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Cranes — Monitoring for crane design working period

Appareils de levage à charge suspendue — Surveillance continue de la période d'activité de conception

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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 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 meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 96, *Cranes*, SC 5, *Use, operation and maintenance*.

ISO 12482 cancels and replaces ISO 12482-1:1995, which has been technically revised.

Introduction

Cranes are designed for a finite lifetime duty, which is specified in load cycles and load spectrum and is not principally related to calendar working time. Classification of crane duty provides the crane owner a means to specify the intended duty in order to achieve the intended useful operational lifetime of the crane.

Typically the operational period for industrial cranes is from 10 to 20 years. However, a specified crane classification may be related to any calendar time depending on the application, e.g. 5 to 10 years for a special limited use or 40 years for a long-term investment.

Monitoring of crane use does not in any way change requirements for periodic inspections of the cranes, independent of whatever type of instruments are used for the monitoring. Neither does it remove the requirement for regular maintenance of cranes. Inspections and monitoring of use are methods, which complete each other, giving different information of the condition.

The design working period (DWP) introduced in this standard is derived from the design classification of cranes and is not to be considered as a guaranteed operational period in any respect. Due to the probabilistic nature of metal fatigue and other influencing factors, premature failures during the DWP cannot be ruled out. However, the DWP represents a reliable estimate of a safe operational period of the crane, with due consideration to specified design regulations and standardized design safety factors.

Cranes — Monitoring for crane design working period

1 Scope

This International Standard specifies a method for monitoring, during long-term operation, the actual duty of the crane, and a means of comparing this to the original design duty which was specified through classification. The related design standard is ISO 4301-1. Approaching the design life limit means an increased probability of hazards. Monitoring of crane use — as described herein — provides a tool for predicting the approach of the design limits and for focusing special inspections on the critical areas of a crane.

This International Standard is intended to be used for adjusting/modifying the inspections defined in ISO 9927-1.

It is applicable to cranes with a permanent construction throughout the life of the crane.

It is not applicable to mobile or tower cranes, except permanently installed tower cranes.

NOTE The method specified in this International Standard can be adapted to standards or rules other than ISO 4301-1 which specify classifications.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4301-1:1986, *Cranes and lifting appliances — Classification — Part 1: General*

ISO 4306-1, *Cranes — Vocabulary — Part 1: General*

ISO 9927-1, *Cranes — Inspections — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 4301-1, ISO 4306-1 and the following apply.

3.1
design duty
production capacity of a crane or hoist during its total useful operational period, specified by the original design classification

3.2
design life
estimation of the allowable period of use for a crane based on its original design specifications and taking into consideration the load cycles and load spectra expected during its intended usage

3.3
design working period
DWP
operation period in a specific actual duty, within which the design duty is reached

3.4
special assessment
SA
thorough examination and evaluation of the crane or hoist, to be made when the actual crane or hoist duty approaches the design duty

3.5
general overhaul
GO
all refurbishment and maintenance actions based upon a special assessment (SA), required to extend the safe operation life of a crane

3.6
work cycle
operating sequence starting from hoisting a load, transferring the load, lowering and grounding the load, detaching the load and moving the unloaded load lifting attachment back to a starting position ready to hoist another load

4 Recording crane operation

4.1 General

The crane owner should keep records of the crane use, adequate to identify the criteria specified by the crane manufacturer and applicable to carry out the assessments described in this standard. Records should also be kept of maintenance, inspections, repairs, modifications and exceptional occurrences, e.g. overloads, extreme climatic conditions and collisions. Records should be updated at least once a year during periodic inspections, see ISO 9927-1.

4.2 Methods for counting duty

Estimation of the duty history can be divided into the following categories, based on systematic and reliable data collection and documentation procedures.

a) Crane operation data are recorded by a special, purpose-built system, which always operates automatically when the crane is in use. The crane operator does not have a possibility to switch off the recording system.

b) The crane is provided with counters recording the crane operation data. The user collects and documents the operation data manually from the counters.

c) The crane duty history is calculated based upon a regular process in which the crane is working. The crane is an integral part of the process. Process data are documented.

d) The crane duty history is estimated based upon a general production data of the site where the crane is working.

e) The crane duty history is incomplete.

f) The crane duty history is unknown (e.g. in the case of a second-hand crane). The duty for DWP calculation is based on estimate or assumed to be according to design classification and design life reduced using the factor f_1 from Table 1, item 5.

The basic Information for counting the crane use is in all cases provided by the crane owner/user.

Where recording instruments or counters are installed, the user should regularly inspect the instruments to ensure that they are properly functioning.

4.3 Safety factor for duty counting

When calculating the design working period (DWP) of a crane, the estimated duty from the history shall be increased by a safety factor, f_1, according to Table 1, to cover the unreliability in the duty recording and estimation.

Table 1 — Safety factor f_1 for duty counting

No.	Method of duty recording	f_1
1	Automatic recording system, 4.2 a), or Counters and manual documentation, 4.2 b)	1,0
2	Estimation based upon a special, documented process, 4.2 c)	1,1
3	Estimation based upon documented production of the crane site, 4.2 d)	1,2
4	Estimation based upon undocumented, estimated production of the crane site, 4.2 e)	1,3
5	Crane duty history is unknown, 4.2 f)	1,5

5 Assessment of design working period

5.1 General

Many components of a crane may fail because of metal fatigue, which is difficult to predict or estimate by physical inspections. Safeguarding against fatigue failure by physical inspections may be difficult due to the following:

— the safe time window for an inspection from detectable to critical crack size can be short, leading to unnecessary frequent inspections;

— detecting a fatigue crack would require in many cases a full disassembly of a component;

— planning and scheduling future repairs of the crane is not possible, and non-acceptance by an inspection typically requires immediate action and possibly interruption of crane operation.

The purpose of the assessment of DWP is to estimate accumulated duty of the crane and assess its remaining life.

It is assumed that

— all periodic inspections scheduled for the crane have been carried out,

— any damage suffered during the operation is recorded and appropriately repaired, and

— maintenance work, as well as replacement of worn parts, is carried out in accordance with the manufacturer's instructions.

5.2 Schedule

Collecting the data on the use of a crane and the assessment of DWP should be carried out in conjunction with periodic inspections (see ISO 9927-1) at 12 month intervals.

5.3 DWP calculation method

The applied DWP calculation method should follow the specification and classification of the original design standard as closely as possible. Annexes A and B give DWP calculation methods for cranes classified and designed in accordance with ISO 4301-1.

The DWP calculation shall cover both the crane as a whole (structures) and the mechanisms.

The classification and design basis in the older standards might not be according to the state of the art. In order to have a solid theoretical basis for the DWP calculation, the owner may ask the manufacturer or an expert engineer (see ISO 9927-1) to conduct a re-calculation in accordance with the applicable crane standards.

6 Special assessment

6.1 General

The special assessment goes into more detail and deals with critical components of the structure/hoisting mechanisms of the crane. The special assessment shall contain both

— a theoretical part, where the remaining DWP of each critical component of the crane is analysed based on the recorded, actual duty, and

— a practical part, where the crane is subjected to a major inspection in accordance with ISO 9927-1.

Once it has reached the end of its design life, the crane may only be used after a general overhaul, based on a special assessment, has been carried out.

It should be recognized that the different components of the crane approach the design limits at different intervals, depending on the type of use and the configuration of the crane. These differences should be considered in the special assessment by selecting only the most critical components regarding the fatigue behaviour.

The theoretical analysis of the component's remaining DWP does not have to rely on the methods of the original design standard, but state-of-the-art methods may be applied instead. The revised analysis should take into consideration the actual, measured work cycles and their true effect on fatigue of the components. Information on use should be provided by the crane owner/user.

The special assessment shall be carried out by an expert engineer (see ISO 9927-1).

6.2 Criteria for special assessment

A special assessment shall be made to survey the condition of the crane, when the assessment of DWP indicates that the crane duty will reach one of the design limits prior to the next periodic inspection, or one or more of the following indicates it should be done earlier:

— any increase in the frequency of reported failures;

— significant increase of the loads;

— when a periodic inspection reveals a significant deterioration in the condition of the crane, e.g. failed or damaged elements, increase in vibration or displacement characteristics, corrosion;

— a significant modification of the crane configuration that changes the initial selection of critical components.

The first special assessment shall be performed no later than the specified operational lifetime of the crane or hoist as given by the manufacturer. For subsequent special assessments see 6.5.

In cases where the owner takes into operation a second-hand crane for which there is no information on earlier operation, the special assessment shall be made prior to taking the crane into use.

6.3 Responsibilities of crane user/owner

The crane owner is responsible for carrying out the periodic DWP assessments and for initiating the special assessment with possible consequent actions, including a general overhaul (GO).

The crane owner shall include the special assessment reports with the crane service documents as background information for future assessments.

The crane owner shall inform the expert engineer carrying out the special assessment about any modifications of the crane made after the crane was taken into use.

6.4 Manufacturer's instructions

The manufacturer shall provide the owner with the classification data necessary for the DWP assessment. This information shall be given in the owner's manual of the crane.

Additionally, the manufacturer should specify

— limits for exceptional conditions and loadings to which the crane is designed,

— a list of components and areas to be specially assessed,

— methods and acceptance criteria for physical inspections, and

— recommendations for a GO in respect of findings in the special assessment.

The expert engineer carrying out a special assessment is to rely on the design information provided by the manufacturer.

6.5 Report

A report of the special assessment shall be prepared. The report shall be kept with other service documents of the crane.

The report shall contain, at minimum, the following:

— a description of the criteria used;

— the results of the DWP analysis and significant findings in inspections;

— requirements for action to be taken to permit further use of crane, e.g. repair, change of inspection interval, reducing rated load;

— recommendations for actions to be carried out within a given operational time;

— revised criteria and the time period for the next special assessment and GO, if required;

— a modified inspection program before the next special assessment, if required.

7 General overhaul (GO)

7.1 General

The GO is a set of repair, replacement and maintenance actions necessary for the further safe use of the crane. Some issues may require immediate action; some may be postponed, in which case these actions must be scheduled according to the actual, future use of the crane. This distinction is illustrated by categories A, B and C in Figure 1.

The need for and timing of a general overhaul is specified through the special assessment. The contents of the GO should be based on the manufacturer's instructions.

7.2 Categories of actions

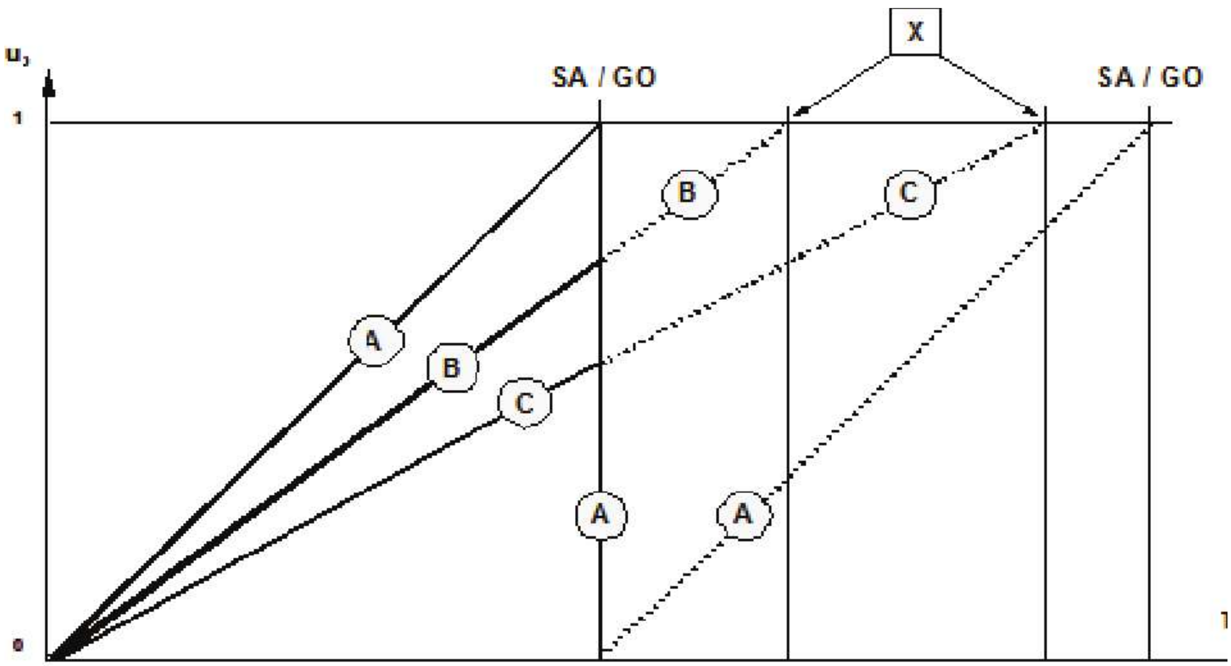
At the time of the first GO, different components are at different stages of their cumulative fatigue or wear, see Figure 1. Based on the type of the component and stage of fatigue, the component under consideration is subject to an appropriate type of GO action. The following categories of actions can be distinguished:

— the component is always replaced in a GO, which replacement may be necessary even though no physical evidence is detectable;

— the component can be repaired, and possibly some parts only replaced;

— replacement of the component is uneconomical, in which case at the first GO a full inspection is carried out and an increased frequency of inspections and rejection criteria are specified for the future.

The manufacturer shall provide maintenance instructions for the crane, including information on inspection, repair and replacement criteria of the components.



Key

SA special assessment

GO general overhaul

u_D relative usage of design duty

T operating time of the crane

A component is replaced at the 1st GO

B, C components are inspected at the 1st GO

X DWP of components B and C is reached, if no actions were taken in the preceding SA

Figure 1 — Usage of design duty in relation to GOs and SAs

Annex A
(normative)

DWP calculation for cranes designed to ISO 4301-1

A.1 General

Two basic duty factors and the crane classification as a combination of the two duty factors are presented in ISO 4301-1:

— the number of work cycles, grouped into classes U_0 to U_9;

— a load spectrum factor, K_P, grouped into classes Q1 to Q4.

The group classification of the crane into classes A1 to A8 is derived as a combination of the two duty factors U and Q.

In cases where values for the basic duty factors or their classes are specifically given and known to the owner, the DWP calculation shall be carried out according to Clauses A.2 and A.3. In cases where the crane classification only is known, the DWP calculation shall be carried out according to Clause A.4.

For the purposes of this International Standard, the two duty factors are considered to be of equal importance. The DWP of the crane is reached when either of the factors reaches its design limit. It is then an aim of the SO to establish which of the crane components are critical in respect to each duty factor.

A.2 Number of work cycles

In cases where the manufacturer has specified the class of utilization for the crane, the design limit for the number of work cycles, D_N, shall be taken from Table A.1.

Table A.1 — Design limit D_N for the number of work cycles

Class of utilization (ISO 4301-1)	D_N
U_0	16 000
U_1	32 000
U_2	63 000
U_3	125 000
U_4	250 000
U_5	500 000
U_6	1 000 000
U_7	2 000 000
U_8	4 000 000
U_9	8 000 000

The DWP of the crane is reached — i.e. the actual duty has reached the design limit in respect of the total number of working cycles — when:

$$f_1 \cdot C_a = D_N \tag{A.1}$$

where

f_1 is the safety factor for duty counting according to 4.3;

C_a is the actual total number of work cycles at a point of time of inspection;

D_N is the design limit for the number of work cycles according to Table A.1.

A.3 Cumulative loading

A starting point of this clause is that design limits for the parameters, number of work cycles and load spectrum factor, are specified separately.

In cases where the manufacturer has specified the load spectrum class for the crane, the design value for the load spectrum factor, K_p, shall be taken from Table A.2.

Table A.2 — Design value K_p for load spectrum factor

Spectrum class (ISO 4301-1)	K_p
Q1	0,125
Q2	0,25
Q3	0,50
Q4	1,00

For calculation of the load spectrum class from the actual operation history, values of payloads from each working cycle must be recorded or estimated.

The DWP of the crane is reached — i.e. the actual duty has reached the design limit in respect of cumulative loading — when:

$$f_1 \cdot \sum_{i=1}^{C_a} \left(\frac{P_i}{P} \right)^3 = K_p \cdot D_N \tag{A.2}$$

where

f_1 is the safety factor for duty counting according to 4.3;

C_a is the actual total number of work cycles at a point of time of inspection;

i is the index for an individual work cycle;

P_i is the handled payload in an work cycle i;

P is the rated value of the payload for the crane;

K_p is the design value for the load spectrum factor according to Table A.2.

D_N is the design limit for the number of work cycles according to Table A.1.

A.4 Crane classification

This clause applies to cases where the basic duty factors or their classes are not specified separately and the crane classification only is known. In the DWP calculation, the load spectrum and the number of work cycles are combined and converted to correspond to the state of loading, $K_p = 1$.

The DWP of the crane is reached, that is the actual duty has reached the design limit in respect to crane classification, when:

$$f_1 \cdot \sum_{i=1}^{C_a} \left(\frac{P_i}{P} \right)^3 = D_C \tag{A.3}$$

where

f_1 is the safety factor for duty counting according to 4.3;

C_a is the actual total number of work cycles at a point of time of inspection;

i is the index for an individual work cycle;

P_i is the handled payload in work cycle i;

P is the rated value of the payload for the crane;

D_C is the design limit for converted number of work cycles according to Table A.3.

Table A.3 — Design limits for converted number of work cycles

Crane class	A1	A2	A3	A4	A5	A6	A7	A8
DC cycles	$8 \cdot 10^3$	$16 \cdot 10^3$	$32 \cdot 10^3$	$63 \cdot 10^3$	$125 \cdot 10^3$	$250 \cdot 10^3$	$500 \cdot 10^3$	$1{,}0 \cdot 10^6$

Annex B
(normative)

DWP calculation for hoisting mechanisms designed to ISO 4301-1

B.1 General

Annex B is applicable both to hoist mechanisms as an integral part of a crane and to serial hoist units with a given class of mechanism.

Two basic duty factors and the class of mechanism as a combination of the two duty factors are dealt with as follows:

— total operation time, T;

— load spectrum factor, K_m, representing the state of loading, L, of the mechanism;

— class M of the mechanism as a combination of the two duty factors.

In cases where separate design limits for the basic duty factors (T, K_m) are known (e.g. for a purpose built crane), the DWP calculation shall be based on those factors according to Clause B.2. In cases where the mechanism classification only is known, the DWP calculation shall be carried out according to Clause B.3.

B.2 Crane's specific design duty factors are known

In cases where the manufacturer has specified the state of loading through the L class of the load spectrum factor, the design value for this shall be taken from Table B.1. Otherwise, a crane-specific value of K_{mD} shall be used.

Table B.1 — Design value K_{mD} for load spectrum factor

L1	0,125
L2	0,25
L3	0,50
L4	1,00

In cases where the manufacturer has specified the total duration of use through the classification, the design limit for the total duration of use, D_T, shall be taken from Table B.2. Otherwise, a crane-specific value of D_T shall be used.

Table B.2 — Design limit D_T for total duration of use

Class of utilization (ISO 4301-1)	D_T h
T_0	200
T_1	400
T_2	800
T_3	1 600
T_4	3 200
T_5	6 300
T_6	12 500
T_7	25 000
T_8	50 000
T_9	100 000

For calculation of the cumulative loading for a hoist mechanism, values of total hoisted loads from each work cycle must be recorded or estimated. Both the effective, working part of the load cycle and the return part of the work cycle shall be considered.

The DWP of the hoist mechanism is reached — i.e. the actual duty has reached the design limit — when:

$$f_1 \cdot \sum_{i=1}^{C_a} \left[t_i \cdot \left(\frac{P_i + P_A}{P + P_A} \right)^3 + t_{R,i} \cdot \left(\frac{P_A}{P + P_A} \right)^3 \right] = K_{mD} \cdot D_T \tag{B.1}$$

where

f_1 is the safety factor for duty counting according to 4.3;

C_a is the actual total number of work cycles at a point of time of inspection;

i is the index for an individual work cycle;

P_i is the handled payload in work cycle i;

P is the rated value of the payload for the crane;

P_A is the sum weight of the fixed and non-fixed load lifting attachments;

t_i is the hoist mechanism running time during a loaded part of work cycle i;

$t_{R,i}$ is the hoist mechanism running time during a return part of work cycle i;

D_T is the design limit for the total operation time, see Table B.2;

K_{mD} is the design value for the load spectrum factor of the mechanism, see Table B.1.

B.3 Mechanism classification is known

This clause applies to cases where the basic duty factors or their classes are not separately specified and the mechanism classification only is known. In the DWP calculation, the load spectrum and the total operation time are combined and converted to correspond the state of loading, K_m = 1,0.

The DWP of the hoist mechanism is reached — i.e. the actual duty has reached the design classification — when:

$$f_1 \cdot \sum_{i=1}^{C_a} \left[t_i \cdot \left(\frac{P_i + P_A}{P + P_A} \right)^3 + t_{R,i} \cdot \left(\frac{P_A}{P + P_A} \right)^3 \right] = D_M \quad (B.2)$$

where

f_1 is the safety factor for duty counting according to 4.3;

C_a is the actual total number of work cycles at a point of time of inspection;

i is the index for an individual work cycle;

P_i is the handled payload in work cycle i;

P is the rated value of the payload for the crane;

P_A is the sum weight of the fixed and non-fixed load lifting attachments;

t_i is the hoist mechanism running time during a loaded part of work cycle i;

$t_{R,i}$ is the hoist mechanism running time during a return part of work cycle i;

D_M is the design limit for converted number of the total operation time according to Table B.3.

Table B.3 — Design limits for converted, total operation time

Mechanism class (ISO 4301-1)	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**
D_M h	100	200	400	800	1 600	3 200	6 300	12 500

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