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Contents

	Page
Foreword	III
Introduction	1
1 Scope	1
2 Normative references	1
3 Terms and definitions	2
4 Maintenance strategy	4
4.1 General	4
<i>Figure 1 — Flowchart for classification of maintenance priority</i>	4
4.2 Maintenance plan	5
<i>Figure 2 — Management of maintenance of machinery</i>	5
4.3 Maintenance approach	7
<i>Figure 3 — Planned preventive maintenance process</i>	8
<i>Figure 4 — Planned predictive maintenance process</i>	9
5 Determining maintenance tasks	10
5.1 General	10
5.2 Scheduling tasks	11
<i>Figure 5 — Example of an established methodology for scheduling tasks</i>	11
6 Specific maintenance requirements	13
6.1 General	13
6.2 Machine electrical maintenance	13
6.3 Maintenance of software	15
6.4 Lubrication	17
6.5 Pipework and hose assemblies	17
6.6 Remote maintenance	19
6.7 Replacement and spare parts	19
7 Ongoing review	20
7.1 General	20
7.2 Maintenance records (for the task undertaken)	20
7.3 Record format/medium	20
7.4 Environmental conditions	20
7.5 Factors influencing human error in maintenance	21
<i>Figure 6 — Assessment of human interaction</i>	22
<i>Figure 7 — Human individual factors</i>	24
7.6 Change of use/modification	24
7.7 Maturity assessment of ageing machinery	25
7.8 Monitoring the performance of the maintenance system	25
7.9 Root cause failure analysis	26
7.10 Remaining operating life	28
Annex A (informative) Maturity risk assessment	29
<i>Table A.1 — Example process map and audit tool for revalidation of machinery</i>	31
Annex B (informative) Non-destructive testing (NDT)	33
Annex C (normative) Pipework and hose assemblies	37
Annex D (informative) Management of spare parts	38
Annex E (informative) Contract maintenance	39
Annex F (informative) Example of a competence matrix	40
<i>Figure F.1 — Example of competency (KSE) matrix for a specific task</i>	40

Annex G	(informative) Analysis of potential cause of failure	41
	<i>Figure G.1 — Fishbone diagram to analyse cause and affect</i>	41
	<i>Figure G.2 — Bearing illustration</i>	43
	Bibliography	46

Summary of pages

This document comprises a front cover, an inside front cover, pages I to IV, pages 1 to 47, an inside back cover and a back cover.

Foreword

Publishing information

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The provisions of this standard are presented in roman (i.e., upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is “shall”.

Commentary, explanation, and general informative material is presented in smaller italic type and does not constitute a normative element.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. “organization” rather than “organisation”).

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Introduction

This British Standard provides guidance to those responsible for advising or managing the ongoing maintenance requirements of machinery (including associated work equipment and pressure components) after it is placed into service, so that it remains safe, reliable and in good repair.

The expectation is that machinery once commissioned and placed into service is fully functional. Age and duty are important factors when assessing the maintenance regime for a piece of machinery. Typically, as equipment continues to be operated, it is often assumed that equipment wears out, with its reliability being reduced solely as a result of increased age and cumulation of service. Accordingly, processes need to be in place to identify and monitor the decay, to adjust the inspection and maintenance frequencies, as appropriate, so that the equipment continues to operate in a safe and reliable condition by acting in good time.

Whilst some maintenance regimes focus on determining the age at which machinery is likely to fail, this British Standard also takes into account other relevant factors, such as environmental influences and the human factors relating to how interventions are identified and how the competence of persons undertaking the tasks are identified and reviewed. Further emphasis is given to investigating the root cause of component failures, so that repeat failures can be eliminated and lessons learnt and acted upon.

1 Scope

This British Standard specifies requirements for the approaches to be taken so that machinery remains in a safe, reliable and effective condition throughout its working life.

It applies to powered machinery, including all elements of the machinery (e.g. pipework, hoses and vessels), where deterioration of the equipment performance could expose persons to a significant increase in risk to their health and safety.

NOTE This British Standard can also be applied to manually powered machinery outside the scope of the Supply of Machinery (Safety) Regulations 2008 [1].

This British Standard is relevant to those advising, planning, preparing and supervising the maintenance of machinery. It is intended to supplement specific manufacturer instructions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions, or limits the application, of this document¹⁾. For dated references, only the edition cited applies. For undated references, the latest edition of the reference document (including any amendments) applies.

[BS EN 1829-2:2008](#), *High-pressure water jet machines – Safety requirements – Part 2: Hoses, hose lines and connectors*

[BS EN ISO 9712](#), *Non-destructive testing – Qualification and certification of NDT personnel*

[BS EN ISO 13849-1:2023](#), *Safety of machinery – Safety related parts of control systems – Part 1: General principles for design*

[BS EN IEC 60812](#), *Failure modes and effects analysis (FMEA and FMECA)*

¹⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

3 Terms and definitions

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

3.1 breakdown maintenance

repair in reaction to the failure of machine parts or assemblies

NOTE Typically by replacement or repair of affected parts in response to an unplanned event.

3.2 design life

original equipment manufacturer (OEM) and/or manufacturer's predicted number of operating cycles or the theoretical design life expectancy of a machine, or parts and assemblies used in a machine

NOTE Design life is based upon factors that could include a combination of:

- a) expected life of the machine;
- b) manufacturer's datasheets;
- c) theoretical analysis, such as mechanical stress and fatigue calculations, etc.;
- d) duty cycle; and
- e) intended environmental and operating conditions.

3.3 failure mode, effects and criticality analysis (FMECA)

technique designed to identify:

- a) potential failures;
- b) possible effects of those failures; and
- c) the causes of failures

3.4 machine

apparatus consisting of:

- a) powered assembly or components, the failure or deterioration of which endangers the safety of persons;
- b) accessory connected to, or which could be connected to, a machine for the purposes of transporting or storing energy;

NOTE 1 Examples include pipework, air receivers, etc.

- c) safety components; and
- d) lifting accessories

NOTE 2 Attention is drawn to the Supply of Machinery (Safety) Regulations 2008 [1] regarding the definition of installed machinery.

3.5 maintenance plan

intended/actual approach for the preservation of machinery in a safe and efficient working state through a series of pre-determined inspections, tests and interventions

NOTE The maintenance plan sets out how the overarching maintenance strategy is achieved. Within the maintenance plan there are scheduled tasks that set out intended activities to be undertaken to achieve the maintenance plan.

3.6 maintenance strategy

defined goals for machinery operability and safety

3.7 mission time

period of time covering the intended use of a safety related part of a control system (SRP/CS)

NOTE A maturity risk assessment might be required to extend the mission time.

3.8 modification

change to the configuration, assembly or function of a machine from its original or pre-existing state

3.9 original equipment manufacturer (OEM)

organization that produces or approves parts or assemblies under its own name

3.10 planned maintenance

routine checking of equipment to reduce the risk of unexpected deterioration or failure of machinery

3.11 predicted operating life

anticipated duration of the machine's ability to work in a safe, efficient condition and in good repair

NOTE The knowledge of the future condition of the machine, based on OEM expectations adjusted through the actual learning of the ongoing machine condition and estimated rate of decay.

3.12 predictive maintenance

maintenance activities that are scheduled when sufficient deterioration is anticipated or needed to repair, renew or replace component parts before failure

3.13 preventive maintenance

maintenance activities scheduled at regular (periodic) intervals to repair, renew or replace component parts to prevent failure

3.14 reactive maintenance

intervention activity carried out in response to events, before a machine has a complete breakdown or failure

3.15 root cause analysis (RCA)

wide range of approaches, tools and techniques used to uncover the underlying cause(s) of problems (typically failures) with machinery

3.16 run-to-failure

situation where a machine is allowed to run until it breaks down

NOTE Run-to-failure might be catastrophic in nature.

3.17 safety critical part(s)

component or assembly, the failure or malfunction of which endangers persons

NOTE It is expected that the intended OEM risk reduction measures for safety critical part(s) are implemented in order to prevent exposure of personnel to hazards.

3.18 single point of failure (SPOF)

reliability of the machine or its components, where if an individual part of that machine or system fails, the entire machine or system cannot continue to work/function

3.19 substantial modification

change of a machine by physical or digital means not foreseen or planned by the OEM/manufacturer, and which affects the safety of a machine by creating a new hazard, or by increasing an existing risk, requiring the:

- a) addition of guards or protective devices to a machine, which necessitates the modification of the existing safety control system; or
- b) adoption of additional protective measures to provide the stability or mechanical strength of a machine

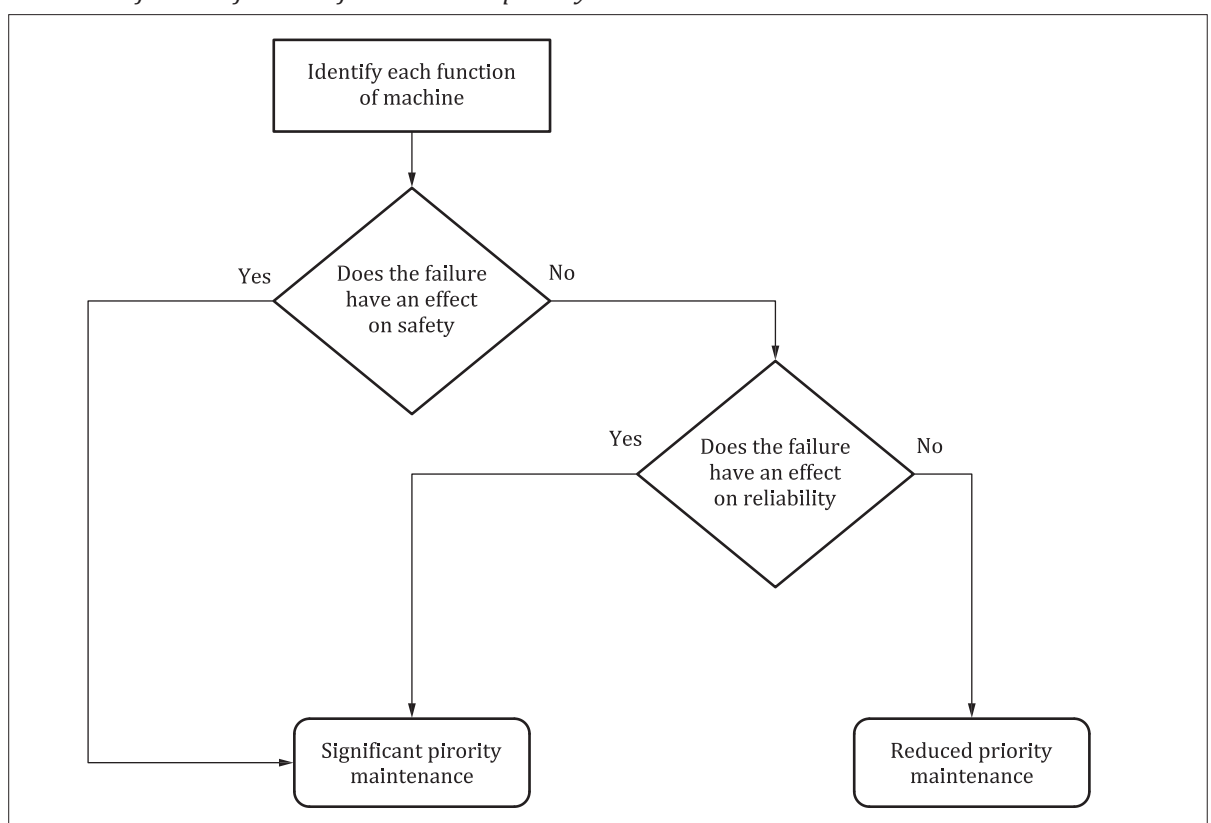
4 Maintenance strategy

4.1 General

The user shall identify the required outcomes for performance, resource input (financial and human resources) and machine availability, in order to define the overall priority for a sustainable maintenance system.

NOTE 1 Such an approach is intended to minimize risk though targeting matters of machine safety and reliability. This approach is illustrated in Figure 1, where a machine (or process) is considered through the interaction of individual machine elements and/or component parts.

Figure 1 — Flowchart for classification of maintenance priority



NOTE 2 There are differences between safety and reliability issues, however some maintenance routines affect both the way the equipment works and its safety. The reliability of safety-related components, such as, guarding interlocks, pressure relief valves, temperature and pressure limit sensors, etc. is crucial to the ongoing safety of machinery, e.g. where the passenger lift develops a fault, allowing landing doors to open when the lift car is not present, creates an immediate safety risk. Reliability issues affect non-safety-critical and safety-critical components alike.

NOTE 3 Reliability issues might or might not necessarily be limited to matters concerning the production efficiency of a machine, e.g. where a passenger lift develops a fault and responds by securing the access doors in the closed position, then descending in a controlled manner to remain at rest (with or without persons inside) it has behaved in a safe way, as persons within are not exposed to danger. The issue at this stage is one of operability of the lift, i.e. reliability, as it is no longer able to carry out its intended function.

4.2 Maintenance plan

4.2.1 General

The user shall assess the structural components, fixed and moving parts of each machine, to identify the expected lifetime.

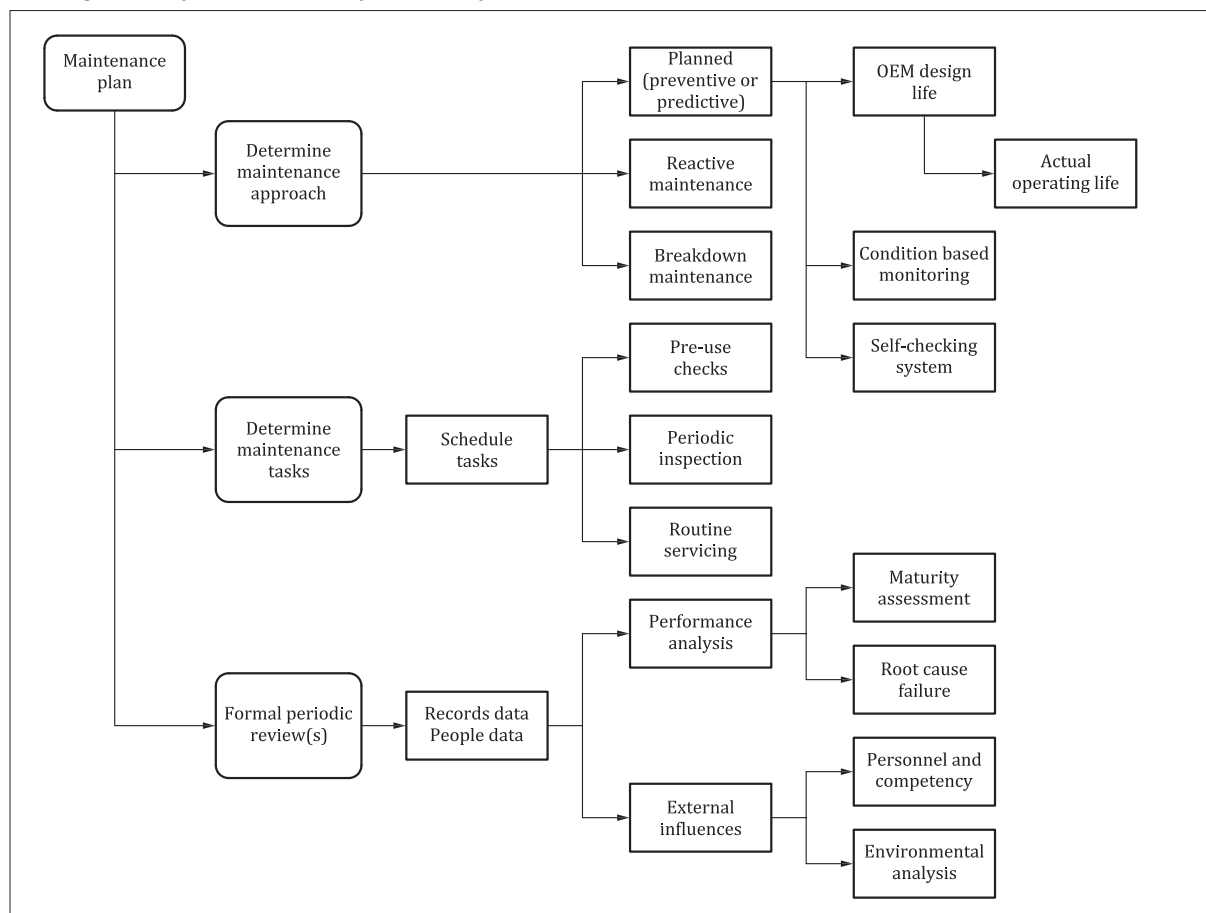
NOTE 1 This might consist of a theoretical design life assessment, which should be subsequently evaluated in order to derive a predicted operating life.

Having established a predicted operating life, the user shall determine the most suitable approach for the ongoing optimization, reliability, and safety, appropriate to the type of machinery elements (see [Figure 2](#)).

To continue to meet the specific outcomes of the strategy, the user shall continue to monitor, adapt, or change elements of the plan.

NOTE 2 This ongoing review is often informal and carried out on a continual basis. A formal re-assessment of the maintenance plan can only be undertaken as operational and maintenance history becomes available, or significant concerns arise. Formal review of the maintenance plan is detailed in [Clause 7](#) and due to the extensive nature of this re-evaluation, is realistically only possible to undertake on a periodic basis (determined by whether it achieves the maintenance strategy).

Figure 2 — Management of maintenance of machinery



4.2.2 Original equipment manufacturer design life

The user shall, where possible, obtain essential details of the theoretical design life to determine the original equipment manufacturer (OEM) intended lifetime of the overall machine.

NOTE 1 The OEM determines the foreseeable lifetime of the machinery, based on theoretical design life, involving calculation of operational factors, including corrosion, mechanical stresses and degradation, cyclic operation, environmental and transportation loads, the choice of components and the drafting of the maintenance instructions, etc. The manufacturer should specify the foreseeable lifetime in the technical file if it has a bearing on the integration of safety into the design and to justify certain choices. Whilst it is good practice for the OEM to make users aware of specific requirements relating to the continued safe operation of a machine, there is no obligation to inform the client thereof, unless the manufacturer believes the need to inform users of the residual risk due to any shortcomings of the protected measures adopted.

Based on the OEM design life, the user shall evaluate how safety and reliability issues, such as those resulting from a single point of failure (SPOF) are intended to be minimized, documenting these instructions accordingly.

NOTE 2 SPOF should have been evaluated at the design stage; the user should consult with the manufacturer to clarify machine vulnerabilities to determine the intended basis of safety. Potentially, a product safety recall might be appropriate.

The user shall identify and document, as part of the instruction manual, the manufacturer's recommended maintenance requirements, based on the criteria specified within the OEM design life, to include structural components, fixed and moving parts of the machine.

The instruction manual shall include, where applicable, the following information, as a minimum:

- a) description of the adjustment and maintenance operations to be carried out by the user and the preventive maintenance measures to be observed, together with the recommended periodicity of such intervention, adjustment or maintenance;
- b) instructions designed to enable adjustment and maintenance to be carried out safely, including the protective measures to be taken during these operations; and
- c) the specifications of the spare parts to be used, when these affect the health and safety of operators.

The user shall identify the manufacturer's intended purpose and/or limitations of use of the machine, in order to determine the suitability for intended application.

NOTE 3 When designing and constructing machinery, including drafting instructions, the responsible person should envisage not only the intended use of the machinery but also reasonably foreseeable misuse thereof.

Where the manufacturer is unable to/does not provide a design life, the user shall take a first principles approach using comparator benchmarks and references to evaluate a generic design life and review all stated conditions within this subclause.

4.2.3 Predicted operating life

The user shall take into account the intended use(s) the machine, in what application, environment, how often it is to be used, etc., which assists in determining the predicted operating life.

NOTE 1 Evidence could be obtained from comparison to similar machines in the absence of actual service history.

Where the machine's history is unknown and/or there is insufficient information, the basis of safety shall be applied from first principles and reflect the impact from site-specific criteria; this could be achieved through a maturity risk assessment (see [Annex A](#) for an example of this process).

The user shall periodically review the actual tasks for which the machine is used, in order to evaluate whether the machine remains within the intended purpose and/or limitations of use criteria specified by the OEM design life, or if additional maintenance issues have been created.

NOTE 2 Equipment needs to be suitable, by design, construction or adaptation, for the actual work it is provided to do, meaning that where work equipment is provided, the user should confirm it is suitable for the work being undertaken and is used in accordance with the manufacturer's specifications and instructions. If work equipment is adapted, it still needs to be suitable for its intended purpose.

The user shall determine the acceptability of the operational life of machinery by evaluating the effectiveness of the maintenance plan for the intended reliability and safety based on:

$$\text{OEM design life} \pm \text{intended application} = \text{actual operating life}$$

Where the user deviates in the intended application, based on the limitations of use specified by the OEM (on which the OEM design life is based), a further assessment relating to change of use shall be carried out.

4.3 Maintenance approach

4.3.1 General

Based upon the maintenance strategy, the user shall identify one or more of the maintenance approaches provided in this British Standard, in order to achieve the desired outcomes of the maintenance plan.

NOTE Approaches can consist of planned, reactive and breakdown elements, as shown in [Figure 2](#).

4.3.2 Planned maintenance

A schedule of preventive and/or predictive tasks shall be prepared so that the planned maintenance regime is regularly monitored, and frequencies adjusted, as appropriate, to confirm that:

- a) the maintenance regime remains suitable and sufficient to prevent unexpected outage or performance decay;
- b) intervention through maintenance work is carried out in a timely and effective manner;
- c) underlying trends, repeat problems, maintenance inadequacies, safety and reliability issues, etc. are identified in good time;
- d) significant changes to the amount of use of the machine (e.g. an increase or decrease load or duty cycle, etc.) are reflected in the maintenance schedule;
- e) when necessary, the maintenance schedule is updated to correct deficiencies in the schedule or address issues arising from previous maintenance work; and
- f) the OEM design life is reviewed, taking into account how the machinery is being used in order to review the actual operating life.

NOTE Planned maintenance is intended to target intervention before failure or breakdown occurs. There are two types of planned maintenance process – either predictive or preventive. Both are evolving processes that monitor the machine condition, utilizing information, and involve proactive replacement of those elements that have deteriorated.

4.3.3 Planned preventive maintenance

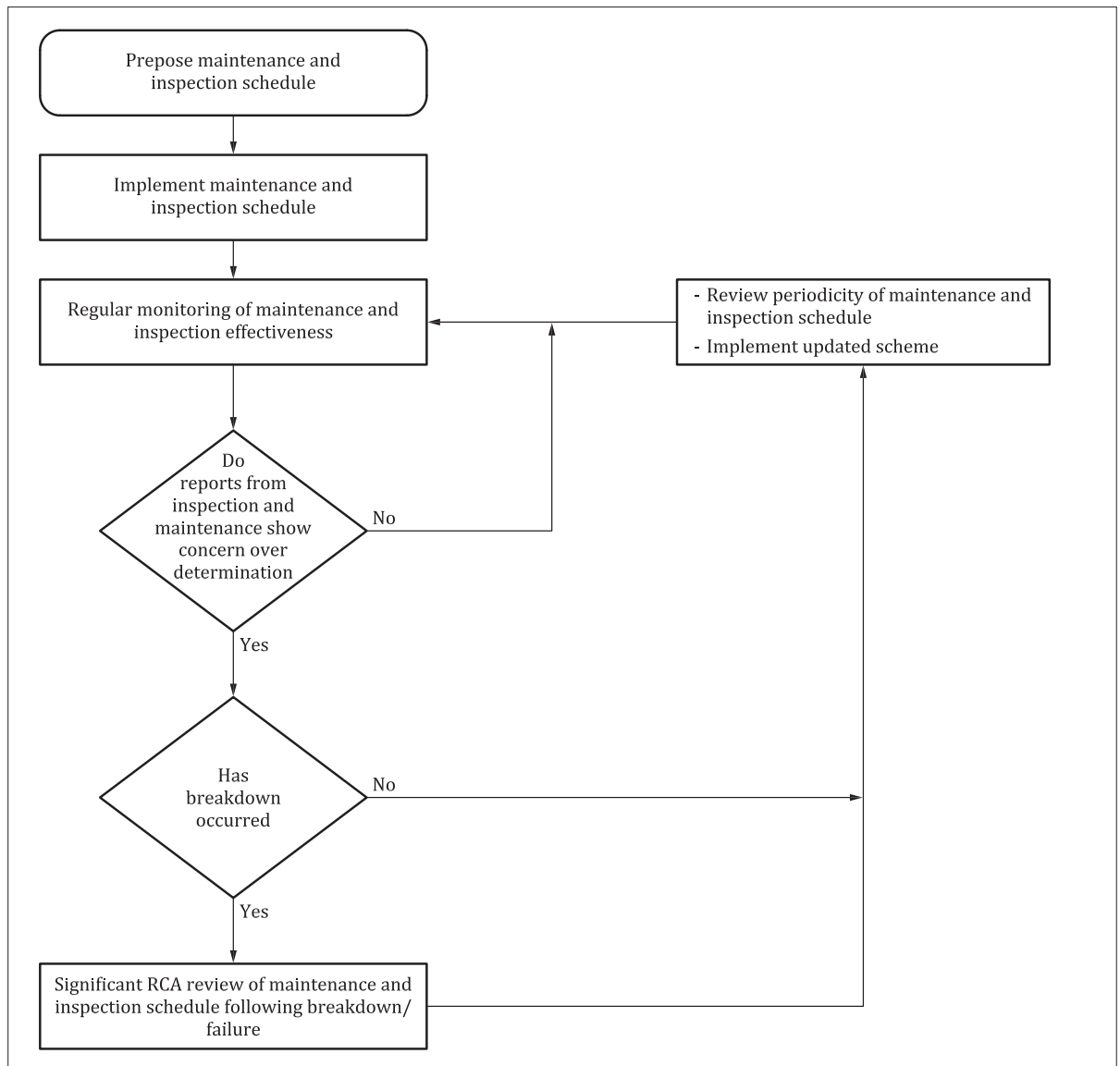
The user shall schedule intervention work based on periodic/calendar-based time or machinery runtime (see [Figure 3](#)), taking into account the OEM design life.

NOTE Where breakdowns or unplanned downtime are to be decreased, a solution would be to implement a planned preventive (PM) program for the safety or reliability critical assets. Work orders are scheduled for

inspections, parts replacement, lubrication, etc., based on recommendations from an OEM design life. Often PM maintenance implementation costs are less than predictive.

The user shall identify items of equipment, e.g. fire pumps, which have a low demand and high consequence if inoperable when required. The user shall schedule specific maintenance for these items of equipment.

Figure 3 — *Planned preventive maintenance process*

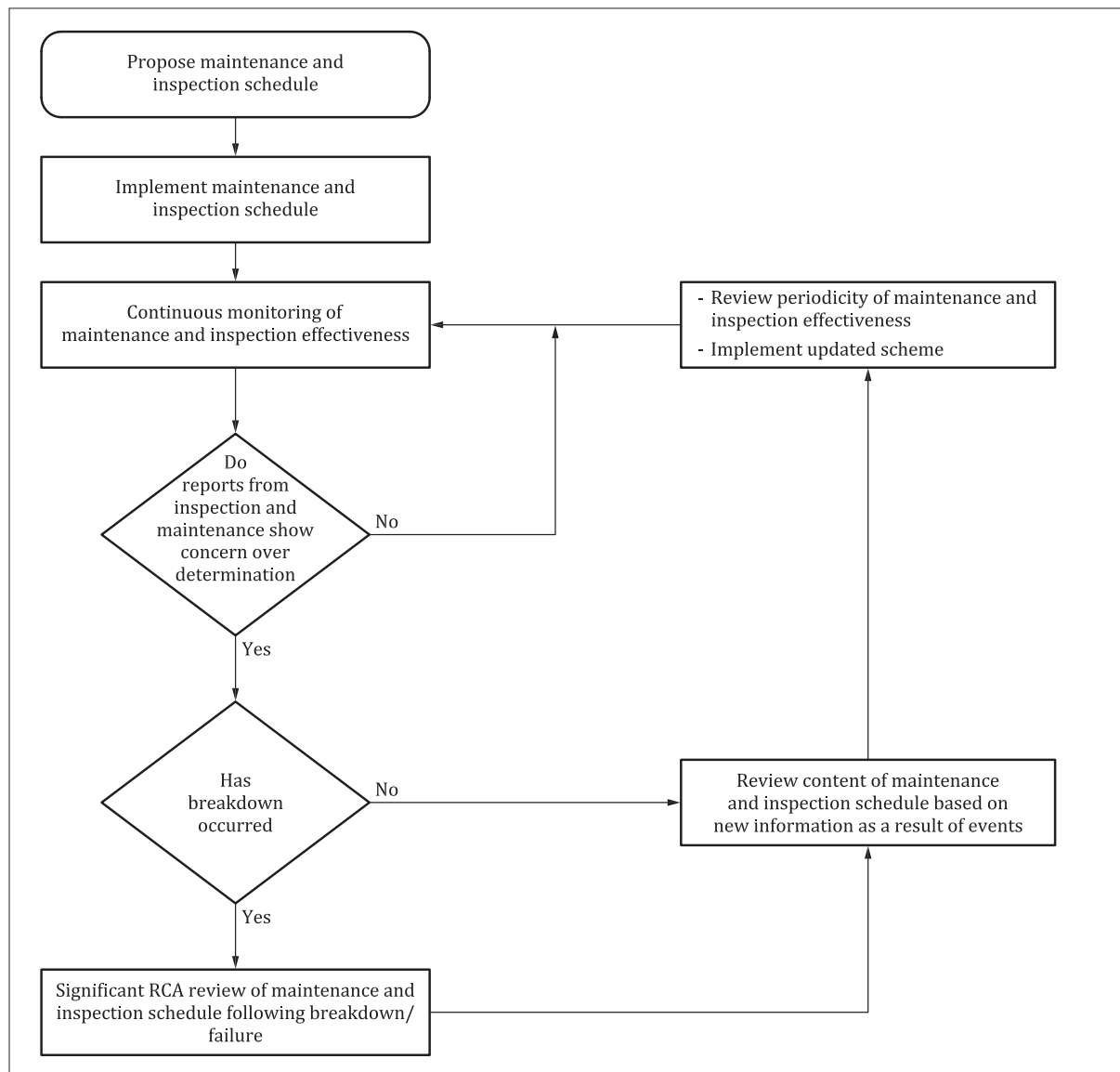


4.3.4 Planned predictive maintenance

COMMENTARY ON 4.3.4

Predictive maintenance relies on condition-based monitoring, which involves a significant element of non-destructive testing (see [Annex B](#)). This is likely to be an ongoing, evolving process.

The user shall determine a proactive interval for repair or replacement, based on the ongoing monitoring of components, by following the steps in [Figure 4](#), to optimize the useful function of wearing parts, whilst not compromising the ongoing reliability or safety of machinery by forecasting the likely timescale to failure.

Figure 4 — *Planned predictive maintenance process*

4.3.5 Reactive maintenance

The user shall take into account adopting a passive arrangement for machinery or related work equipment which meet the following criteria:

- a) not essential to ongoing safety or operational reliability;
- b) have a low repair cost; and
- c) do not incur significant repair costs.

NOTE 1 Although reactive maintenance is largely based on an unscheduled timetable, it still needs to be planned. It is an approach deployed by organizations to provide regular maintenance of equipment and machinery and which can be a suitable strategic approach under the right circumstances. In asset-heavy industries, such as manufacturing and engineering, the reliability and availability of assets are critical. This is why organizations require an effective maintenance schedule to keep machines and assets in constant working order, as well as meet production demands, keep up with competitors, and sustain growth.

Within the aspects of a reactive maintenance regime, the user shall subsequently select the most relevant measures to meet the criteria stated in a) to c) through emergency or corrective approaches.

NOTE 2 Reactive criteria listed in this subclause involves taking account of numerous factors that can be beyond user control. Technicians and in-field workers should be on hand to provide the necessary maintenance and repair support. Having the ability to react to situations such as this also means the user should have the initiative to recover quickly in an emergency.

4.3.6 Breakdown maintenance

The user shall identify machinery (or parts thereof) where there is no major consequence from outage, or failure does not compound or lead to other issues (i.e. upstream or downstream) based on the maintenance strategy; in such circumstances, the user can continue to run such equipment until it fails and parts are subsequently repaired or replaced as they arise.

NOTE 1 This type of maintenance work is the most difficult to manage as it might not be foreseen where and when the failure might occur. Relying solely on breakdown maintenance inevitably results in unexpected down time and/or catastrophic failure.

The purpose of repair is to restore a machine (or part of a machine) back to its original state of full functionality; where the repair of a safety-related part is not by replacement but involves some form of salvage action, repairs shall be designed, documented and approved by a suitably competent person or organization.

NOTE 2 The ability to restore full functionality is based upon the point of breakdown, which might be further limited if a run-to-failure has taken place. Where full functionality cannot be achieved, a review of the consequences for returning the repair into service is necessary so that residual safety or reliability are not compromised to below an acceptable level (determined by the maintenance strategy).

5 Determining maintenance tasks

5.1 General

The user shall identify the tasks required to maintain machinery in a safe and reliable condition, including, but not be limited to:

- a) carrying out a risk assessment of maintenance tasks to prevent exposure to hazards;
- b) the potential for harm in the event of a failure;
- c) taking into account the control of hazardous energy;

NOTE 1 See [BS 14100](#) for further guidance on the control of hazardous energies.

- d) the need to maintain cost-effective production; and
- e) the necessity to maintain emissions within appropriate environmental standards, etc.

NOTE 2 The main factors (non-exhaustive list) include:

- a) the manufacturer's maintenance information;
- b) how the machine could deteriorate based on how it's being used; and
- c) the potential for harm associated with equipment failure or deterioration.

NOTE 3 The extent and complexity of maintenance can vary substantially from simple checks on basic equipment to integrated programmes for complex plants. In all circumstances, for maintenance to be effective, it needs to be targeted at the parts of work equipment where failure or deterioration could lead to reliability, health and safety risks.

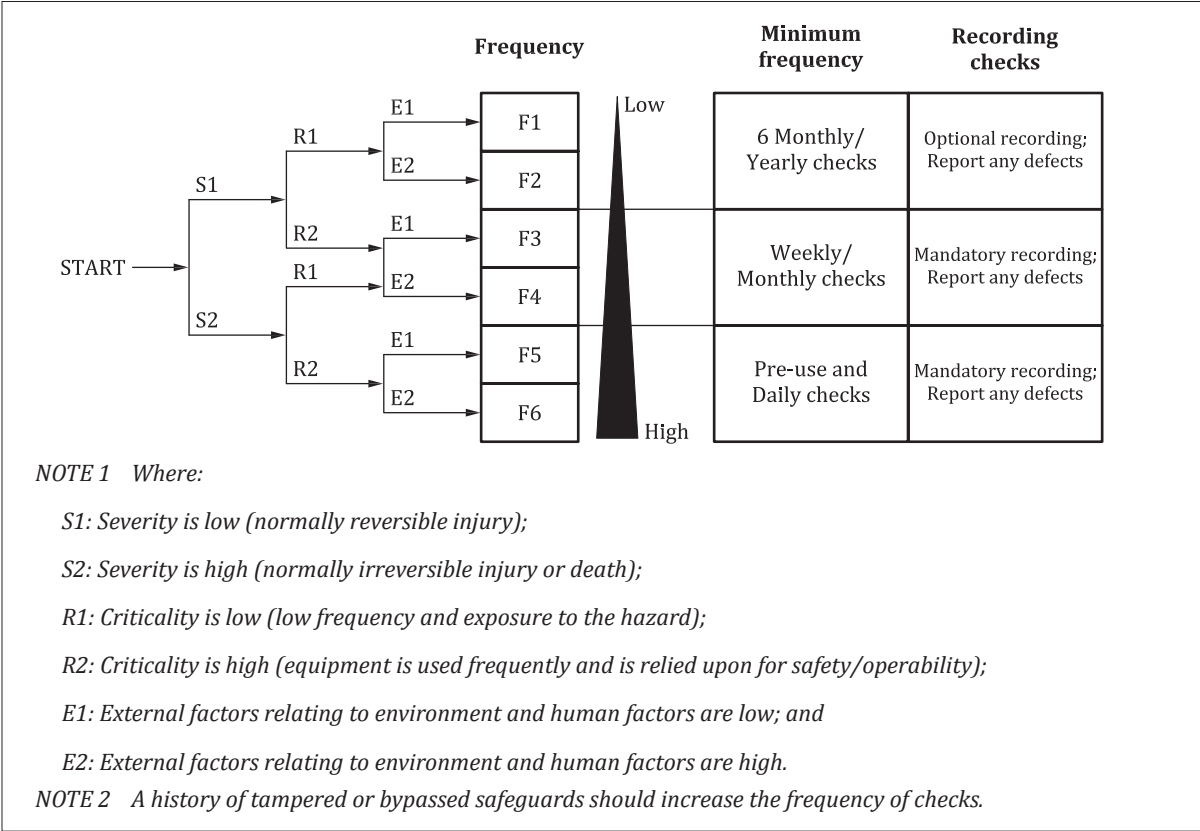
5.2 Scheduling tasks

5.2.1 General

The user shall record the details and frequency of required maintenance tasks, such as inspections, tests or interventions in a maintenance schedule. To identify which maintenance tasks are needed, the user shall include details of inspections, tests or interventions necessary to maintain the machine in a safe and reliable condition. To establish task frequency, relevant parameters shall be applied to reflect the maintenance strategy.

NOTE 1 An example methodology is shown in Figure 5 where different frequencies can be selected by a user.

Figure 5 — Example of an established methodology for scheduling tasks



The user shall carry out an assessment to determine a suitable schedule, taking into account the intensity of use, likely misuse, operating environment and variety of operations, including factors such as:

- a) what machinery preparations are required for repair;
- b) what resources are required for repair;
- c) factors which are different to or exceed the manufacturer's operating limitations;
- d) the environment in which the machine is to operate;
- e) actual duty and load cycles;
- f) component life and what failure could occur;
- g) competence of persons undertaking the maintenance work; and
- h) other site-specific application requirements.

NOTE 2 Such site-specific information would not necessarily be available to the manufacturer.