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Condition monitoring and diagnostics of machine systems — Data interpretation and diagnostics techniques

Part 1: General guidelines

National foreword

This British Standard is the UK implementation of ISO 13379-1:2025. It supersedes BS ISO 13379-1:2012, which is withdrawn.

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**International
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ISO 13379-1

**Condition monitoring and
diagnostics of machine systems —
Data interpretation and diagnostics
techniques —**

**Part 1:
General guidelines**

*Surveillance et diagnostic de l'état des systèmes de machines —
Interprétation des données et techniques de diagnostic —*

Partie 1: Lignes directrices générales

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Foreword

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

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

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This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 5, *Condition monitoring and diagnostics of machine systems*.

This second edition of ISO 13379-1 cancels and replaces the first edition (ISO 13379-1:2012), which has been technically revised. The main changes are as follows:

- the Scope of the document has been extended by the addition of [Clause 1 c](#));
- [Clause 4](#) has been added to outline recommended steps to perform diagnostics;
- new methods for assessing the failure mode symptoms analysis have been added, see [5.3.4](#) and [5.3.5](#);
- new examples and descriptions of elements used for diagnostics have been added in [Clause 6](#);
- information provided in [7.1](#), [7.3](#) and [Annexes E](#) and [F](#) has been updated to reflect the state of the art;
- descriptions of data-driven methods have been moved to (informative) [Annex E](#);

A list of all parts in the ISO 13379 series can be found on the ISO website.

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

Introduction

Effective management of machine systems throughout their life cycles requires maintaining their performance, reliability and availability. One of the key strategies to support this objective is condition monitoring, which provides information on the state of the machine system.

Condition monitoring serves two principal roles:

- a) to identify trends that indicate the remaining useful life of the machine system, deterioration of its performance or increased risk of failures; and
- b) to detect nonconformities, referred to as anomalies in the context of condition monitoring, by identifying deviations from baseline values or expected operating conditions. Such deviations, when compared against predefined criteria, can result in alarms.

Once an anomaly has been detected, it is often needed to identify its cause(s). Identifying the cause(s) of the anomaly is referred to as diagnostics and supports the determination of appropriate corrective actions. Stakeholders typically expect a certain level of accuracy in diagnostics, as its output — a diagnosis — can directly influence machine system operation, maintenance planning and resource allocation. This document supports users in developing diagnostic procedures and models, and in evaluating their confidence level, applicability and limitations.

Condition monitoring and diagnostics of machine systems — Data interpretation and diagnostics techniques —

Part 1: General guidelines

1 Scope

This document

- a) establishes common concepts for condition monitoring and diagnostics of machine systems, simplifying communication between the users and manufacturers of condition monitoring and diagnostics systems;
- b) establishes technical characteristics and describes principles for condition monitoring and diagnostics of machine systems;
- c) gives guidance on developing condition monitoring and diagnostics systems; and
- d) gives guidance on selecting an appropriate diagnostic approach in the particular application.

This document is applicable to any machine system whose state can be described by measuring or observing its operational parameters (or inputs) and responses (or outputs).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13372, *Condition monitoring and diagnostics of machines — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13372 apply.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org>

3.1 confidence level

figure of merit, e.g. percentage, that indicates the degree of certainty that the diagnosis or prognosis is correct.

Note 1 to entry: This figure essentially represents the cumulative effect of error sources on the final certainty or confidence in the accuracy of the outcome. Such a figure can be determined algorithmically or via a weighted assessment system.

[SOURCE: ISO 13381-1:2025, 3.3, modified by adding 'or' and removing parentheses]

3.2**diagnostic approach**

methodology used to perform diagnostics, typically by analysing observed or simulated data (data-driven approach) or by explicitly representing fault or system behaviour (knowledge-based approach).

3.3**diagnostic model**

mathematical or logical construct used to identify, analyse or interpret data and information for the purpose of supporting diagnostics

4 Diagnostics and its relation to condition monitoring

Condition monitoring involves continuous or scheduled measurement of machine system parameters, processing these measurements into data and information, and often the presentation and storage of the processed data and information. Diagnostics is generally triggered by detecting an anomaly during routine condition monitoring, routine analysis, random analysis or human perception. This detection is carried out by making a comparison between the present descriptors of a machine system and baseline (also called baseline values or reference sets) chosen from experience, from the manufacturer's specifications, from commissioning tests or computed from statistical information (e.g. long-term average for a particular operational state).

Diagnostics is a systematic approach used to identify the root cause of anomalies and plays an essential role in decision making for operation and maintenance tasks. It should include the following steps:

- a) **Anomaly validation:** At the start of diagnostics, it should be ensured that the anomaly has not been caused by the malfunction of a transducer or any other part of the condition monitoring system.
- b) **Data and information collection:** Next, relevant elements used for diagnostics should be gathered. These elements are described in [Clause 6](#) and include measurements, descriptors derived from measurements, symptom and fault characteristics, records of the fault history, operation history and maintenance history, and specific information that describes machine system construction and operational parameters. ISO 17359 provides further guidelines for data and information collection.
- c) **Analysis:** The gathered elements should be analysed to identify patterns, trends and deviations from the baseline. The particular analysis method shall depend on the selected diagnostic approach. The diagnostic approaches are described in [Clause 7](#), together with guidelines for their selection.
- d) **Hypothesis formulation:** Potential causes of the anomaly, also called hypothesis, should be reasoned using the information generated by the analysis. When formulating the hypotheses, consideration shall be given to the factors outlined in [Clause 5](#). The hypothesis that no fault is present shall always be considered.
- e) **Hypothesis testing:** Hypotheses should be tested for by taking additional actions, such as making targeted measurements or carrying out further tests, inspections or simulations. A hypothesis shall be rejected if the test results contradict it. If the test results do not contradict the hypothesis, it shall be considered not rejected. In cases where the test results provide a sufficiently high level of confidence, a hypothesis may be considered accepted for the purpose of diagnosis synthesis.
- f) **Diagnosis synthesis:** The diagnosis should be formulated using hypotheses that were not rejected. If a higher confidence level is needed, only accepted hypotheses should be used. Further information on determining diagnosis confidence level is given in [7.4](#).
- g) **Recommendation:** Recommendations for taking corrective actions shall be formulated based on diagnosis. The corrective actions can include maintenance tasks such as refurbishments, repairs and replacements, adjustments of operational parameters or further monitoring. To develop recommendations, the diagnostician should be aware of provisions given in [Clause 5](#) and ISO 17359.
- h) **Follow-up:** After implementing the recommended corrective actions, the machine system should be further monitored to assess whether the expected behaviour has been restored or additional actions

are needed. If the recommendations made during diagnostics prove to be accurate when the follow-up takes place, then this becomes useful knowledge that should be stored for future reference.

Diagnostics is iterative and carrying out multiple cycles through individual steps can be needed to arrive at an accurate diagnosis. Diagnostics depends on constraints, such as financial, temporal or organisational, and external dependencies which influence the feasibility of the individual steps. However, stakeholders should be made aware that missing any of the steps listed in 4 a) to h) can reduce the accuracy of the diagnosis and consequently, the confidence in the output of the diagnostics.

Diagnostics should be documented in the form of a diagnostic report. An example of the diagnostic report is given in [Table A.1](#).

Diagnostics may be used in parallel with prognostics. Guidance on how to develop and apply prognostics and formulate prognosis (output of prognostics) is provided in ISO 13381-1.

5 Requirements to set-up condition monitoring and diagnostics

5.1 General

Condition monitoring and diagnostics have an essential role to play in decision making for operation and maintenance tasks. To be effective, a condition monitoring and diagnostics system shall be set up according to the faults that can occur in the machine system. Therefore, a preliminary study should be carried out when preparing the requirements for the condition monitoring and diagnostics system of a particular machine system.

5.2 Establishing diagnostics needs

A life cycle of the condition monitoring and diagnostics system is shown in [Figure 1](#). The V-shape represents the high-level (e.g. maintenance, machine system and risk assessment) and the low-level concerns (e.g. measurements, monitoring, periodical tests and data processing).

The left branch of [Figure 1](#) corresponds to the preliminary study, which prepares, for a particular machine system, the necessary information for condition monitoring and diagnostics. The right branch corresponds to the condition monitoring and diagnostics that are normally undertaken after the machine system has been commissioned. Vertical layers depict individual phases of the life cycle.

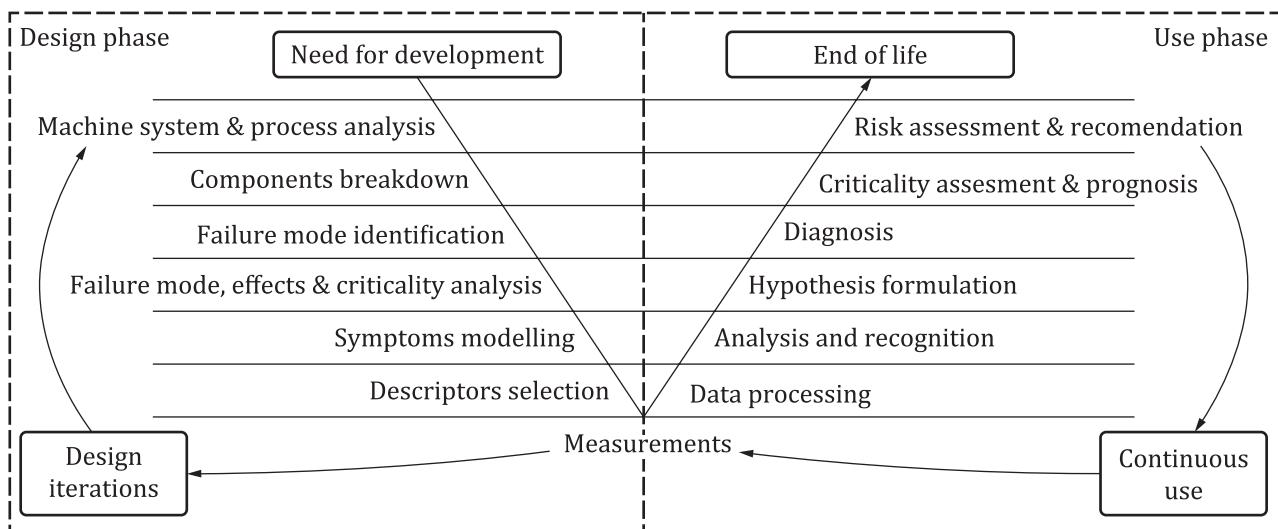


Figure 1 — Typical life cycle of condition monitoring and diagnostics system

The generic steps of the preliminary study should include:

- a) analysing the machine system availability, maintainability and criticality within the context of the entire functional process;
- b) listing major components and auxiliaries and their functions;
- c) analysing components and auxiliaries failure modes and their causes;
- d) expressing the failure mode criticality, taking into account the significance (safety, availability, maintenance costs, production quality) and the likelihood of fault occurrence;
- e) deciding in accordance with [5.2 d\)](#) which failure modes should be covered by diagnostics;
- f) analysing operating conditions under which the individual faults can be best observed;
- g) define the operating conditions for which the baselines should be established;
- h) setting out symptoms that can help in assessing the condition of the machine system and that can be used for diagnostics;
- i) listing descriptors that can be used to evaluate (recognize) the different symptoms; and
- j) identifying measurements to be taken from which the descriptors are derived or computed.

The steps given in [5.2 a\)](#) and [b\)](#) are outlined in ISO 17359. The steps given in [5.2 a\)](#) to [d\)](#) may be followed using maintenance optimization such as failure modes and effects analysis (FMEA) or failure mode effects and criticality analysis (FMECA), which are outlined in IEC 60812. They also may be accomplished within a more general process of maintenance optimization, such as reliability-centred maintenance.

NOTE Guidelines for developing failure management policies using reliability-centred maintenance are set out in IEC 60300-3-11.

The steps given in [5.2 c\)](#) to [f\)](#) and [5.2 h\)](#) to [j\)](#) may be followed using the methodology explained in [5.3](#).

5.3 Failure mode symptoms analysis (FMSA)

5.3.1 General

The purpose of the FMSA is to support the selection of monitoring techniques, technologies and strategies to maximize the confidence level in the detection, diagnosis and prognosis of each identified failure mode.

FMSA focuses on the ability of a monitoring technique to detect symptoms produced by each identified failure mode and assess their rate of change. When confidence in the sensitivity of a monitoring technique and the resulting accuracy of diagnosis or prognosis is questionable, it is recommended that additional monitoring technique(s), known as correlation monitoring technique(s), be used.

FMSA is a methodological extension of the FMEA and should therefore be used in conjunction with any existing FMEA or FMECA that has already identified and ranked possible failure modes.

5.3.2 Usage guidance

The information needed to perform the FMSA is best compiled into a worksheet that should include:

- a) list of the components and auxiliaries involved;
- b) list of the possible failure modes for each component or auxiliary;
- c) list of the effects of each failure mode;
- d) list of the causes of each failure mode;
- e) list of the symptoms produced by each failure mode;

- f) list of the most appropriate monitoring techniques;
- g) list of the estimated monitoring frequency;
- h) rating of each failure mode by severity, detectability, diagnosis confidence level and prognosis confidence level;
- i) list of the most appropriate correlation monitoring techniques; and
- j) list of the monitoring frequency for the correlation monitoring techniques.

For each item listed, the failure mode, effect, and cause should read logically across the worksheet. An example of an appropriate FMSA worksheet is given in [Table B.1](#).

The greatest difficulty is in establishing the correct terms for failure modes, effects, and causes. Care shall be taken to avoid duplication of failure mode and cause on the same line of the worksheet. However, a term can appear as a cause of failure in one line and as a failure mode in another line. A term can also appear as an effect in one line when dealing with a component and as a failure mode when dealing with an assembly. It may be helpful to remember that a failure mode can result in an effect due to a cause.

When considering monitoring strategies, these forms may also be used:

- a failure mode produces symptoms, which are best detected using a primary monitoring technique resulting in a high diagnosis and prognosis confidence when monitored at a given monitoring frequency; and
- diagnosis and prognosis confidence level increases by using correlation monitoring techniques when monitored at a given monitoring frequency.

Continuous reassessment should be carried out when experience with a newly installed machine system is gained or when either the machine system or the condition monitoring system is modified.

5.3.3 Rating guidance

5.3.3.1 General

Ratings which estimate the failure severity (SEV), the likelihood of detection (DET), the diagnosis confidence level (DGN) and the prognosis confidence level (PGN) should be assigned to each failure mode. All four ratings can be combined in accordance with [5.3.4](#) to give a monitoring priority number (MPN). DET, DGN and PGN can be combined in accordance with [5.3.5](#) to give a monitoring confidence number (MCN).

Note that there is no universal definition for individual ratings, as the scale for each rating depends on specific needs of the user of this document. It is recommended to use a consistent scale for DET, DGN and PGN ratings to ensure that these ratings hold equal weight when establishing MCN or MPN.

5.3.3.2 Failure severity (SEV)

SEV indicates the potential worst-case impact of a failure mode on the machine system or its function, where lower values represent minor or negligible consequences and higher values reflect increasingly serious consequences for safety, performance, or operation. The assigned SEV rating should align with the outcomes of any performed FMEA or FMECA.

An example of the SEV rating using a scale of 1 to 5 is provided in [Table C.1](#). Other examples can be found in IEC 60812:2018, Annex B.

5.3.3.3 Likelihood of detection (DET)

DET indicates the likelihood of successfully detecting the symptoms of a failure mode, regardless of DGN or PGN. Lower values represent a low likelihood, such as when symptoms are undetectable, unrepeatable, not measurable in practice, or potentially masked by other failure mode symptoms. Higher values reflect a greater likelihood that the failure mode can be reliably detected during monitoring or diagnostics.

An example of the DET rating using a scale of 1 to 5 is provided in [Table C.2](#). Further examples of DET ratings are provided in IEC 60812:2018, Annex B, which uses a decreasing scale for detectability rankings. Therefore, when using DET values from any FMEA or FMECA performed in accordance with IEC 60812, the scale shall be reversed to maintain consistency with this document.

5.3.3.4 Diagnosis confidence level (DGN)

DGN indicates the expected accuracy of identifying a specific failure mode once its symptoms have been detected. Lower values represent a low diagnosis confidence level, such as when symptoms are ambiguous, non-distinctive, unknown or unrepeatable with respect to the specific failure mode. Higher values reflect a high confidence level.

An example of the DGN rating using a scale of 1 to 5 is provided in [Table C.2](#).

5.3.3.5 Prognosis confidence level (PGN)

PGN indicates the expected accuracy of predicting the remaining useful life or the future fault or failure probability associated with a specific failure mode. Lower values represent a low prognosis confidence level, such as when symptoms are unrepeatable, insensitive to degradation progression, ambiguous, or when failure rates are unknown. Higher values reflect a high confidence level. The prognosis confidence level can also be influenced by the monitoring frequency, i.e. a higher prognosis confidence level can be expected with the higher monitoring frequency.

An example of the PGN rating using a scale of 1 to 5 is provided in [Table C.2](#).

5.3.4 Assessing FMSA results using a monitoring priority number (MPN)

MPN is typically defined as the product of four ratings: $MPN = SEV \times DET \times DGN \times PGN$.

MPN is assigned to each combination of the failure mode and monitoring technique. The assessment of these values shall consider the following:

- a) The range of MPN values depends on the scales used to rate SEV, DET, DGN and PGN;
- b) The numerical ratio between two MPN values has no specific meaning;
- c) Low MPN values, in relation to the range defined in [5.3.4 a\)](#), do not imply that condition monitoring is not necessary but rather that a low confidence level for detection, analysis, and prognosis can be expected with the nominated monitoring technique and frequency; and
- d) When two or more monitoring techniques are evaluated in relation to a single failure mode, the highest MPN value indicates that the associated monitoring technique is the most appropriate for the detection, diagnosis, and prognosis of that failure mode.

The assessment of whether the MPN value is sufficiently high for a single failure mode shall take into consideration additional factors:

- e) the safety risks associated with that failure mode;
- f) the expected deterioration rate of that failure mode;
- g) the mean time between failures for that failure mode;
- h) the presence of secondary or subsequent failure modes;
- i) interrelationships with other failure modes;
- j) the maintenance lead time needed for corrective or preventive actions;
- k) the availability and delivery time of spare parts; and
- l) the targeted reliability and availability of the machine system.

5.3.4.1 Alternative method to calculate MPN

If the scales used to express SEV, DET, DGN and PGN are logarithmic, an alternative calculation of MPN may be used: $MPN = SEV + DET + DGN + PGN$.

This alternative calculation reflects the additive nature of logarithmic scales, where multiplication of linear values corresponds to addition in the logarithmic domain. The use of this method is particularly appropriate when rating systems are designed to express orders of magnitude.

5.3.5 Assessing FMSA results using a diagram

This assessment method uses an FMSA diagram shown in [Figure 2](#). The horizontal axis of the FMSA diagram represents the range of possible SEV values, while the vertical axis represents the range of possible monitoring confidence levels (MCN), which is typically defined as the product of three ratings: $MCN = DET \times DGN \times PGN$.

The FMSA diagram is divided into a set of regions. Typically, four regions, denoted as R1 to R4 in [Figure 2](#), are used; however, a different number of regions may be defined. The number of regions and the boundaries between them shall be determined taking into consideration the scales used to rate SEV, DET, DGN and PGN, as well as the factors listed in [5.3.4 e\)](#) to [l\)](#). The boundaries between the regions may take the form of simple lines, as shown in [Figure 2 a\)](#), curves, as shown in [Figure 2 b\)](#), or a combination of both. If a discrete scale is used for any of the ratings, the use of step-wise boundaries, as illustrated in [Figure 2 c\)](#), may be appropriate.

An example of how to construct an FMSA diagram is provided in [Table C.3](#).

Each combination of the failure mode and monitoring technique is allocated to the FMSA diagram based on the corresponding pair of SEV and MCN values. The assessment of this combination should take into account the region in which it is located. The boundaries of the regions, as shown in [Figure 2](#), reflect the principle that failure modes with higher SEV typically require higher monitoring effectiveness to mitigate the risk of undetected or late-detected faults.

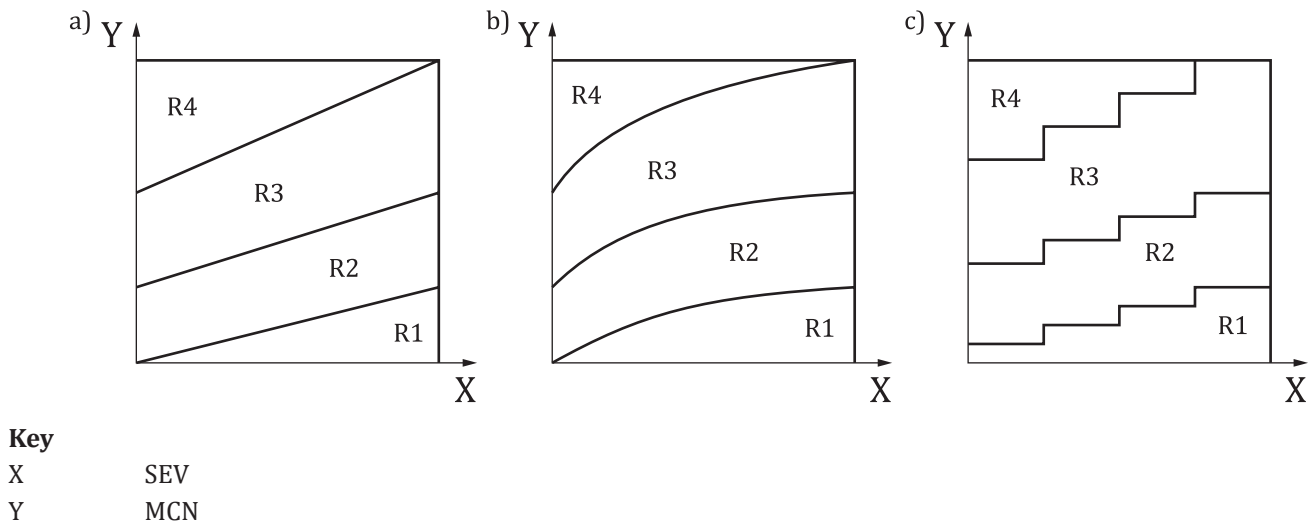


Figure 2 — Examples of FMSA diagrams with four regions R1 to R4 delimited by a) linear boundaries, b) boundaries formed by curves and c) step-wise boundaries

EXAMPLE An example of how the combination of the failure mode and monitoring technique can be assessed depending on the region from [Figure 2](#) in which it is located:

- R1 — The combination is not acceptable. In general, an alternative monitoring technique or additional correlation monitoring technique(s) need to be used.
- R2 — The combination is acceptable in some cases, e.g. if the likelihood of fault occurrence is significantly lower than once during the machine system life, or measures to reduce SEV are feasible. Otherwise, an alternative monitoring technique or additional correlation monitoring technique(s) need to be used.