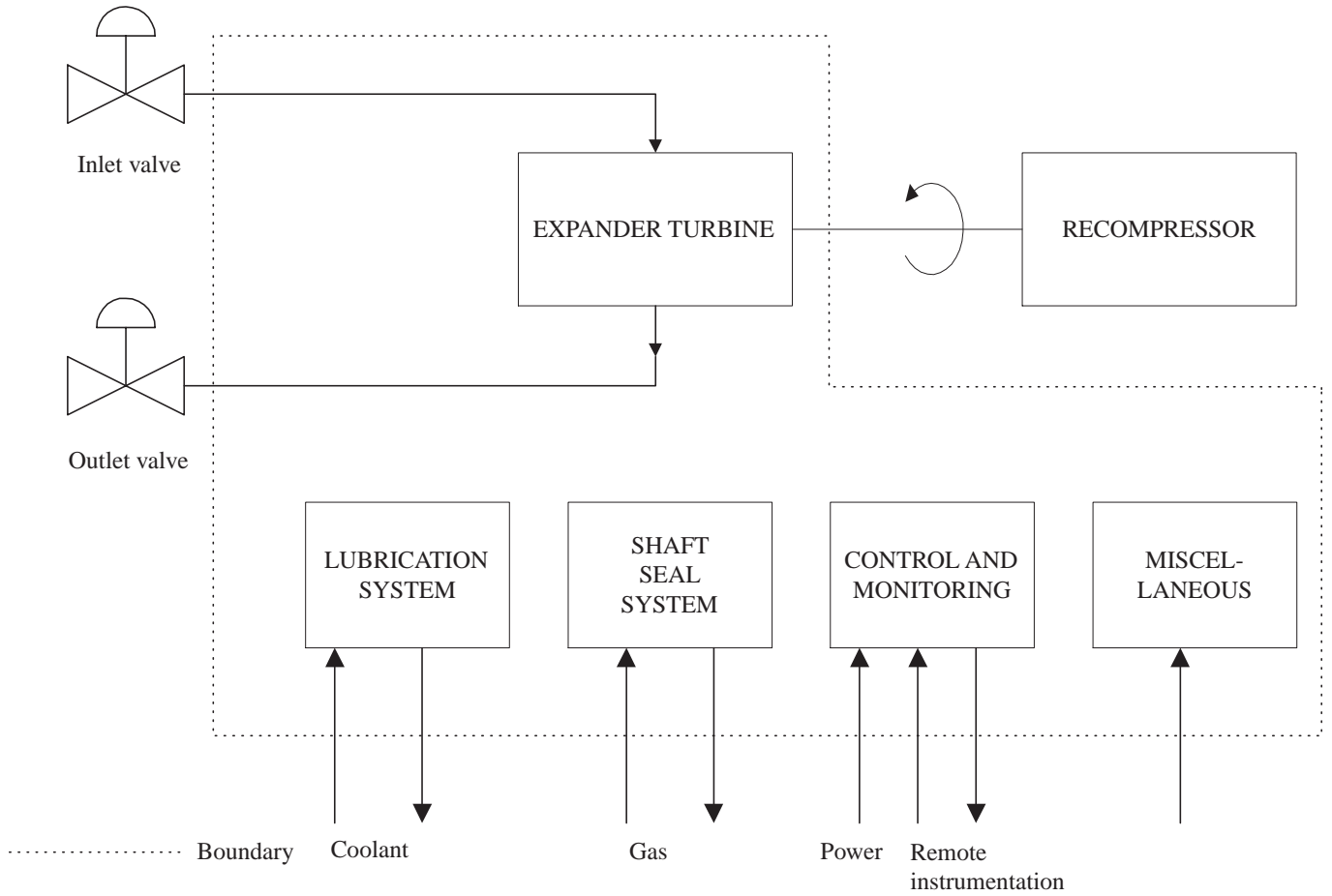
**Table A.42 — Taxonomy classification — Turboexpanders**

| Equipment class |      | Type        |      | Application           |      |
|-----------------|------|-------------|------|-----------------------|------|
| Description     | Code | Description | Code | Description           | Code |
| Turboexpander   | TE   | Centrifugal | CE   | Gas processing        | GP   |
|                 |      | Axial       | AX   | Gas treatment         | GT   |
|                 |      |             |      | Electrical generation | EG   |

NOTE In Table A.42 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.

**Table A.43 — Equipment unit subdivision — Turboexpanders**

| Equipment unit     | Turboexpander                                                                                                               |                                                                              |                                                                             |                                |               |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------|--------------------------------|---------------|
| Subunit            | Expander turbine                                                                                                            | Control and monitoring                                                       | Lubrication system                                                          | Shaft seal system              | Miscellaneous |
| Maintainable items | Rotor w/impellers<br>Inlet vanes<br>Casing<br>Radial bearing<br>Thrust bearing<br>Seals<br>Inlet screen<br>Valves<br>Piping | Control<br>Actuating device<br>Monitoring<br>Valves<br>Internal power supply | Reservoir<br>Pump with motor<br>Filter<br>Cooler<br>Valves<br>Piping<br>Oil | Seal gas equipment<br>Seal gas | Others        |



Note! Driven units other than recompressors  
(e.g. pumps or generators) are outside the boundary

Figure A.11 — Equipment boundary — Turboexpanders

Table A.44 — Equipment unit specific data — Turboexpanders

| Name                                     | Description                                                                                                                                                                                                 | Unit or code list                                                            |
|------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Driver application                       | Type of driven unit                                                                                                                                                                                         | Pump, electric generator, compressor                                         |
| Power - design (*)                       | Max. design output power                                                                                                                                                                                    | kW                                                                           |
| Power - operating                        | Specify the approximately power at which the unit has been operated for most of surveillance time                                                                                                           | kW                                                                           |
| Speed (*)                                | Design speed                                                                                                                                                                                                | r/min                                                                        |
| Inlet flow (*)                           | Design inlet flow, turbine                                                                                                                                                                                  | kg/h                                                                         |
| Inlet temperature (*)                    | Design inlet temperature, turbine                                                                                                                                                                           | °C                                                                           |
| Inlet pressure (*)                       | Design inlet pressure, turbine                                                                                                                                                                              | pascal (bar)                                                                 |
| Gas handled                              | Average molar mass<br>(specific gravity x 28,96)                                                                                                                                                            | g/mol                                                                        |
| Gas corrosive/erosive (*)                | Benign (clean and dry gas)<br>Moderately corrosive/erosive (some particles or droplets, some corrosiveness)<br>Severe corrosive/erosive (sour gas, high CO <sub>2</sub> content, high content of particles) | Benign, moderate, severe                                                     |
| Type of design (*)                       | Type                                                                                                                                                                                                        | Centrifugal, axial                                                           |
| Number of stages                         | Number of stages (in series)                                                                                                                                                                                | Numeric                                                                      |
| Casing split type                        | Type                                                                                                                                                                                                        | Horizontal/vertical                                                          |
| Shaft sealing                            | Type                                                                                                                                                                                                        | Mechanical, oil, seal, dry gas, packed, gland, dry seal, labyrinth, combined |
| Flow control turbine                     | Type                                                                                                                                                                                                        | Variable nozzles, nozzle group valves, throttle valve, fixed inlet           |
| Radial bearing<br>Thrust bearing         | Bearing type<br>Specify in comment field whether any thrust pressure regulator is installed                                                                                                                 | Antifrictional, antifrictional magnetic or journal                           |
| (*) Indicates high-priority information. |                                                                                                                                                                                                             |                                                                              |



Table A.45 — Failure modes — Turboexpanders

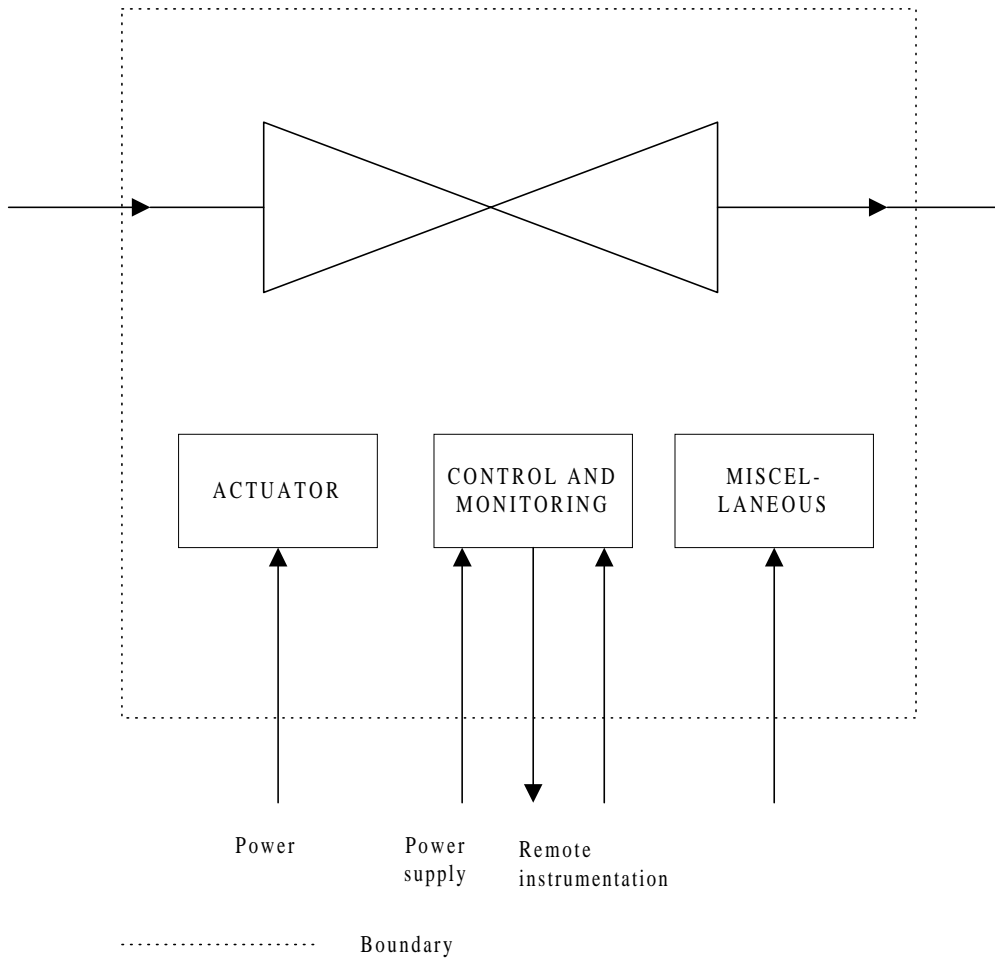
| Equipment unit | Code    | Definition                      | Description                                         |
|----------------|---------|---------------------------------|-----------------------------------------------------|
| Turboexpander  | FTS     | Fail to start on demand         | Unable to activate turboexpander                    |
|                | STP     | Fail to stop on demand          | Unable to stop or incorrect shutdown process        |
|                | SPS     | Spurious stop                   | Unexpected shutdown of turboexpander                |
|                | BRD     | Breakdown                       | Serious damage (seizure, breakage, explosion, etc.) |
|                | HIO     | High output                     | Overspeed/output above specification                |
|                | LOO     | Low output                      | Output below specification                          |
|                | ERO     | Erratic output                  | Unstable operation/ rpm hunting                     |
|                | VIB     | Vibration                       | Excessive vibration                                 |
|                | NOI     | Noise                           | Excessive noise                                     |
|                | ELP     | External leakage process medium | Process medium escape to environment                |
|                | ELU     | External leakage utility medium | Lube/seal/hydraulic oil, coolant, etc.              |
|                | INL     | Internal leakage                | E.g. process medium in lube oil                     |
|                | PDE     | Parameter deviation             | Monitored parameter exceeding tolerances            |
|                | AIR     | Abnormal instrument reading     | E.g. false alarm, faulty reading                    |
|                | STD     | Structural deficiency           | E.g. cracks in support or suspension                |
|                | SER     | Minor in-service problems       | Loose items, discoloration, dirt, etc.              |
|                | OTH     | Other                           | Specify in comment field                            |
| UNK            | Unknown | Inadequate/missing information  |                                                     |

## A.2.12 Valves

Table A.46 — Taxonomy classification — Valves

| Equipment class |      | Type                         |      | Application          |      |
|-----------------|------|------------------------------|------|----------------------|------|
| Description     | Code | Description                  | Code | Description          | Code |
| Valves          | VA   | Ball                         | BA   | Oil processing       | OP   |
|                 |      | Gate                         | GA   | Oil export           | OE   |
|                 |      | Globe                        | GL   | Gas processing       | GP   |
|                 |      | Flapper                      | FL   | Gas export           | GE   |
|                 |      | Butterfly                    | BP   | Oily water treatment | OW   |
|                 |      | Plug                         | PG   | Gas injection        | GI   |
|                 |      | Multiple orifice             | MU   | Water injection      | WI   |
|                 |      | Needle                       | NE   | Chemical injection   | CI   |
|                 |      | Check                        | CH   | NGL treatment        | NT   |
|                 |      | Diaphragm                    | DI   | LPG treatment        | LT   |
|                 |      | Slide                        | SL   | Cooling water        | CW   |
|                 |      | Eccentric disc               | ED   | Steam                | ST   |
|                 |      | 3-way                        | WA   |                      |      |
|                 |      | PSV-conventional             | SC   |                      |      |
|                 |      | PSV-conventional with bellow | SB   |                      |      |
|                 |      | PSV-pilot operated           | SP   |                      |      |
|                 |      | PSV-vacuum relief            | SV   |                      |      |
| Shuttle         | SH   |                              |      |                      |      |

NOTE In Table A.46 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.



**Figure A.12 — Equipment boundary — Valves**

**Table A.47 — Equipment unit subdivision — Valves**

| Equipment unit     | Valves                                                                   |                                                                                                                                                                            |                                                                              |                         |
|--------------------|--------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|-------------------------|
| Subunit            | Valves                                                                   | Actuator                                                                                                                                                                   | Control and monitoring                                                       | Miscellaneous           |
| Maintainable items | Valve body<br>Bonnet<br>Seat rings<br>Packing<br>Seals<br>Closure member | Diaphragm<br>Spring<br>Case<br>Piston<br>Stem<br>Indicator<br>Seals/gaskets<br>Pilot valve <sup>a</sup><br>Positioner<br>Electrical motor <sup>b</sup><br>Gear<br>Solenoid | Control<br>Actuating device<br>Monitoring<br>Valves<br>Internal power supply | Flange joints<br>Others |

<sup>a</sup> Applicable for hydraulic/pneumatically actuated valves.

<sup>b</sup> Electric motor actuator only.

Table A.48 — Equipment unit specific data — Valves

| Name                                     | Description                                                                                                                                                                                                                                                              | Unit or code list                                                                                                                                                                                                                                            |
|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Application (*)                          | Where applied                                                                                                                                                                                                                                                            | Shut-off, process control, emergency shut-down/process shutdown, fire and gas detection, check, relief, pressure reduction, by-pass, blow-down, monitoring, combined                                                                                         |
| Actuation (*)                            | Type                                                                                                                                                                                                                                                                     | Motor, hydraulic, pneumatic, self-acting, self-acting/pilot, manual                                                                                                                                                                                          |
| Pilot valve configuration                | Specify; e.g. 1×3/2 (= Single 3/2 pilot valve), 2×4/3 (= Double 4/3 pilot valve). Applicable for pilot/solenoid-operated valves only                                                                                                                                     |                                                                                                                                                                                                                                                              |
| Location on installation (*)             | Where installed                                                                                                                                                                                                                                                          | Wellhead, christmas tree, wellhead flow line, wellhead injection line, pump, turbine, generator, separator, heat exchanger, vessel, header, electric motor, diesel motor, turboexpander, drilling, pipeline, mud process, utility, living quarter, air inlet |
| Fluid handled (*)                        | Main fluid only                                                                                                                                                                                                                                                          | Oil, gas, condensate, freshwater, steam, sea water, crude oil, oily water, flare gas, fuel gas, water/glycol, methanol, nitrogen, chemicals, hydrocarbon combined, gas/oil, gas/condensate, oil/water, gas/oil/water, NGL, LPG, slurry, etc.                 |
| Fluid corrosive/erosive (*)              | Benign (clean fluids, e.g. air, water, nitrogen)<br>Moderately corrosive/erosive (oil/ gas not defined as severe, sea water, occasionally particles)<br>Severe corrosive/erosive (sour gas/oil (high H <sub>2</sub> S), high CO <sub>2</sub> content, high sand content) | Benign, moderate, severe                                                                                                                                                                                                                                     |
| Flowing pressure (*)                     | Normal operating pressure (inlet)                                                                                                                                                                                                                                        | pascal (bar)                                                                                                                                                                                                                                                 |
| Shut-off pressure                        | Maximum differential pressure when valve closed (design)<br>For safety pressure-relief valves: Set-point opening pressure                                                                                                                                                | pascal (bar)                                                                                                                                                                                                                                                 |
| Fluid temperature                        |                                                                                                                                                                                                                                                                          | °C                                                                                                                                                                                                                                                           |
| Size (*)                                 | Internal diameter                                                                                                                                                                                                                                                        | mm                                                                                                                                                                                                                                                           |
| Type of valve end                        | Specify                                                                                                                                                                                                                                                                  | Welded, flanged                                                                                                                                                                                                                                              |
| Stem sealing                             | Specify                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                              |
| (*) Indicates high-priority information. |                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                                                              |

Table A.49 — Failure modes — Valves

| Equipment unit | Code    | Definition                      | Description                                                           |
|----------------|---------|---------------------------------|-----------------------------------------------------------------------|
| Valves         | FTC     | Fail to close on demand         | Stuck open or fail to close fully                                     |
|                | FTO     | Fail to open on demand          | Stuck closed or fail to open fully                                    |
|                | FTR     | Fail to regulate                | "Stuck" valve, control valves only                                    |
|                | OWD     | Operates without demand         | Undesired closure/opening                                             |
|                | DOP     | Delayed operation               | Opening/closure time different from specification                     |
|                | HIO     | High output                     | Faulty regulation, control valves only                                |
|                | LOO     | Low output                      | Faulty regulation, control valves only                                |
|                | ELP     | External leakage process medium | Process medium escape to environment                                  |
|                | ELU     | External leakage utility medium | Actuation fluid, lubrication, etc.                                    |
|                | INL     | Internal leakage                | Internal leakage of actuating fluid, or valve-actuator communication  |
|                | LCP     | Leakage in closed position      | Leak-through valve in closed position                                 |
|                | PLU     | Plugged/Choked                  | Partial or full flow restriction                                      |
|                | STD     | Structural deficiency           | Reduced integrity due to impact, unacceptable corrosion, cracks, etc. |
|                | AIR     | Abnormal instrument reading     | E.g. faulty position indication                                       |
|                | SER     | Minor in-service problems       | Loose items, discoloration, dirt, etc.                                |
|                | OTH     | Other                           | Specify in comment field                                              |
| UNK            | Unknown | Inadequate/missing information  |                                                                       |

## A.2.13 Vessels

Table A.50 — Taxonomy classification — Vessels

| Equipment class |      | Type         |      | Application           |      |
|-----------------|------|--------------|------|-----------------------|------|
| Description     | Code | Description  | Code | Description           | Code |
| Vessel          | VE   | Stripper     | SP   | Oil processing        | OP   |
|                 |      | Separator    | SE   | Oily water treatment  | OW   |
|                 |      | Coalescer    | CA   | Gas processing        | GP   |
|                 |      | Flash drum   | FD   | Gas treatment         | GT   |
|                 |      | Scrubber     | SB   | Gas export            | GE   |
|                 |      | Contactator  | CO   | Flare, vent, blowdown | FL   |
|                 |      | Surge drum   | SD   | NGL treatment         | NT   |
|                 |      | Hydrocyclone | HY   | LPG treatment         | LT   |
|                 |      |              |      | Chemical storage      | CS   |

NOTE In Table A.50 the lists in columns headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.

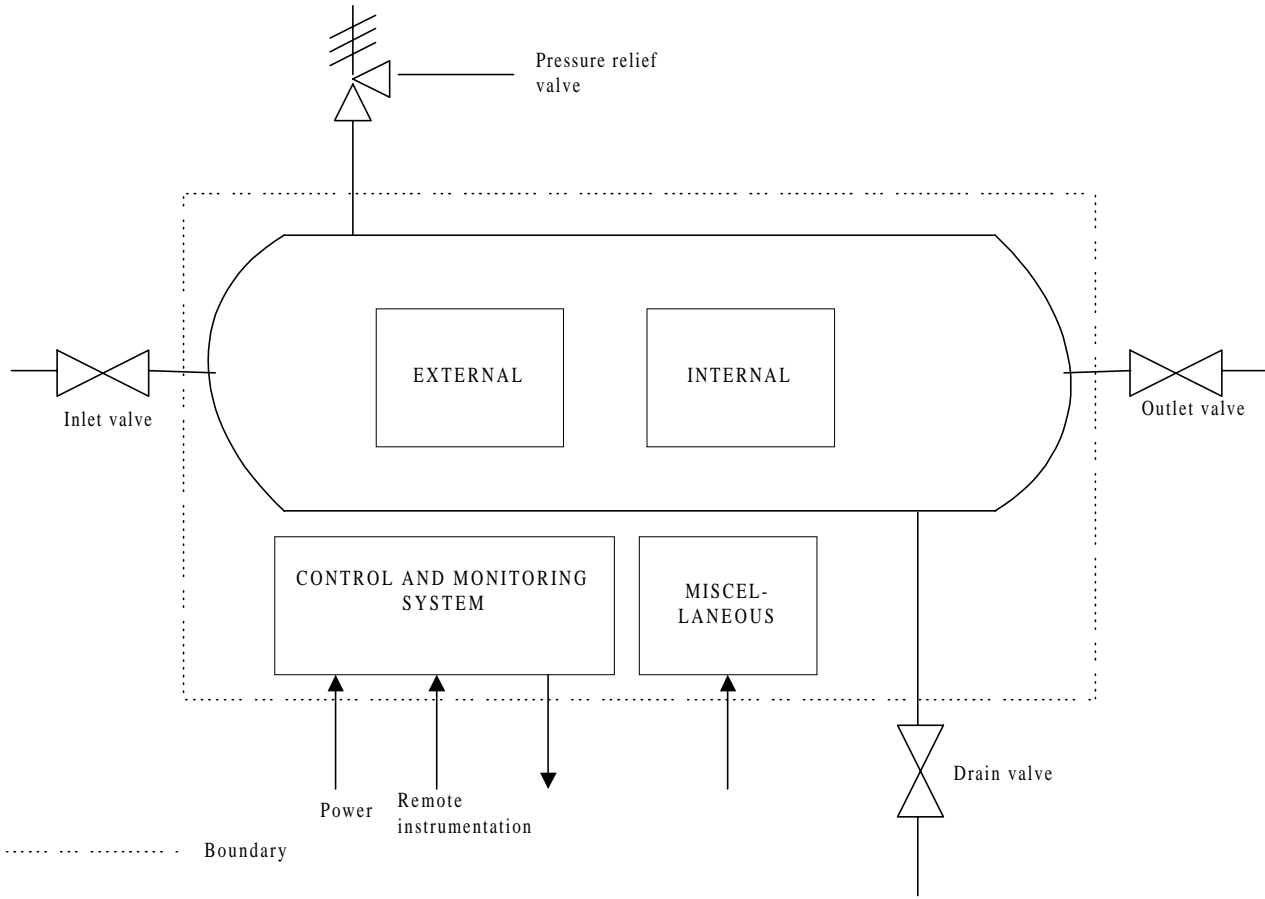


Figure A.13 — Equipment boundary — Vessels

Table A.51 — Equipment unit subdivision — Vessels

| Equipment unit     | Vessels                                   |                                                                                                                       |                                                                              |               |
|--------------------|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------|
| Subunit            | External items                            | Internal items                                                                                                        | Control and monitoring                                                       | Miscellaneous |
| Maintainable items | Support<br>Body/Shell<br>Valves<br>Piping | Body/Shell<br>Plates, trays, vanes, pads<br>Sand trap system<br>Heater<br>Corrosion protection<br>Distributor<br>Coil | Control<br>Actuating device<br>Monitoring<br>Valves<br>Internal power supply | Others        |

Table A.52 — Equipment unit specific data — Vessels

| Name                                     | Description                  | Unit or code list                                                                                                                                                                                                    |
|------------------------------------------|------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Fluid(s) (*)                             | Main fluid                   | Oil, gas, condensate, freshwater, steam, sea water, crude oil, oily water, flare gas, fuel gas, water/glycol, methanol, nitrogen, chemicals, hydrocarbon combined, gas/oil, gas/condensate, oil/water, gas/oil/water |
| Pressure - design (*)                    | Design pressure              | pascal (bar)                                                                                                                                                                                                         |
| Temperature - design                     | Design temperature           | °C                                                                                                                                                                                                                   |
| Pressure - operating (*)                 | Operating pressure           | pascal (bar)                                                                                                                                                                                                         |
| Temperature - operating                  | Operating temperature        | °C                                                                                                                                                                                                                   |
| Size - diameter (*)                      | External                     | mm                                                                                                                                                                                                                   |
| Size - length (*)                        | External                     | mm                                                                                                                                                                                                                   |
| Body material                            | Specify type or code         | Free text                                                                                                                                                                                                            |
| Orientation                              |                              | Horizontal/vertical                                                                                                                                                                                                  |
| Number of branches                       | Pressurized connections only | Number off                                                                                                                                                                                                           |
| Internals                                | Design principle             | Baffles, trays, grid plate, de-mister, heat coil, diverter, de-sander, combined                                                                                                                                      |
| (*) Indicates high-priority information. |                              |                                                                                                                                                                                                                      |

Table A.53 — Failure modes — Vessels

| Equipment unit | Code | Definition                      | Description                                                          |
|----------------|------|---------------------------------|----------------------------------------------------------------------|
| Vessels        | ELP  | External leakage process medium | Leakage of primary fluid to the environment                          |
|                | ELU  | External leakage utility medium | Leakage of secondary fluid to the environment                        |
|                | PLU  | Plugged/choked                  | Partial or full flow restriction                                     |
|                | PDE  | Parameter deviation             | Monitored parameter exceeding tolerances                             |
|                | AIR  | Abnormal instrument reading     | E.g. false alarm, faulty reading                                     |
|                | STD  | Structural deficiency           | Reduced strength due to impact, unacceptable corrosion, cracks, etc. |
|                | SER  | Minor in-service problems       | Loose items, discoloration, dirt, etc.                               |
|                | OTH  | Other                           | Specify in comment field                                             |
|                | UNK  | Unknown                         | Inadequate/missing information                                       |

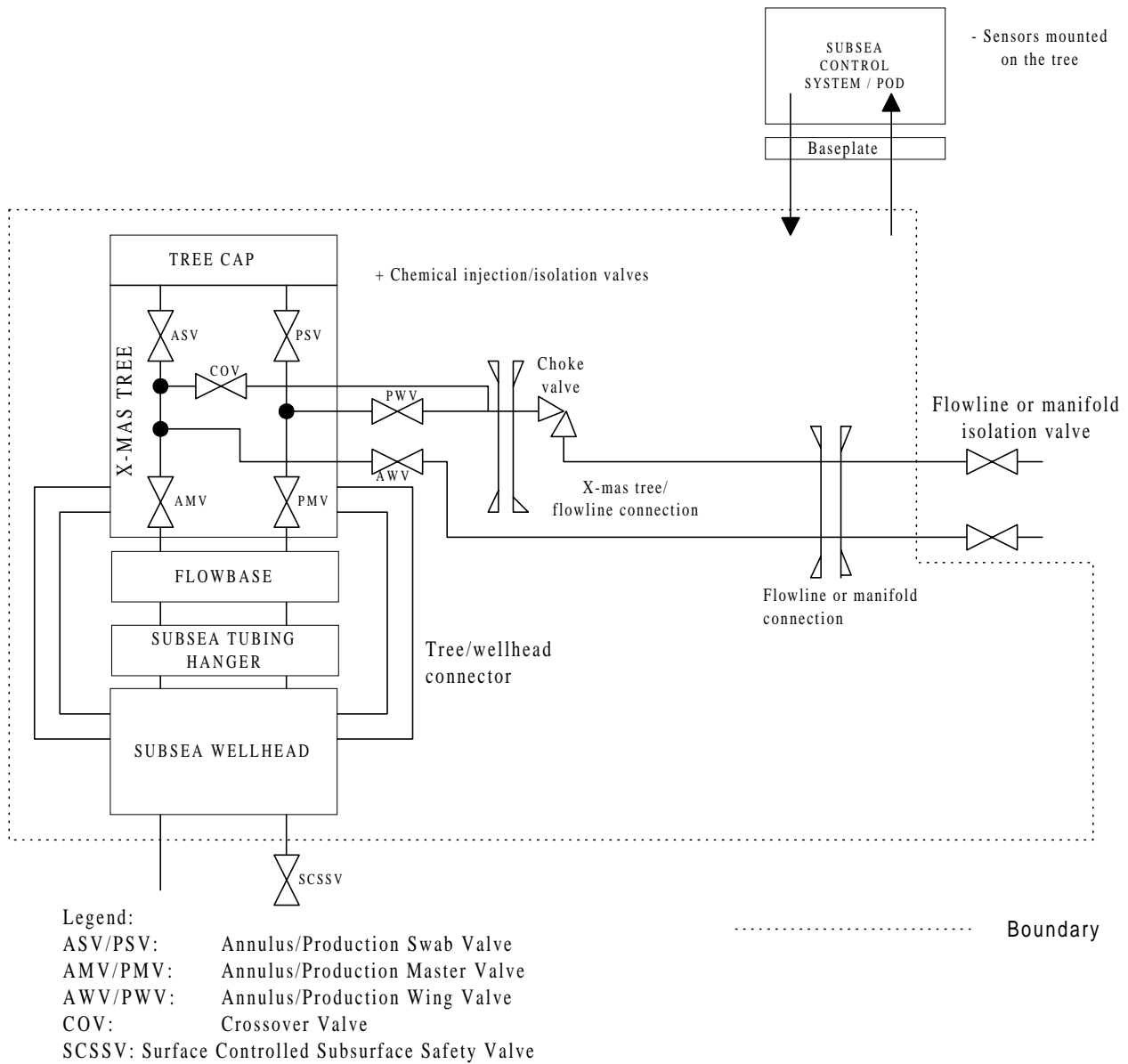
## A.3 Subsea equipment

### A.3.1 Wellhead and Xmas trees

Table A.54 — Taxonomy classification — Wellhead and Xmas trees

| Equipment class        |      | Type              |      | Application     |            |
|------------------------|------|-------------------|------|-----------------|------------|
| Description            | Code | Description       | Code | Description     | Code       |
| Wellhead and Xmas tree | WC   | Conventional tree | CT   | Injection well  | Injection  |
|                        |      | Horizontal tree   | HZ   | Production well | Production |

NOTE In Table A. 54 the lists in column headed "Type" and "Application" are typical examples found in the petroleum and natural gas industries. These lists should not be considered exhaustive.



**Figure A.14 — Equipment boundary — Wellhead and Xmas trees**

**Table A.55 — Equipment unit subdivision — Wellhead and Xmas trees**

| Equipment unit     | Wellhead and Xmas trees                                                                                                                                                                      |                                                                                                                                                                                                                                                                                                                                |                                                                                                                             |                                                                  |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|
| Subunit            | Subsea wellhead                                                                                                                                                                              | Subsea Xmas tree                                                                                                                                                                                                                                                                                                               | Tubing hanger                                                                                                               | Flowbase                                                         |
| Maintainable items | Permanent Guide base (PGB)<br>Temporary Guide base (TGB)<br>Conductor housing<br>Wellhead housing (high pressure housing)<br>Casing hangers<br>Annulus seal assemblies (Packoffs)<br>Unknown | Flowspool<br>Piping (hard pipe)<br>Hoses (flexible piping)<br>Debris cap<br>Tree guide frame<br>Connector<br>Internal isolation cap<br>Internal tree cap valve<br>Internal tree cap plug<br>Tree cap<br>Valve, check<br>Valve, choke<br>Valve, control<br>Valve, other<br>Valve, process isolation<br>Valve, utility isolation | Tubing hanger body<br>Chemical injection coupler<br>Hydrate coupler<br>Power/signal coupler<br>Tubing hanger isolation plug | Flowspool<br>Frame<br>Hub/mandrel<br>Casing hangers<br>Connector |



Table A.56 — Equipment unit specific data — Wellhead and X-mas trees

| Name                                     | Description                                                                                                                                                                                                                                                                          | Unit or code list                                                                                                                       |
|------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Well identification no.(*)               | Operator description                                                                                                                                                                                                                                                                 |                                                                                                                                         |
| Installation layout (*)                  | Define well layout                                                                                                                                                                                                                                                                   | Single satellite, cluster, multiwell manifold template, other                                                                           |
| Install/retrieve guide (*)               | Guideline/guidelineless                                                                                                                                                                                                                                                              | Guideline, guidelineless                                                                                                                |
| Intervention strategy                    | Diver assisted vs. diverless interventions                                                                                                                                                                                                                                           | Diver assisted, Diverless                                                                                                               |
| Protection type (*)                      | Overtrawable, trawl-catching, etc.                                                                                                                                                                                                                                                   | Trawl-catching, trawl-deflecting, none                                                                                                  |
| Water depth (*)                          |                                                                                                                                                                                                                                                                                      | m                                                                                                                                       |
| Xmas tree design pressure (*)            | Specify Xmas tree design pressure                                                                                                                                                                                                                                                    | pascal (bar)                                                                                                                            |
| Xmas tree design temperature (*)         | Specify Xmas tree design temperature                                                                                                                                                                                                                                                 | °C                                                                                                                                      |
| Xmas tree production bore diameter       | Specify diameter of production bore                                                                                                                                                                                                                                                  | mm                                                                                                                                      |
| Xmas tree annulus bore diameter          | Specify diameter of annulus bore                                                                                                                                                                                                                                                     | mm                                                                                                                                      |
| Wellhead design pressure (*)             | Specify wellhead design pressure                                                                                                                                                                                                                                                     | pascal (bar)                                                                                                                            |
| Wellhead design temperature (*)          | Specify wellhead design temperature                                                                                                                                                                                                                                                  | °C                                                                                                                                      |
| Wellhead size (*)                        | Specify                                                                                                                                                                                                                                                                              | mm                                                                                                                                      |
| Mudline suspension system                | Define whether a mudline suspension system exists                                                                                                                                                                                                                                    | Yes, no                                                                                                                                 |
| Multilateral well                        | Define                                                                                                                                                                                                                                                                               | Yes, no                                                                                                                                 |
| Fluid produced/injected (*)              | Main fluid only: oil, gas, condensate, injection water                                                                                                                                                                                                                               | Oil, gas, condensate, injection water, oil and gas, gas and condensate, oil/gas/ water, CO <sub>2</sub> , gas and water, produced water |
| Fluid corrosiveness (*)                  | Neutral - clean fluids with no corrosive effects<br>Sweet - moderately corrosive/erosive (oil/ gas not defined as severe, raw sea water, occasional particles)<br>Sour - severely corrosive/erosive [sour gas/oil (high H <sub>2</sub> S), high CO <sub>2</sub> , high sand content] | Neutral, sweet, sour                                                                                                                    |
| Asphaltenes                              |                                                                                                                                                                                                                                                                                      | Yes, no                                                                                                                                 |
| Scale formation                          |                                                                                                                                                                                                                                                                                      | Yes, no                                                                                                                                 |
| Wax formation                            |                                                                                                                                                                                                                                                                                      | Yes, no                                                                                                                                 |
| Hydrate formation                        |                                                                                                                                                                                                                                                                                      | Yes, no                                                                                                                                 |
| Sand production                          |                                                                                                                                                                                                                                                                                      | Yes, no                                                                                                                                 |
| (*) Indicates high-priority information. |                                                                                                                                                                                                                                                                                      |                                                                                                                                         |

Table A.57 — Failure modes — Wellhead and X-mas trees

| Equipment unit         | Code | Definition                        | Description                                                           |
|------------------------|------|-----------------------------------|-----------------------------------------------------------------------|
| Wellhead and Xmas tree | ELP  | External leakage process medium   | Process medium leak to sea                                            |
|                        | ELU  | External leakage utility medium   | Hydraulic fluid, methanol, etc.                                       |
|                        | ILP  | Internal leakage - Process medium | E.g. annulus to production bore communication                         |
|                        | ILU  | Internal leakage - Utility medium | E.g. internal leakage of hydraulic fluid or chemicals                 |
|                        | PLU  | Plugged/choked                    | Partial or full flow restriction due to hydrate, scale, wax, etc.     |
|                        | STD  | Structural deficiency             | Reduced integrity due to impact, unacceptable corrosion, cracks, etc. |
|                        | OTH  | Other                             | Specify in comment field                                              |
|                        | UNK  | Unknown                           | Inadequate/missing information                                        |
|                        | NON  | No immediate effect               |                                                                       |

Failure modes should be specified on all three indenture levels of the equipment hierarchy, to enhance the usability of the data in later applications. The failure modes in Table A.57 are related to equipment level, i.e. wellhead and Xmas tree.

## A.4 Well-completion equipment

### A.4.1 Equipment data

#### A.4.1.1 Item categories

Well-completion equipment in this context refers to equipment below wellhead level. All major completion equipment items are included, from tubing hanger at the top end to equipment at the bottom of the well.

The following item categories are defined for well-completion equipment:

#### a) String items

String items are defined as items which are all integral parts of the conduit ("string") used for production or injection of well effluents. The string is built by screwing together a variety of equipment items.

#### b) Accessories

Accessories are items which must be tied to a "host" string item to define a system. This is done to be able to logically represent string items which are too complex to be given as just a stand-alone item of the string. Only two such "host" string items, or *string items with accessories*, have been defined to date. These are Electrical Submersible Pump (ESP) and Downhole Permanent Gauge (DHPG) systems.

#### c) Inserted items

Inserted items are defined as items which can be attached (set) inside string items. A typical example is the combination of a lock and wireline-retrievable safety valve set inside a safety valve nipple.

#### d) Control line/cable

The control line/cable category allows information to be stored for control lines and cables and a variety of parts which are normally associated with control lines or cables. Examples of such parts are packer penetrators, electric connectors for gauges, electric wellhead connectors, etc. This category provides the opportunity to build control line/cable "systems" consisting of the hydraulic control line or cable itself and all associated parts.

Reliability analysis will then subsequently be possible for the control line system when the system has been tied to a specific string item in a completion.

Each control line/cable shall always be connected to one or more string items.

e) Casing

The casing category is included to store information on individual casing string sections and associated casing failures. The casing category represents full lengths of individual casing sections and does not represent individual items threaded into the casing string, compared with the production/injection string.

Sealing elements which are designed to seal off against leakage of hydrocarbons between the various sections of casing string (casing pack-offs) are not included.

#### A.4.1.2 Standard equipment specifications

**Table A.58 — Item database format and name specification**

| Item category | Data collection format                              | Predefined item name                                                              |  |
|---------------|-----------------------------------------------------|-----------------------------------------------------------------------------------|--|
| String item   | Annulus safety valve                                | Tubing-retrievable surface-controlled annular subsurface safety valve (TR-SCASSV) |  |
|               | Default                                             | Adjustable union                                                                  |  |
|               |                                                     | Landing nipple                                                                    |  |
|               |                                                     | Millout extension                                                                 |  |
|               |                                                     | Muleshoe                                                                          |  |
|               |                                                     | Nipple for wireline-SCSSV                                                         |  |
|               |                                                     | Gravel pack screen                                                                |  |
|               |                                                     | Perforated pup joint                                                              |  |
|               |                                                     | Pup joint                                                                         |  |
|               |                                                     | Sliding sleeve                                                                    |  |
|               |                                                     | Tubing anchor                                                                     |  |
|               |                                                     | Wireline re-entry guide                                                           |  |
|               | Electrical submersible pump system with accessories | Electrical submersible pump unit (straight)                                       |  |
|               |                                                     | Electrical submersible pump unit (y-tool)                                         |  |
|               | Expansion joint                                     | Expansion joint                                                                   |  |
|               | Flow coupling                                       | Flow coupling                                                                     |  |
|               | Gauge mandrel with accessories                      | Permanent gauge mandrel                                                           |  |
|               | Packer type                                         | Production packer                                                                 |  |
|               |                                                     | Downhole packer/hanger                                                            |  |
|               | Seal assembly                                       | Seal assembly (conventional)                                                      |  |
|               |                                                     | Seal assembly (overshot )                                                         |  |
|               | Side pocket mandrel                                 | Side pocket mandrel (for valve )                                                  |  |
|               | Spacer type                                         | Spacer                                                                            |  |
|               | Tubing type                                         | Tubing                                                                            |  |
|               | Tubing safety valve                                 | Tubing-retrievable surface-controlled subsurface safety valve (TR-SCSSV)(ball)    |  |
|               |                                                     | Tubing-retrievable surface-controlled subsurface safety valve (TR-SCSSV)(flapper) |  |
|               | X-over                                              | X-over                                                                            |  |
| Y-block       | Y-block                                             |                                                                                   |  |

Table A.58 (end)

| Item category      | Data collection format     | Predefined item name                                                          |
|--------------------|----------------------------|-------------------------------------------------------------------------------|
| Accessories        | Default                    | None defined                                                                  |
|                    | Downhole gauge             | Permanent gauge                                                               |
|                    | Intake section             | Intake section                                                                |
|                    | Motor                      | Electrical submersible pump motor                                             |
|                    | Motor lead extension       | Motor lead extension                                                          |
|                    | Motor seal system          | Motor seal system                                                             |
|                    | Pump                       | Pump with electric drive                                                      |
| Inserted item      | Annulus safety valve       | Wireline surface-controlled subsurface safety valve (SCSSV)                   |
|                    | Default                    | Brain (sideguard)                                                             |
|                    |                            | Lock for wireline surface-controlled annular subsurface safety valve (SCASSV) |
|                    | Gas lift valve             | Gas lift valve                                                                |
|                    |                            | Chemical injection valve                                                      |
| Safety valve       | Wireline-SCSSV             |                                                                               |
| Control line/cable | Default                    | None defined                                                                  |
|                    | Electric connector, gauge  | Electric connector downhole gauge                                             |
|                    | Electric connector, hanger | Electric connector tubing hanger                                              |
|                    | Hydraulic line             | Hydraulic control line                                                        |
|                    | Penetrator                 | Wellhead penetrator                                                           |
|                    |                            | Hanger penetrator                                                             |
|                    |                            | Packer penetrator                                                             |
|                    | Power cable                | Power cable                                                                   |
|                    | Signal cable               | Signal/instrument cable                                                       |
| Surface controller | Surface controller         |                                                                               |
| Casing             |                            |                                                                               |

An example of data collection format with associated data field definitions and registration alternatives is shown for a tubing item in Table A.59.

Table A.59 — Data collection format for string item example — Tubing

| Name                                                                                 | Description                                                                                  | Unit or code list                               |
|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-------------------------------------------------|
| Manufacturer (*)                                                                     | Generic tubing manufacturer's code list applied                                              |                                                 |
| Model                                                                                | Model designation or part number                                                             |                                                 |
| Effective length                                                                     | Actual length of tubing when integrated in completion string (i.e. exclusive of pin and box) | m                                               |
| Nominal size                                                                         | Nominal size of tubing                                                                       | m                                               |
| Max. outer diameter                                                                  | Maximum outer diameter of pipe, not joint                                                    | m                                               |
| Min. inner diameter                                                                  | Minimum inner diameter of pipe, not joint                                                    | m                                               |
| Material (*)                                                                         | Tubing material in pipe section                                                              | Free text                                       |
| Joint type (*)                                                                       |                                                                                              | Free text                                       |
| Connection type (*)                                                                  |                                                                                              | Free text                                       |
| Grade                                                                                | Material yield strength and type                                                             |                                                 |
| Nominal mass                                                                         | Mass per unit length                                                                         | kg/m                                            |
| Plastic coating (*)                                                                  | Indication whether or not tubing is internally plastic-coated                                | With plastic coating<br>Without plastic coating |
| Coating material (*)                                                                 |                                                                                              | Free text                                       |
| Remarks                                                                              | Other information considered relevant                                                        |                                                 |
| NOTE Information fields indicated with an asterisk (*) are coded alternative fields. |                                                                                              |                                                 |

#### A.4.2 Failure data

The failure-reporting format for a well-completion equipment item is shown in Table A.60. The failure-reporting format is nearly identical for all item categories. For control line/cables and string items with accessories, failed parts or failed accessories should be quoted as applicable.

The fields *Remedial action date* and *Remedial action details* are normally left blank when the failure is reported, unless information about the remedial action is available at the time of reporting the failure. Completing these fields is important when a downhole repair is successfully performed, as this will influence reliability calculations.

For string items with accessories it should be noted that a single failure of the host string item may involve failure of more than one component, e.g. an Electrical Submersible Pump (ESP) system failure may be caused by a penetrator and power cable failure.

A control line/cable failure may be specified independently from the connected item(s). This allows subsequent reliability analysis of individual control line/cables.

NOTE If the control line/cable failure causes a knock-on failure of a conventional string item or an inserted item, a failure record should additionally be stored for this item. When this failure is reported for the actual item, reference should be made to the control line failure in the failure cause field for the item(s) served by the control line/cable.

Table A.60 — Failure data report — Well-completion equipment

| Data                            | Description                                                                                                                             | Codes/comments                                                                                                                                                                                                                                                                                                  |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Failure mode                    | Item-specific failure mode as per previous definition.<br><br>(Ref. <i>tubing</i> example, next column)                                 | Burst tubing<br>Collapsed tubing<br>Restriction in tubing<br>Tubing broken/parted<br>Tubing leak<br>Other                                                                                                                                                                                                       |
| Failure effect                  | Observed direct effect of failure on safety and/or production                                                                           | Production affected<br>Safety affected<br>Both safety and production affected<br>Operational delay<br>No immediate effect on safety/production                                                                                                                                                                  |
| Failure date                    | Date of detection of equipment failure                                                                                                  |                                                                                                                                                                                                                                                                                                                 |
| Failure class                   |                                                                                                                                         | Item-related failure<br>Non-item-related failure<br>Other                                                                                                                                                                                                                                                       |
| Failure detection method        |                                                                                                                                         | Periodic testing<br>Test prior to well intervention<br>Production interference                                                                                                                                                                                                                                  |
| Failure cause                   | Used to specify details on underlying and direct causes of failure                                                                      | Free text information                                                                                                                                                                                                                                                                                           |
| Remedial action                 |                                                                                                                                         | Item replaced by wireline operation<br>Item replaced by full workover<br>Item replaced by partial workover<br>Item locked open and ran insert item<br>Item repaired by pressure manipulation<br>Item repaired through tubing<br>No remedial action planned/performed<br>Item still downhole in failed condition |
| Remedial action date            | Used to identify the date when <i>downhole</i> remedial action was performed.                                                           |                                                                                                                                                                                                                                                                                                                 |
| Remedial action details         |                                                                                                                                         | Free text information                                                                                                                                                                                                                                                                                           |
| Failed control line/cable parts | Applicable only when reporting control line/cable failures. One or more parts may have caused individual control line or cable failures |                                                                                                                                                                                                                                                                                                                 |
| Failed accessories              | Applicable only to string items with accessories                                                                                        |                                                                                                                                                                                                                                                                                                                 |

### A.4.3 Environmental data

Environmental data which should be collected for well-completion equipment are listed in Table A.61. The data are well specific, and will provide a generic reference to the working environment for all equipment in the well. The well environmental are periodical and listed as monthly averages.

Table A.61 — Environmental data — Monthly average

| Data                           | Description                                            | Unit or code list                        |
|--------------------------------|--------------------------------------------------------|------------------------------------------|
| Year                           |                                                        |                                          |
| Month                          |                                                        |                                          |
| Wellhead pressure              | Flowing wellhead pressure                              | pascal (bar)                             |
| Wellhead temperature           | Temperature at wellhead under flowing conditions       | °C                                       |
| Daily flow, gas                | Representative daily flow of gas                       | SCM/day                                  |
| Daily flow, oil                | Representative daily flow of oil                       | SCM/day                                  |
| Daily flow, condensate         | Representative daily flow of condensate                | SCM/day                                  |
| Daily flow, water              | Representative daily flow of water                     | SCM/day                                  |
| H <sub>2</sub> S concentration | Representative daily concentration of H <sub>2</sub> S | amount × 10 <sup>-6</sup> (ppm) or mol % |
| CO <sub>2</sub> concentration  | Representative daily concentration of CO <sub>2</sub>  | amount × 10 <sup>-6</sup> (ppm) or mol % |
| Remarks                        | Other information on information considered relevant   |                                          |

#### A.4.4 Maintenance data

The permanently installed well-completion equipment is normally run to failure. Preventive replacement may be performed for some string items, such as wireline-retrievable surface-controlled subsurface safety valves (SCSSV).

In rare cases, items may be repaired downhole. This typically may be the case with casing- or tubing-retrievable surface-controlled subsurface safety valves (SCSSV).

If a downhole repair action actually succeeds in restoring the function of an item, this can be reported by identifying the failure record for the item which initially failed. Depending on item category, the item failure record can be accessed as described above. The downhole repair action is reported by changing the *remedial action* code and giving the *remedial action date*. Should a failure occur on the same item at a later stage, a new failure record should be entered as described previously.

Information on downhole testing of valves should be collected, as this provides valuable information concerning interpretation of downhole failure trends.

#### A.4.5 Comments on Terms, definitions and abbreviations

The following comments on Terms, definitions and abbreviations (clause 3) are applicable for well-completion equipment:

**A.4.5.1 Critical failure (3.14):** failure which causes loss of the barrier function of the well-completion equipment, i.e. the equipment cannot maintain its ability to contain hydrocarbons within a predefined acceptance criteria, and corrective action shall be taken. A critical failure is defined relative to acceptance criteria set either in relevant standards (ISO/API), or in accordance with the equipment user's own acceptance criteria. In the event that the equipment user is applying his own acceptance criteria, this should be clearly stated when reporting critical failures.

**A.4.5.2 Non-critical failure (3.1.22):** All other completion equipment failures which do not fall into the "critical" category as defined above:

In Table A.62 the relationship between critical/non-critical failures and failure modes is indicated, using the item TR-SCSSV as an example. The relationship between failure effect (see Table A.62) and critical/non-critical failures for well-completion equipment in general is that failures which are of the 'safety affected' or 'production and safety affected' code are critical, while the remaining are non-critical.

**Table A.62 — Critical and non-critical failures — Tubing-retrievable surface-controlled subsurface safety valve (TR-SCSSV) example**

| Type of failure      | Failure mode                             |
|----------------------|------------------------------------------|
| Critical failure     | Fail to close on demand (FTC)            |
|                      | Leakage in closed position (LCP)         |
|                      | Well-to-control-line communication (WCL) |
| Non-critical failure | Premature closure (PCL)                  |
|                      | Failure to open on demand (FTO)          |
|                      | Control-line-to-well communication (CLW) |

**A.4.5.3 Equipment class:** The corresponding term applied for well-completion equipment is "item category", ref. A.4.1.1.

**A.4.5.4 Operating time:** The equivalent term used for well-completion equipment is "run time". This term is currently used only for Electrical Submersible Pump (ESP) systems, and denotes the time the equipment has been in active operation, driven by an external power source.

## A.5 Drilling equipment

### A.5.1 Top drives

#### A.5.1.1 Taxonomy classification

**Table A.63 — Taxonomy classification — Top drives**

| Equipment class    |      | Type                 |      | Application          |      |
|--------------------|------|----------------------|------|----------------------|------|
| Description        | Code | Description          | Code | Description          | Code |
| Drilling equipment | DE   | Hydraulically driven | HD   | Exploration drilling | DE   |
|                    |      | Electrically driven  | ED   | Production drilling  | DP   |
|                    |      |                      |      | Workover             | DW   |

#### A.5.1.2 Boundary definition

A top drive (frequently also referred to as a power swivel) is a piece of equipment that serves several functions. These are:

- rotating the drill string (formerly undertaken by the rotary table);
- providing conduit for drilling mud (formerly undertaken by the rotary swivel);
- disconnecting/connecting pipe (formerly undertaken by the iron roughneck);
- closing in the drill pipe (formerly undertaken by the kelly valve);
- lifting/lowering drill string (formerly undertaken by the hook).

Top drives may be either electrically or hydraulically driven. If they are hydraulically driven, several hydraulic motors are normally used.

Bailes and elevators are not regarded as a part of the top drive.



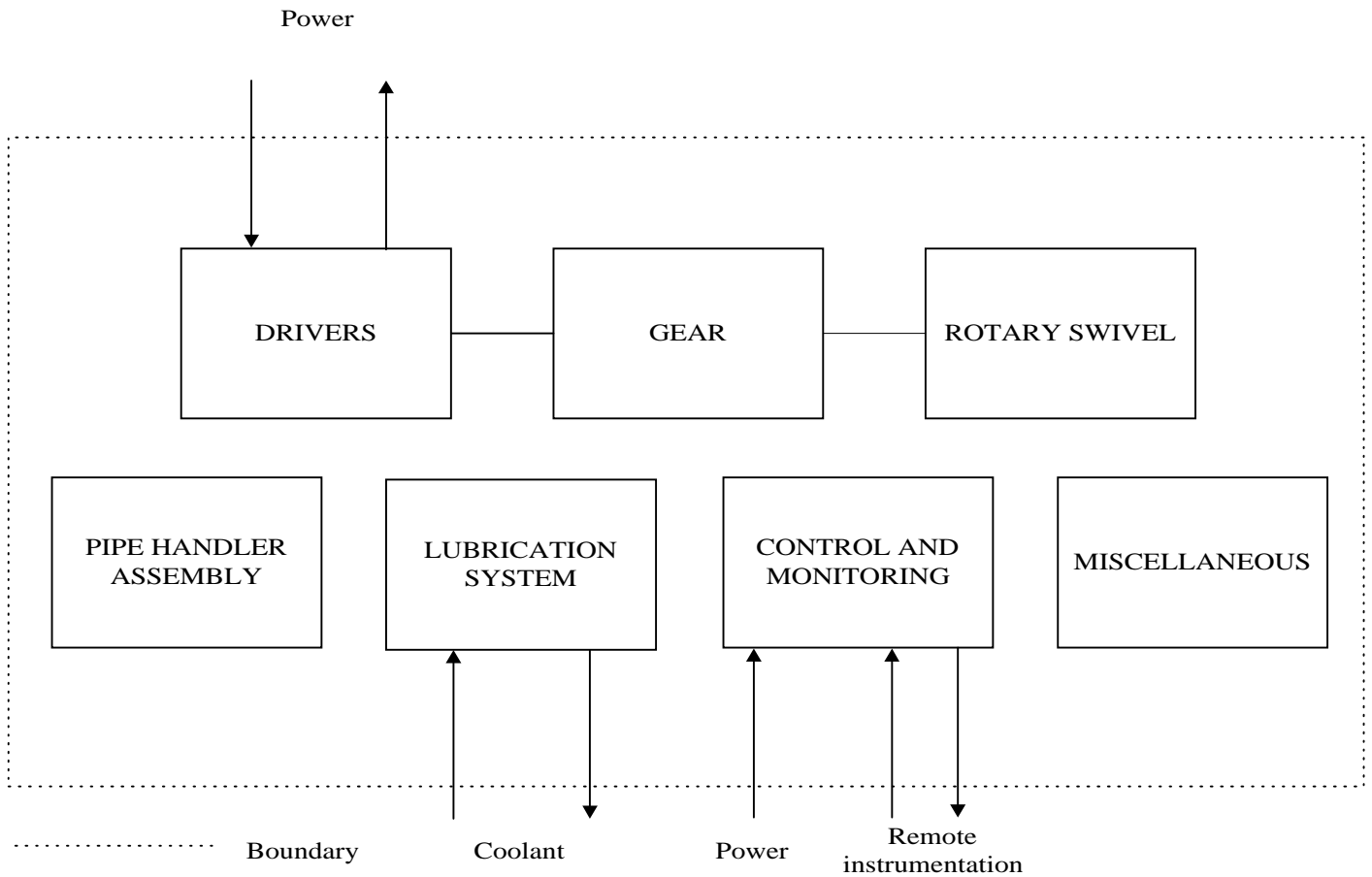


Figure A.15 — Equipment boundary — Top drives

**A.5.1.3 Equipment unit subdivision**

Top drives are subdivided in subunits and maintainable items as in Table A.64.

**Table A.64 — Equipment unit subdivision — Top drives**

| Equipment unit     | Top drive/power swivel                                                                                                                                                                                                              |                                                                                                          |                                                                                                 |                                                                                                     |                                                                                    |                                                                                                                      |                                                                           |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Subunit            | Drivers                                                                                                                                                                                                                             | Gear                                                                                                     | Rotary swivel                                                                                   | Pipe-handler assembly                                                                               | Lubri-cation                                                                       | Control and monitoring                                                                                               | Miscellaneous                                                             |
| Maintainable items | <b>Electric driver:</b><br>Stator<br>Rotor<br>Overload protection<br><br><b>Hydraulic driver:</b><br>External seals<br>Gear<br>Angle piston<br>Piping/ hoses<br><br><b>General:</b><br>Coupling<br>Radial, thrust and axial bearing | Bearings<br>Gear lubrication pump<br>Packing/seals<br>Coupling to driver<br>Coupling to swivel<br>Pinion | Gooseneck<br>Packing/seals<br>Axial, radial and thrust bearing<br>Swivel housing<br>Swivel stem | Link hanger incl. tilt actuators<br>Pipe-handler position motor<br>Swivel coupling<br>Torque wrench | Oil tank<br>Heaters<br>Coolers<br>Pump with motor<br>Valves<br>Filters<br>Lube oil | Control panel<br>Control<br>Electric and/or hydraulic solenoid cabinet<br>Service loops<br>Manifolds<br>Junction box | Dolly frame<br>Internal blow-out preventer<br>Counter-balance compensator |

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### A.5.1.4 Equipment unit specific data

Table A.65 lists the specific equipment data to be collected for top drives.

**Table A.65 — Equipment unit specific data — Top drives**

| Name                                                                        | Description        | Unit or code list        |
|-----------------------------------------------------------------------------|--------------------|--------------------------|
| Type of driver (*)                                                          | Specify type       | Electric<br>Hydraulic    |
| Number of drives (*)<br>(applicable for hydraulic drives only)              | Specify number     | Numeric                  |
| Hydraulic power requirements (*)<br>(applicable for hydraulic drives only)  | Pressure           | pascal (bar)             |
|                                                                             | Flowrate           | l/min                    |
| Motor category (*)<br>(applicable for electric drives only)                 | Specify type       | Induction<br>Synchronous |
| Electrical supply requirements (*)<br>(applicable for electric drives only) | Voltage            | volt                     |
|                                                                             | Current            | ampere                   |
| Rated power (*)                                                             | Max. output        | kW                       |
| Normal operating power (*)                                                  | Power              | kW                       |
| Speed (*)                                                                   | Max. speed         | r/min                    |
|                                                                             | Normal speed       | r/min                    |
| Torque (*)                                                                  | Max. torque        | N · m                    |
|                                                                             | At normal speed    | N · m                    |
|                                                                             | At max speed       | N · m                    |
| Pressure utilities                                                          | Hydraulic pressure | pascal (bar)             |
|                                                                             | Air pressure       | pascal (bar)             |
| Flow utilities                                                              | Hydraulic flow     | l/min                    |
|                                                                             | Air flow           | l/min                    |
| Retractable dolly frame                                                     | Specify            | Yes/No                   |
| Mud pressure capacity                                                       | Pressure           | pascal (bar)             |
| Inside BOP design pressure                                                  | Pressure           | pascal (bar)             |
| Torque wrench capacity                                                      | Diameter           | mm                       |
|                                                                             | Torque             | N · m                    |
| Elevator link hanger capacity (*)                                           | Capacity           | kg (metric)              |
| (*) Indicates high priority-information.                                    |                    |                          |

## A.5.1.5 Failure mode

Table A.66 — Failure mode

| Equipment Unit     | Code    | Definition                      | Description                                  |
|--------------------|---------|---------------------------------|----------------------------------------------|
| Drilling equipment | FTS     | Fail to start on demand         | Unable to activate top drive                 |
|                    | STP     | Fail to stop on demand          | Unable to stop or incorrect shutdown process |
|                    | SPS     | Spurious stop                   | Unexpected shutdown of top drive             |
|                    | HIO     | High output                     | Output torque above specification            |
|                    | LOO     | Low output                      | Output torque below specification            |
|                    | ERO     | Erratic output                  | Oscillating or unstable operation            |
|                    | ELU     | External leakage utility medium | Hydraulic oil, lube, oil, coolant etc.       |
|                    | INL     | Internal leakage                | As above                                     |
|                    | VIB     | Vibration                       | Excessive vibration                          |
|                    | NOI     | Noise                           | Excessive noise                              |
|                    | OHE     | Overheating                     | Excessive temperature                        |
|                    | AIR     | Abnormal instrument reading     | E.g. false alarm, faulty instrument reading  |
|                    | STD     | Structural deficiency           | E.g. cracks in support or load-bearing items |
|                    | SER     | Minor in-service problems       | Loose items, discoloration, dirt etc.        |
|                    | OTH     | Other                           | None of above apply. Specify                 |
| UKN                | Unknown | Inadequate/missing information  |                                              |

## Annex B (informative)

### Failure and maintenance notations

**Table B.1 — Failure descriptors**

| No.        | Notation                            | Description                                                                                                                                                                                 |
|------------|-------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1.0</b> | <b>Mechanical failure - general</b> | A failure related to some mechanical defect, but where no further details are known                                                                                                         |
| 1.1        | Leakage                             | External and internal leakages, either liquids or gases. If the failure mode at equipment unit level is leakage, a more causal-oriented failure descriptor should be used wherever possible |
| 1.2        | Vibration                           | Abnormal vibration. If the failure mode at equipment level is vibration, a more causal-oriented failure descriptor should be used wherever possible                                         |
| 1.3        | Clearance/alignment failure         | Failure caused by faulty clearance or alignment                                                                                                                                             |
| 1.4        | Deformation                         | Distortion, bending, buckling, denting, yielding, shrinking, etc.                                                                                                                           |
| 1.5        | Looseness                           | Disconnection, loose items                                                                                                                                                                  |
| 1.6        | Sticking                            | Sticking, seizure, jamming due to reasons other than deformation or clearance/alignment failures                                                                                            |
| <b>2.0</b> | <b>Material failure - general</b>   | A failure related to a material defect, but no further details known                                                                                                                        |
| 2.1        | Cavitation                          | Relevant for equipment such as pumps and valves                                                                                                                                             |
| 2.2        | Corrosion                           | All types of corrosion, both wet (electrochemical) and dry (chemical)                                                                                                                       |
| 2.3        | Erosion                             | Erosive wear                                                                                                                                                                                |
| 2.4        | Wear                                | Abrasive and adhesive wear, e.g. scoring, galling, scuffing, fretting, etc.                                                                                                                 |
| 2.5        | Breakage                            | Fracture, breach, crack                                                                                                                                                                     |
| 2.6        | Fatigue                             | If the cause of breakage can be traced to fatigue, this code should be used                                                                                                                 |
| 2.7        | Overheating                         | Material damage due to overheating/burning                                                                                                                                                  |
| 2.8        | Burst                               | Item burst, blown, exploded, imploded, etc.                                                                                                                                                 |
| <b>3.0</b> | <b>Instrument failure - general</b> | Failure related to instrumentation, but no details known                                                                                                                                    |
| 3.1        | Control failure                     |                                                                                                                                                                                             |
| 3.2        | No signal/indication/alarm          | No signal/indication/alarm when expected                                                                                                                                                    |
| 3.3        | Faulty signal/indication/alarm      | Signal/indication/alarm is wrong in relation to actual process. Could be spurious, intermittent, oscillating, arbitrary                                                                     |
| 3.4        | Out of adjustment                   | Calibration error, parameter drift                                                                                                                                                          |
| 3.5        | Software failure                    | Faulty or no control/monitoring/operation due to software failure                                                                                                                           |
| 3.6        | Common mode failure                 | Several instrument items failed simultaneously, e.g. redundant fire and gas detectors                                                                                                       |
| <b>4.0</b> | <b>Electrical failure - general</b> | Failures related to the supply and transmission of electrical power, but where no further details are known                                                                                 |
| 4.1        | Short circuiting                    | Short circuit                                                                                                                                                                               |
| 4.2        | Open circuit                        | Disconnection, interruption, broken wire/cable                                                                                                                                              |
| 4.3        | No power/voltage                    | Missing or insufficient electrical power supply                                                                                                                                             |
| 4.4        | Faulty power/voltage                | Faulty electrical power supply, e.g. overvoltage                                                                                                                                            |
| 4.5        | Earth/isolation fault               | Earth fault, low electrical resistance                                                                                                                                                      |

Table B.1 (end)

| No.                                                                                                                                                | Notation                                    | Description                                                                                                       |
|----------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| <b>5.0</b>                                                                                                                                         | <b>External influence - general</b>         | The failure where caused by some external events or substances outside boundary, but no further details are known |
| 5.1                                                                                                                                                | Blockage/plugged                            | Flow restricted/blocked due to fouling, contamination, icing, etc.                                                |
| 5.2                                                                                                                                                | Contamination                               | Contaminated fluid/gas/surface, e.g. lubrication oil contaminated, gas detector head contaminated                 |
| 5.3                                                                                                                                                | Miscellaneous external influences           | Foreign objects, impacts, environmental, influence from neighbouring systems                                      |
| <b>6.0</b>                                                                                                                                         | <b>Miscellaneous - general <sup>a</sup></b> | Descriptors that do not fall into one of the categories listed above                                              |
| 6.1                                                                                                                                                | Unknown                                     | No information available related to the failure descriptor                                                        |
| <sup>a</sup> The data acquirer should judge which is the most important descriptor if more than one exist, and try to avoid the 6.0 and 6.1 codes. |                                             |                                                                                                                   |

Table B.2 — Failure causes

| No.                                                                                                                                           | Notation                                                  | Description                                                                                                                 |
|-----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| <b>1.0</b>                                                                                                                                    | <b>Design-related causes - general</b>                    | Failure related to inadequate design for operation and/or maintenance, but no further details known                         |
| 1.1                                                                                                                                           | Improper capacity                                         | Inadequate dimension/capacity                                                                                               |
| 1.2                                                                                                                                           | Improper material                                         | Improper material selection                                                                                                 |
| 1.3                                                                                                                                           | Improper design                                           | Inadequate equipment design or configuration (shape, size, technology, configuration, operability, maintainability, etc.)   |
| <b>2.0</b>                                                                                                                                    | <b>Fabrication/installation-related causes - general</b>  | Failure related to fabrication or installation, but no further details known                                                |
| 2.1                                                                                                                                           | Fabrication error                                         | Manufacturing or processing failure                                                                                         |
| 2.2                                                                                                                                           | Installation error                                        | Installation or assembly failure (assembly after maintenance not included)                                                  |
| <b>3.0</b>                                                                                                                                    | <b>Failure related to operation/maintenance - general</b> | Failure related to operation/use or maintenance of the equipment, but no further details known                              |
| 3.1                                                                                                                                           | Off-design service                                        | Off-design or unintended service conditions, e.g. compressor operation outside envelope, pressure above specification, etc. |
| 3.2                                                                                                                                           | Operating error                                           | Mistake, misuse, negligence, oversights, etc. during operation                                                              |
| 3.3                                                                                                                                           | Maintenance error                                         | Mistake, errors, negligence, oversights, etc. during maintenance                                                            |
| 3.4                                                                                                                                           | Expected wear and tear                                    | Failure caused by wear and tear resulting from normal operation of the equipment unit                                       |
| <b>4.0</b>                                                                                                                                    | <b>Failure related to administration - general</b>        | Failure related to some administrative system, but no further details known                                                 |
| 4.1                                                                                                                                           | Documentation error                                       | Failure related to procedures, specifications, drawings, reporting, etc.                                                    |
| 4.2                                                                                                                                           | Management error                                          | Failure related to planning, organization, quality control/assurance, etc.                                                  |
| <b>5.0</b>                                                                                                                                    | <b>Miscellaneous - general <sup>a</sup></b>               | Causes that do not fall into one of the categories listed above                                                             |
| 5.1                                                                                                                                           | Unknown <sup>a</sup>                                      | No information available related to the failure cause                                                                       |
| <sup>a</sup> The data acquirer should judge which is the most important cause if more than one exist, and try to avoid the 5.0 and 5.1 codes. |                                                           |                                                                                                                             |

Table B.3 — Method of detection

| No. | Notation                        | Description                                                                                                                                                                                       |
|-----|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Preventive maintenance          | Failure discovered during preventive service, replacement or overhaul of an item when executing the preventive maintenance programme                                                              |
| 2   | Functional testing              | Failure discovered by activating an intended function and comparing the response against a predefined standard                                                                                    |
| 3   | Inspection                      | Failure discovered during planned inspection, e.g. visual inspection, non-destructive testing                                                                                                     |
| 4   | Periodic condition monitoring   | Failures revealed during a planned, scheduled condition monitoring of a predefined failure mode, either manually or automatically, e.g. thermography, vibration measuring, oil analysis, sampling |
| 5   | Continuous condition monitoring | Failures revealed during a continuous condition monitoring of a predefined failure mode                                                                                                           |
| 6   | Corrective maintenance          | Failure observed during corrective maintenance                                                                                                                                                    |
| 7   | Observation                     | Observation during routine or casual non-routine operator checks mainly by senses (noise, smell, smoke, leakage, appearance, local indicators)                                                    |
| 8   | Combination                     | Several of above methods involved. If one of the methods is the predominant one, this should be coded                                                                                             |
| 9   | Production interference         | Failure discovered by production upset, reduction, etc.                                                                                                                                           |
| 10  | Other                           | Other observation method                                                                                                                                                                          |

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Table B.4 — Maintenance activity

| No. | Activity           | Description                                                                                                                                                             | Examples                                                                                                       | Use <sup>a</sup> |
|-----|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|------------------|
| 1   | Replace            | Replacement of the item by a new, or refurbished, of the same type and make                                                                                             | Replacement of a worn-out bearing                                                                              | C, P             |
| 2   | Repair             | Manual maintenance action performed to restore an item to its original appearance or state                                                                              | Repack, weld, plug, reconnect, remake, etc.                                                                    | C                |
| 3   | Modify             | Replace, renew, or change the item, or a part of it, with an item/part of different type, make, material or design                                                      | Install a filter with smaller mesh diameter, replace a lubrication oil pump with another type, etc.            | C                |
| 4   | Adjust             | Bringing any out-of-tolerance condition into tolerance                                                                                                                  | Align, set and reset, calibrate, balance                                                                       | C                |
| 5   | Refit              | Minor repair/servicing activity to bring back an item to an acceptable appearance, internal and external                                                                | Polish, clean, grind, paint, coat, lube, oil change, etc.                                                      | C                |
| 6   | Check <sup>b</sup> | The cause of the failure is investigated, but no maintenance action performed, or action deferred. Able to regain function by simple actions, e.g. restart or resetting | Restart, resetting, etc. In particular relevant for functional failures, e.g. fire and gas detectors           | C                |
| 7   | Service            | Periodic service tasks. Normally no dismantling of the item                                                                                                             | E.g. cleaning, replenishment of consumables, adjustments and calibrations                                      | P                |
| 8   | Test               | Periodic test of function availability                                                                                                                                  | Function test of fire pump, gas detector etc.                                                                  | P                |
| 9   | Inspection         | Periodic inspection/check. A careful scrutiny of an item carried out with or without dismantling, normally by use of senses                                             | All types of general <i>checks</i> . Includes minor servicing as part of the inspection task                   | P                |
| 10  | Overhaul           | Major overhaul                                                                                                                                                          | Comprehensive inspection/overhaul with extensive disassembly and replacement of items as specified or required | P(C)             |
| 11  | Combination        | Several of the above activities are included                                                                                                                            | If one activity is the dominating, this could alternatively be recorded                                        | C, P             |
| 12  | Other              | Maintenance activity other than specified above                                                                                                                         |                                                                                                                | C, P             |

<sup>a</sup> C = used typically in corrective maintenance, P = used typically in preventive maintenance.

<sup>b</sup> "Check" includes both circumstances where a failure cause was revealed, but no maintenance action considered necessary, and where no failure cause could be found.



## Annex C (informative)

### Quality control checklist

#### C.1 Quality control before and during data collection

A quality check procedure should be performed by the data acquirer for each new installation on which data are collected and documented in proper format. The self-check should be an ongoing activity during the planning and execution of the data collection process, and can typically be divided into two main phases:

- a) before the data collection starts, viz.:
  - are data collection plans prepared and approved?
  - are relevant specifications of data to be collected in place, and procedures for quality control of data available to and understood by personnel involved?
  - are required resources available (trained personnel, software, data sources, etc.)?
- b) during data collection and finalization:
  - are data of sufficient quality and consistency, e.g.:
    - are definitions of boundaries and failure events adhered to?
    - are data correctly coded and commented for later analysis?
    - are data collected only for the time periods and equipment units specified?
  - are the following procedures followed:
    - reporting of deviations and interpretation problems?
    - a requirement on confidentiality, security and storing/shipment of data?

#### C.2 Verification of collected data

Typical checks to verify the quality of collected data would be:

- frequency analyses to detect missing information, incorrect interpretation, proper coding, data consistency, irregular distributions;
- spot checks on data as indicated in C.1 b).

The results of these checks should be documented and errors corrected. An example quality control form is given in Table C.1.

Table C.1 — Data quality control form (example)

| Operator:  |       | Installation:          |   |     | Equipment class: |  |  | Database number:      |  |  | Date checked: |       | Signature: |  |
|------------|-------|------------------------|---|-----|------------------|--|--|-----------------------|--|--|---------------|-------|------------|--|
| Report No. |       | Data type <sup>a</sup> |   |     | Data field       |  |  | Deviation/<br>comment |  |  | Corrections   |       |            |  |
| Inventory  | Event | G                      | I | F/M |                  |  |  |                       |  |  | Date          | Sign. | Comment    |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |
|            |       |                        |   |     |                  |  |  |                       |  |  |               |       |            |  |

<sup>a</sup> G = General, I = Inventory, F/M = Failure/Maintenance event.

## Annex D (informative)

### Typical requirements for data

The collection of RM data has to be carefully considered so that the type of data is consistent with the intended purpose. There are five main areas of application for RM data (see also Table D.1).

- a) High Safeguarding Performance — reliability of key safeguarding functions, e.g. firewater systems can be demonstrated by reference to actual RM data from the facility, where appropriate.
- b) Optimization of Plant Configuration — accurate RM data for equipment classes can assist with determining the appropriate sparing requirements for a facility by balancing increased costs with higher plant throughput.
- c) Reliability-Centred Maintenance — improvement of the maintenance strategy for a facility can be made by reference to suitable RM data from the facility itself.
- d) Benchmarking — by collecting consistent RM data, comparison can be made between subgroups of equipment.
- e) Life Cycle Cost Analysis — by obtaining comprehensive data during the operational phase (maintenance hours, down time), the true life cycle cost can be estimated and compared.

Due to the variety of different uses for RM data, it is stressed that for each data-collection programme attention should be given to the appropriate level of data required.

It is envisaged that the RM data can be used to compare operational performance among different equipment items located in various facilities and companies by interested parties, including operators, owners, consultants, vendors, insurers, etc.

Table D.1 — Data requirements for various applications

| Data requirements      |                                                                                                                  | Analysis category |             |             |             |     |
|------------------------|------------------------------------------------------------------------------------------------------------------|-------------------|-------------|-------------|-------------|-----|
|                        |                                                                                                                  | QRA               | RAM         | RCM         | BEN         | LCC |
| Equipment data         | Identification:<br>- equipment location<br>- classification<br>- installation data                               | x                 | x           | x           | x           | x   |
|                        | Design:<br>- manufacturers data<br>- design characteristics                                                      | x                 | x           | x           | x           | x   |
|                        | Application:<br>- surveillance period<br>- accumulated operating time<br>- number of demands<br>- operating mode | x<br><br>x<br>x   | x<br>x<br>x | x<br>x<br>x | x<br>x<br>x | x   |
| Failure data           | Failed item<br>- equipment unit<br>- subunit<br>- maintainable item                                              | x                 | x<br>x<br>x | x<br>x<br>x | x           | x   |
|                        | Failure mode                                                                                                     | x                 | x           | x           |             |     |
|                        | Severity class                                                                                                   | x                 | x           | x           | x           |     |
|                        | Failure descriptor                                                                                               |                   | x           | x           |             |     |
|                        | Failure cause                                                                                                    | x                 | x           | x           |             |     |
|                        | Method of observation                                                                                            |                   | x           | x           |             |     |
|                        | Impact of failure on operation                                                                                   | x                 | x           | x           |             |     |
|                        |                                                                                                                  |                   |             |             |             |     |
| Maintenance data       | Maintenance category                                                                                             | x                 | x           | x           |             | x   |
|                        | Maintenance activity                                                                                             |                   |             | x           |             |     |
|                        | Down time                                                                                                        |                   | x           | x           |             | x   |
|                        | Active maintenance time                                                                                          |                   | x           | x           |             |     |
|                        | Maintenance resources:<br>- maintenance man-hours, per discipline<br>- maintenance man-hours, total              |                   | x           | x           | x           | x   |
| Additional information | Description of the failure/<br>maintenance event                                                                 | x                 | x           | x           |             | x   |

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