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# Condition monitoring and diagnostics of machines — General guidelines

*Surveillance et diagnostic d'état des machines — Lignes directrices générales*



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# Foreword

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

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



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 third edition cancels and replaces the second edition (ISO 17359:2011), which has been technically revised.

The following changes have been made:

— reference to the ISO 55000 family of asset management standards has been included;

— power transformers have been added to Annex A and Annex B;

— Annex D has been updated;

— the Bibliography has been revised.

# Introduction

This document provides guidelines for condition monitoring and diagnostics of machines using parameters such as vibration, temperature, tribology, flow rates, contamination, power, and speed typically associated with performance, condition, and quality criteria. The evaluation of machine function and condition may be based on performance, condition or product quality.

Condition monitoring forms a vital component of asset management and this document is the parent document of a group of standards which cover the field of condition monitoring and diagnostics. The range of condition monitoring standards are indispensable for the use and implementation of the ISO 55000 family of asset management standards. This document provides general procedures to be considered when setting up a condition monitoring programme for all types of machine, and includes references to other International Standards and other documents required or useful in this process.

An overview of the current status of condition monitoring International Standards is shown in Annex D.

This document presents an overview of a generic procedure recommended to be used when implementing a condition monitoring programme, and provides further detail on the key steps to be followed. It introduces the concept of directing condition monitoring activities towards identifying and detecting symptoms of root cause failure modes and describes the generic approach to setting alarm criteria, carrying out diagnosis and prognosis, and improving the confidence in diagnosis and prognosis, which are developed further in other International Standards.

Particular techniques of condition monitoring are only introduced briefly and are covered in more detail in other International Standards referenced in the Bibliography.



 

# Condition monitoring and diagnostics of machines — General guidelines

## 1 Scope

This document gives guidelines for the general procedures to be considered when setting up a condition monitoring programme for machines and includes references to associated standards required in this process. This document is applicable to all machines.

## 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 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

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

ISO 13379-1, *Condition monitoring and diagnostics of machines — Data interpretation and diagnostics techniques — Part 1: General guidelines*



## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 13372 and the following apply.

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

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

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

**3.1**
**equipment**
machine or group of machines including all machine or process control components

## 4 Overview of condition monitoring procedure

A generic procedure which may be used when implementing a condition monitoring programme is described in Clauses 5 to 11 and shown in diagrammatic form in Figure 1. Details on the key steps to be followed are provided. Condition monitoring activities should be directed towards identifying and avoiding root cause failure modes.

Particular techniques of condition monitoring are only introduced briefly. They are covered in more detail in other International Standards referenced in Annex D and the Bibliography.

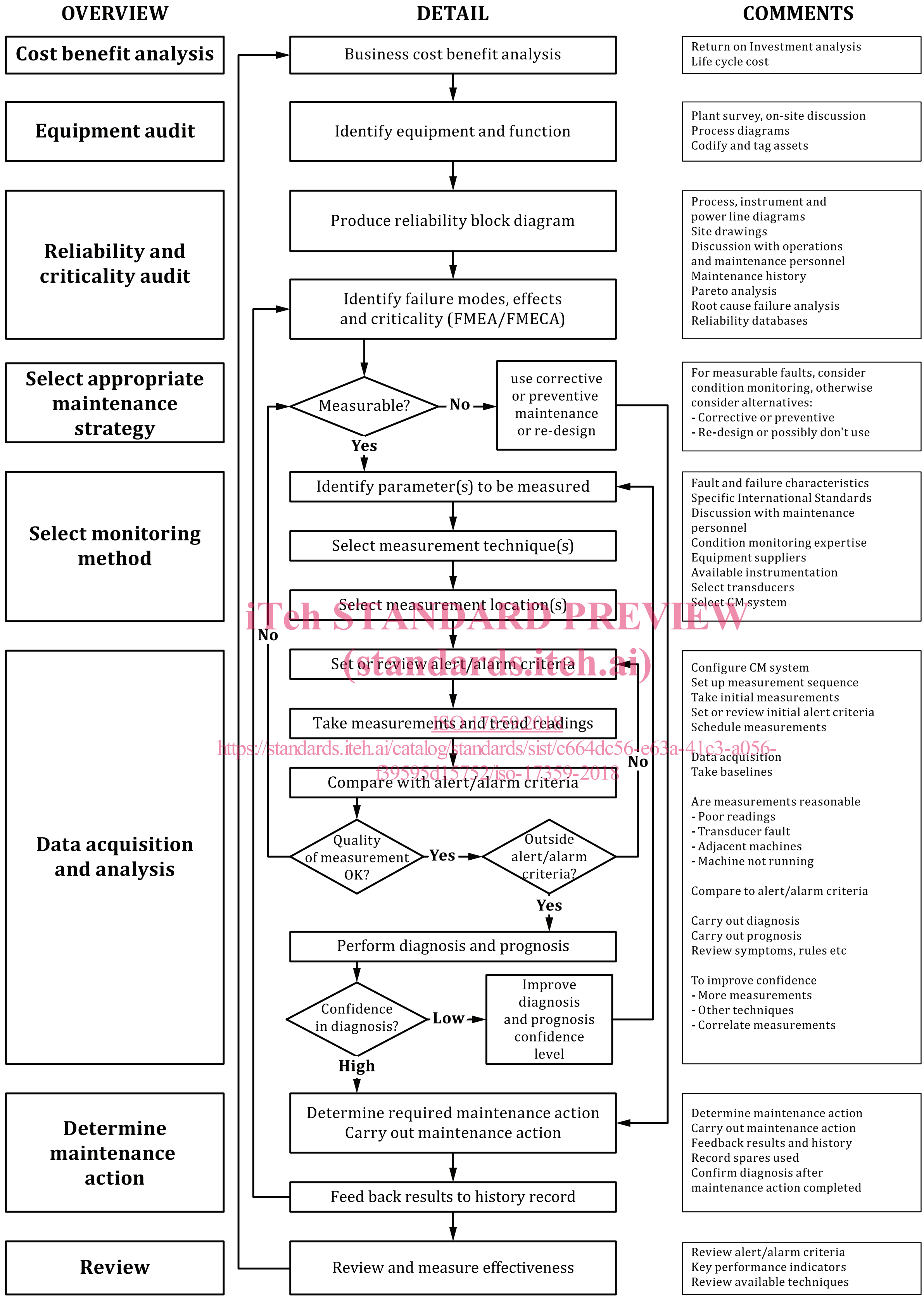




**Figure 1 — Condition monitoring procedure flowchart**

## 5 Cost benefit analysis

An initial feasibility and cost benefit analysis helps in establishing accurate key performance indicators and benchmarks to measure the effectiveness of any condition monitoring programme. Items to consider include the following:

a) life cycle cost;

b) cost of lost production;

c) consequential damage;

d) warranty and insurance.

## 6 Equipment audit

### 6.1 Identification of equipment

A generic machine schematic of the typical components and processes to be considered in the condition monitoring management process is shown in Figure 2.

List and clearly identify all equipment and associated power supplies, control systems and existing surveillance systems.

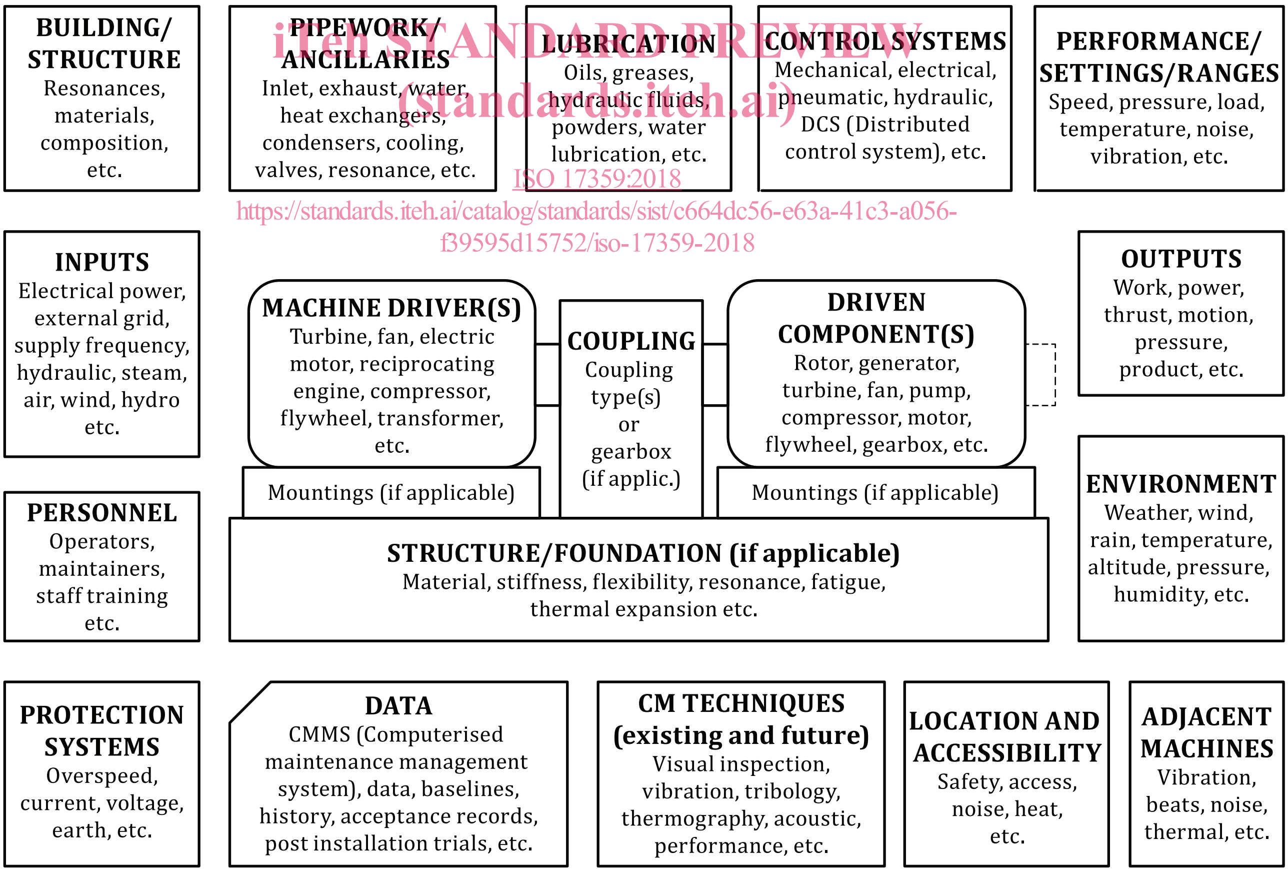




**Figure 2 — System factors influencing condition monitoring**

### 6.2 Identification of equipment function

Identify the following information.

a) What is the system, machine or equipment required to do?

b) What are the machine or system operating conditions or range of operating conditions?

## 7 Reliability and criticality audit

### 7.1 Reliability block diagram

It can be useful to produce a simple high-level reliability block diagram, including whether the equipment has a series or parallel reliability effect. The use of reliability and availability factors is recommended to improve the targeting of the condition monitoring processes.

Detailed information on producing reliability block diagrams is contained in references in the Bibliography.

### 7.2 Equipment criticality

A criticality assessment of all machines is recommended in order to create a prioritized list of machines to be included (or not) in the condition monitoring programme. This may be a simple rating system based on factors such as the following:



a) cost of machine down-time or lost production costs;

b) failure rates and mean time to repair;

c) redundancy;

d) consequential or secondary damage;

e) replacement cost of the machine;

f) cost of maintenance or spares;

g) life cycle costs;

h) cost of the monitoring system;

i) safety and environmental impact.

One or more of the above factors may be weighted and included in a formula to produce the prioritized list.

The results of this process may be used when selecting methods of monitoring (see Clause 8).

### 7.3 Failure modes, effects and criticality analysis

It is recommended that a failure modes and effects analysis (FMEA) or failure mode effect and criticality analysis (FMECA) be performed in order to identify expected faults, symptoms and potential parameters to be measured which indicate the presence or occurrence of faults.

The FMEA and FMECA audits produce information on the range of parameters to be measured for particular failure modes. Parameters to be considered are generally those which indicate a fault condition, by either an increase or a decrease in the particular or characteristic measured value or by some other change to a characteristic value such as pump or compressor performance curves, reciprocating internal combustion engine pressure-volume performance curves and other efficiency curves.

Examples of measured parameters which can be useful to consider for a range of typical machine types are given in Annex A.

 

Annex B contains an example of a form (Table B.1) which can be completed for each machine type, linking each fault to one or more symptoms or measured parameters showing the occurrence of the fault. Completed examples for the machine types shown in Annex A are included in Tables B.2 to B.11.

References to more detailed methods of carrying out FMEA and FMECA are given in the Bibliography.

### 7.4 Alternative maintenance tasks

If the failure mode does not have a measurable symptom, it might be necessary to apply alternative maintenance strategies. These include burn-in (initial testing), run to failure, corrective maintenance, preventive maintenance or modification (design out).

## 8 Monitoring method

### 8.1 Measurement technique

For the particular measurable parameter considered to be applicable following the previous selection process, one or more measurement techniques can be appropriate. Measured parameters can be simple measurements of overall values or values averaged over time. For certain parameters, such as current, voltage, and vibration, simple measurements of overall values might not be sufficient to show the occurrence of a fault. Techniques such as time, spectral and phase measurement can be required to reveal changes caused by faults.

Examples of monitored parameters useful to consider for a number of machine types are given in Annex A. Examples of standards which can be useful in the identification of particular measurement methods and parameters for different machine types are included in the Bibliography.



The range and application area of International Standards relating to condition monitoring and diagnostics are shown in Annex D.



Condition monitoring systems can take many forms. They can utilize permanently installed, semi-permanent, or portable measuring instrumentation, or can involve methods such as sampling fluids or other materials for local or remote analysis.

### 8.2 Accuracy of monitored parameters

In most cases, the accuracy required of the parameters to be used for machine condition monitoring and diagnosis is not necessarily as absolute as the accuracy which might be required for other measurements such as performance testing. Methods using trending of values can be effective where repeatability of measurement is more important than absolute accuracy of measurement. Correction of measured parameters, e.g. to standard atmospheric conditions of pressure and temperature, might not necessarily be required for routine condition monitoring. Where this is required, advice is given in the appropriate acceptance testing standard. A selection of International Standards relating to performance and acceptance testing is included in the Bibliography.

### 8.3 Feasibility of monitoring

Consideration should be given to the feasibility of acquiring the measurement, including ease of access, complexity of the required data acquisition system, level of required data processing, safety requirements, cost, and whether surveillance or control systems exist that are already measuring parameters of interest. Examples of faults and the parameters to be measured to detect them are given by machine type in Annex B. Although presented by machine type, it is recommended that the complete machine system be included in the decision and monitoring process.

 

### 8.4 Operating conditions during monitoring

If possible, monitoring should be carried out when the machine has reached a predetermined set of operating conditions (e.g. normal operating temperature) or, for transients, a predetermined start and finish condition and operating profile (e.g. coast down). These are also conditions which can be used for a specific machine configuration to establish baselines. Subsequent measurements are compared to the baseline values to detect changes. The trending of measurements is useful in highlighting the development of faults.

Measurements of different parameters should be taken wherever possible at the same time or under the same operating conditions. For variable duty or variable speed machines, it might be possible to achieve similar measurement conditions by varying speed, load or some other control parameter.

It is also important to be able to determine if a change in one or more parameters is due to the occurrence of a fault or is due to a change in duty or operating conditions.

### 8.5 Monitoring interval

Consideration should be given to the interval between measurements and whether continuous or periodic sampling is required. The monitoring interval primarily depends on the type of fault, its rate of progression and, thus, the rate of change of the relevant parameters. The elapsed time between the fault detection and actual failure is known as the lead time to failure (LTTF) and particularly influences the measurement interval (frequency of measurements) and type of monitoring system necessary to detect the particular fault syndrome.

However, the monitoring interval is also influenced by factors such as the operating conditions (e.g. duty cycles), cost, and criticality. It is useful to include these factors in the initial cost benefit analysis or criticality analysis.



### 8.6 Data acquisition rate

For steady-state conditions, the data acquisition rate should be fast enough to capture a complete set of data before conditions change. During transients, high-speed data acquisition might be necessary.

### 8.7 Record of monitored parameters

Records of monitored parameters should include, as a minimum, the following information:

a) essential data describing the machine;

b) essential data describing operating conditions;

c) the measurement position;

d) the measured quantity units and processing;

e) date and time information.

Other information useful for comparison includes details of the measuring systems used and the accuracy of each measuring system. It is recommended that details of machine configuration and any component changes also be included. Annex C gives typical information which should be recorded when monitoring and Table C.1 shows an example of a typical form for recording asset and measurement data.

### 8.8 Measurement locations

Measurement locations should be chosen to give the best possibility of fault detection. Measurement points should be identified uniquely. The use of a permanent label or identification mark is recommended.

 