International Standard 6527

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Nuclear power plants — Reliability data exchange — General guidelines

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 6527 was developed by Technical Committee ISO/TC 85, *Nuclear energy*, and was circulated to the member bodies in October 1980.

It has been approved by the member bodies of the following countries :

Austria	Hungary	South Africa, Rep. of
Belgium	Italy	Sweden
Brazil	Japan	Switzerland
Canada	Netherlands	Turkey
Czechoslovakia	New Zealand	United Kingdom
Finland	Poland	USSR
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The member body of the following country expressed disapproval of the document on technical grounds :

France

Nuclear power plants — Reliability data exchange — General guidelines

1 Scope and field of application

This International Standard identifies the typical parameters of a component that permit it to be characterized unequivocally and to allow the corresponding reliability data to be associated with those of other components having equivalent typical parameters. This International Standard deals in particular with exchange of reliability data collected on field. Laboratory reliability test data exchange may require additional information.

For the determination of the equivalence of components, the components shall be characterized as a function of the following parameters :

- technical characteristics including, the physical principle of operation and quality level;
- actual operating conditions and maintenance and test intervals.

In particular, the operating conditions shall have been taken into consideration when selecting the components and, it is considered useful to refer to them as they may affect the performance of the components.

The reliability data may be presented both in a historical and in a statistical form. In order to facilitate their utilization together with the data from other sources, it seems convenient to have them in historical form. However, presentation of reliability data in a processed form is also discussed.

If reliability information is required on a detailed basis, it is necessary to define the failure mode.

2 Definitions[1)]

For the purpose of this International Standard the following definitions apply.

2.1 nuclear power unit : Nuclear steam-supply system, its associated turbine generator(s) and auxiliaries.

2.2 system : Integral part of a nuclear power unit comprising electrical, electronic, or mechanical components (or combinations of them) that may be operated as a separate entity to perform a particular process function.

2.3 line/train : Part of a system which by itself can perform the type of process function.

NOTE — One line on its own may or may not meet full system capacity.

2.4 sub-system : Part of a system which participates in the operation of the latter (for example, electric power supply, controls, mechanical devices, etc.).

2.5 component : Element of a sub-system, having its own defined performance characteristics and forming a whole that can be removed from the process and replaced with a spare.

2.6 failure (of a component) : Termination of the ability of a component to perform any one of its designed functions.

2.7 failure (of a system) : Termination of the ability of a system to perform any one of its designed functions. Failure of a line within a system may occur in such a way that the system retains its ability to perform all its required functions; in this case the system has not failed.

2.8 failure mode : Effect by which the failure is observed.

2.9 failure rate : Number of failures per unit time in a given time interval. The failure rate may be specified for different failure modes.

2.10 failure probability on demand : Failure probability expressed as a number of failures per number of type of actions requested (i.e. start, stop, open, close etc.).

2.11 reliability : Ability of a component or a system expressed as the probability to perform a required function under stated conditions for a stated period of time.

1) Definitions in IEC Publication 271 have been used as a basis for these definitions.

2.12 operating time : Total time during which components or systems are performing their designed functions.

2.13 availability time : Total time during which components or systems are capable of performing their designed functions.

2.14 unavailability time : Total time during which components or systems are incapable of performing their designed functions.

2.15 mean time between failure (MTBF) : Arithmetic average of calender times between failures of components or a system.

NOTE — MTBF is the reciprocal of failure rate when an exponential failure distribution can be assumed.

2.16 mean time to failure (MTTF) : Average time to failure of a new item or a repaired item assumed as new.

2.17 mean time to repair (MTTR) : Arithmetic average of times required to perform a repair activity on the actual item.

2.18 preventive maintenance : Activity performed on a system or component in order to reduce the probability of failures due to known wear-out failure modes.

2.19 corrective maintenance : Activity performed on a system or component in order to eliminate the causes of failures that happened or were revealed by scheduled tests.

3 Component characteristics

This clause identifies the main characteristics of components so as to establish a comparative basis. The characteristics are separated into technical characteristics and quality characteristics.

3.1 Technical characteristics

The following characteristics shall be given wherever applicable.

a) Technical generic description

The technical term designating the component in question shall be specified; as far as possible reference shall be made to existing pertinent regulations, codes, manuals, etc.

b) Definition of the component in question

The definition of the component in question described under a) shall be specified including the interface points with adjacent components.

c) Physical principle of operation

For the individual functions that may be associated with the component in question, the principle of operation by which the function is achieved shall be stated.

d) Component design characteristics

The key design characteristics shall be specified, for example, nominal (connection) dimensions, rated pressure and temperature, materials, design class, rated voltage, etc.

Table 5 (see the annex) gives detailed examples of the design characteristics deemed important for a group of components. Similar tables may be drawn for other components, on the basis of their manufacturing data. Other data may be added to those listed in table 5 according to particular needs.

In addition the following information shall be given, if possible.

e) Manufacturer

f) Manufacturer type designation and fabrication date

The manufacturer's reference is requested in particular cases to allow the user to find another source of data if necessary. Of course, components of the same type made by different manufacturers very seldom have the same characteristics. As a consequence engineering judgement will very often be required to decide whether the component may be considered to have equivalent characteristics or not. In general, it will be necessary for the values of the major parameters to fall within certain ranges.

3.2 Quality characteristics

The quality of a component is an essential characteristic for establishing its equivalence with others. Components having the same technical characteristics may be designed and manufactured, tested and controlled at different quality levels and thus they might not be equivalent. As an example of such a difference in quality, circuit breakers for safety-related systems and for normal loads may be mentioned. The former are subjected to a series of type qualifications, aging, and seismic tests that are not required for the latter. Furthermore, the quality of the safety-related equipment is verified with a quality assurance programme having well-defined characteristics.

For the equivalence of components, it should be adequate to refer to their quality level and, if applicable, to their safety classification.

4 Operation characteristics

While the preceding clause gives guidance to determining the technical equivalence of components, this clause gives guidance to determining whether the operating conditions are comparable or not. A different operating mode and the exposure to different environmental conditions are factors which may affect the behaviour of a single component and thus the reliability data. As a consequence, an engineering judgement on the effects of the following parameters is also necessary before utilizing data from other components.

4.1 Normal operating conditions

The following aspects of the normal operating conditions shall be examined.

4.1.1 Operational stress, load factor

Components or systems are often used below their rated design characteristics power levels. This results in lower wear of the components. For instance, the lifetime of a ball bearing depends on the number of revolutions per minute and on the load whilst the lifetime of insulation depends on the operating temperature and voltage. The data to be recorded depend on the type of component. As an example, the following data are considered to be useful for pumps :

- operating pressure head;
- operating temperature;
- operating flow or velocity;
- driven fluid;
- rotational frequency.

4.1.2 Conditions of use

A component may be operated continuously or in standby with cyclical or random demands. In the first case, time of operation is necessary to assess the component's behaviour. In the other case, the number of demands (including those for test purposes) is the parameter to be considered.

4.1.3 Type of working load

A component may be utilized with different loading conditions. The variation in loading conditions causes additional stresses on the component. The working load shall be described at least as follows :

- steady state operation;
- changing load operation;
- controlled load operation.

4.2 Maintenance and test intervals

The type of maintenance carried out on each component is a parameter that may influence the performance of a component.

The type of maintenance performed on a component may be preventive (periodic), on condition or corrective (break down). The preventive maintenance intervals may be as shown in table 1.

Also the test programme carried out on the component may influence the performance and shall thus be defined.

Test intervals may be classified in a manner similar to that given in table 1.

4.3 Environmental conditions

Environmental conditions as well as all other parameters covered in clause 4 shall be foreseen during the component selection phase and shall then as a consequence influence the choice of a component having adequate technical characteristics.

However it is expected that they may still have an influence on the components behaviour.

Table 2 shows the main parameters that shall be subject to engineering judgement in order to define the equivalence.

Table 1 — Example of preventive maintenance interval

Daily
Weekly
Fortnightly
Monthly
Two-monthly
Three-monthly
Four-monthly
Six-monthly
Nine-monthly
Yearly
Two-yearly

Table 2 — Some environmental conditions to be considered

Condition	Range
Temperature	Normal or inside specification Cycle Shock Outside normal range or outside specification Maximum operating temperature
Humidity	Normal Dry (humidity control) Damp or wet conditions
Vibration	Not present or insignificant Intermittent Continuous or long periods Shock present
Nuclear radiation	High (over 10 R/h) Medium (between 0,1 and 10 R/h) Low (below 0,1 R/h)
Corrosive atmosphere	Not present or insignificant Salt spray Chemical Industrial (sulphur compounds) sand/dust present
Fungus, etc.	Not present Fungus or mould growth Pests

NOTE — For certain components, reference may be made to standardized environmental classes described in IEC Publication 68.

5 Failure data presentation

Presentation of the reliability data may be made in two ways :

- presentation in historical form;
- presentation in statistical form.

Presentation of the data in the historical form is considered more appropriate for the purposes of this International Standard. However, presentation in the statistical form will also be discussed.

In both cases the data supplied shall be based on the following assumptions :

— All the data shall relate to the performance after the early failure period has elapsed i.e. after onset of commercial plant operation. It is, however, of interest to collect failure information prior to commercial operation on a separate basis.

— For corrective maintenance after failures, the actual time required for repair of the component and the man-hours used shall be recorded. The additional time necessary, for example, for decontamination or for construction of special bridges (should they be required by the components particular location) shall be indicated separately.

In case the environmental conditions are different from those indicated in the request of data, it would be advisable, if possible, to indicate by what factor the performance parameters would change if the component was utilized in a different environment.

5.1 Presentation of the data in the historical form

With regard to the exchange of information on components, presentation of the performance data in the historical form leaves the user free to carry out his own statistical processing.

For this purpose, it will be necessary to provide all the successive operating times before failures and/or number of demands and the failure information (raw data).

It is recommended that the following information be included in the historical report :

- failure mode;
- failure cause;
- failure description;
- method of failure detection;
- corrective action taken;
- repair time.

5.2 Presentation of the data in the statistical form

The first form of presentation in statistical terms might be as shown in table 3. Table 3, case a) shows a minimum data presentation scheme that may be employed where the different failure modes require the same repair time. Table 3, case b) shows a data presentation scheme for failure modes or maintenance times markedly different.

For instance, table 3, case a) should be used for a pump the outages of which are caused only by physical-displacement or excessive-leak failure. Table 3, case b) should be used for a circuit breaker that experiences both failures to close and failures to open.

For the presentation of the performance data of a single component in mathematical form, the following information (expressed in millions of hours of operations) shall be supplied for each type of failure :

- observed failure rate;
- lower limit;
- upper limit.

The observed failure rate shall be the mathematical mean of whatever probability density function is chosen to represent the performance of the particular component.

The lower and upper confidence limits form an interval that contains the true value with a probability equal to the confidence level. The preferred confidence level is 90 %.

If, within the context of the preceding paragraphs, the failure rate of the component remains constant throughout the observation period (i.e., an exponential distribution) the observed failure rate may be obtained by the formula

$$\lambda = \frac{r}{T}$$

and the confidence interval with the formula

$$\frac{\chi^2_{\frac{\alpha}{2};\,2r}}{2T} \leqslant \lambda \leqslant \frac{\chi^2_{\left(1-\frac{\alpha}{2}\right);\,2r+2}}{2T}$$

where

λ is the observed failure rate;

χ^2 is the chi-squared distribution;

r is the number of failures of the same mode;

T is the operating time;

$(1 - \alpha)$ is the confidence level.

It is worth noting that an upper limit of λ may be computed even though no failure has occurred, that is :

$$0 \leqslant \lambda \leqslant \frac{\chi^2_{(1-\alpha)\,;\,2}}{2T}$$

This is called the one-sided confidence interval.

Table 3 — Example of data presentation in a statistical form

Data presentation
Case a)
— calender time; — total number of components; — operation time expressed in millions of hours — total number of failures; — failure rate (observed, lower and upper limit); — average unavailability time expressed in hours; — mean time to repair expressed in hours (observed, lower and upper limits); — number of failures for the different failure modes.
Case b)
— calender time; — total number of components; — total operation time expressed in millions of hours — number of failures for a certain failure mode; — failure rate (observed, lower and upper limit); — average unavailability time expressed in hours; — mean time to repair expressed in hours (observed, lower and upper limit).

6 Mode-of-failure classification

As already observed in the preceding paragraphs the failures shall be linked to their mode of failure.

Table 4 lists some possible modes of failure.

Table 4 — Examples of modes of failure

Failure modes
Leak
Crack
Rupture
Displacement
Failure to start
Failure to stop
Failure to close
Failure to open
Failure to function
Degraded performance
Disconnection
Destruction
Short circuit
Earth fault, insulation fault
Zero point drift
etc...

Annex

Table 5 — Examples of component design characteristics[1)]

Component characteristics	Units
Stabilized power supply	
01 Manufacturer reference	
02 Output : continuous, one-phase, three-phase	W
03 Input voltage : continuous, one-phase, three-phase	V
04 Output voltage : stability	%
05 Output current : stability	%
06 Output frequency : stability	%
07 Ripple	%
08 Built-in electric protections	
09 Indoor, outdoor, flameproof, tropical type of construction	
Amplifiers	
01 Manufacturer reference	
02 Magnetic, electric	
03 Rating	
04 Input signal range and type	
05 Input impedance	Ω
06 Gain	dB
07 Output signal range and type	
08 Load impedance	Ω
09 Supply voltage : continuous, alternate	V
10 Valves; solid-state components	
11 Built-in electric protections	
12 Indoor, outdoor, flameproof, tropical type	
Batteries	
01 Manufacturer reference	
02 Alkaline, lead, dry	
03 Capacity	A·h
04 Rated voltage	
05 Electrolyte density at 15 °C	kg/m^3
06 Number of elements per cell : number of cells	
07 Full-charge current	A
08 Normal steady-state current	A
09 Full-discharge current	A
10 Electrolyte quantity per cell	dm^3
Electronic regulators	
01 Manufacturer reference	
02 Type of input	
03 Input range	
04 Output signal range	
05 Regulating action : on — off, P; I; D.	
06 Local or remote set points	
07 Set point range	%
08 Proportional band	%
09 Integral time (repetition per minute)	s^{-1}
10 Derivative time range	s
11 Number and type of contacts, rating	A
12 Supply voltage : continuous, alternating	V
13 Load impedance	Ω

1) These examples are given for guidance only and are not expected to be exhaustive.

Table 5 *(continued)*

Component characteristics	Units
Solenoid valves	
01 Manufacturer reference	
02 Number of ways	
03 Endfittings type	mm
04 Simple, double solenoid	
05 Control circuit voltage : continuous, alternating	V
06 Normal or corrosive fluid; steam	
07 Maximum static pressure	MPa
08 Maximum-minimum differential pressure	MPa
09 Net flow section	mm^2
10 Pulse or continuous command signal	
11 Reset : electric, manual, automatic	
12 Possibility of manual control	
13 Indoor, outdoor, flameproof, tropical type	
14 Operating temperature of fluid	
Limit switches	
01 Manufacturer reference	
02 Linear, rotary drive	
03 Number and type of contacts	
04 Type of link	
05 Indoor, outdoor, flameproof, tropical type	
Flow switches	
01 Manufacturer reference	
02 On-line, bypass	
03 Flow range	dm^3/s
04 Normal, corrosive fluid	
05 Differential : adjustable, fixed	
06 Number and type of contacts	
07 Endfitting type and size	mm
08 Maximum static pressure	MPa
09 Mechanical magnetic coupling	
10 Indicator type	
11 Indoor, outdoor, flameproof, tropical type	
12 Type of electrical connection	
HV Air operated circuit breaker	
01 Manufacturer reference	
02 Rated voltage	kV
03 Rated power	kA
04 Rated break capacity	
05 Unipolar, tripole control	
06 Normal, saline insulator type	
07 Feed pressure	MPa
08 Control circuit voltage : continuous, alternating	V
09 Plate caps, connections diameter	mm
10 Number and type of auxiliary contacts	
11 Rated cycle : normal, heavy	
12 Closing time	ms
13 Opening time	ms
14 Total weight per pole	kg
MT Air circuit breakers with magnetic deionization; MT oil circuit breaker	
01 Manufacturer reference	
02 Rated voltage	V
03 Rated power	kA
04 Rated break capacity	kA
05 Fixed, extractable type	
06 Manual, spring, solenoid actuation	
07 Remote, local actuation	
08 Control circuit voltage : continuous; alternating	V
09 Number and type of aux. contacts	
10 Rated cycle : normal, heavy	

Table 5 (*continued*)

Component characteristics	Units
Hexafluoride circuit breakers	
01 Manufacturer reference	
02 Rated voltage	kV
03 Rated power	
04 Rated break capacity	kA
05 Unipolar, tripole control	
06 Normal, saline insulator type	
07 Feed pressure	MPa
08 Control circuit voltage : continuous, alternating	V
09 Plate caps, connections diameter	mm
10 Number and type of auxiliary contacts	
11 Rated cycle : normal, heavy	
12 Closing time	ms
13 Opening time	ms
14 Total weight per pole	kg
Low-voltage circuit breaker	
01 Manufacturer reference	
02 AC/Rated voltage	V
03 Rated power	
04 Break capacity at 380 V ac	kA
05 Number of poles	
06 Fixed, extractable type	
07 Frontal, back caps	
08 Manual, spring, solenoid actuation	
09 Actuation circuit voltage : continuous, alternating	V
10 Magnetic, thermal, compensated protections	
11 Magnetic protection field; delay : adjustable, fixed	A/s
12 Thermal protection control range	A
13 Number and type of aux. contacts	
14 Electromagnetic maximum current relay : number and type	
15 Minimum voltage protection	
LV asynchronous, three-phase electric motors	
01 Type	
02 Rated power	kW
03 Rated voltage	V
04 Rated current	A
05 Number of poles	
06 Connection type	
07 Isolation class	
08 Construction type	
09 Protection type	
10 Frequency	
11 Power factor	
12 Temperature class	
MV asynchronous three-phase motors	
01 Type	
02 Rated power	kW
03 Rated voltage	V
04 Rated current	A
05 Number of poles	
06 Connection type	
07 Isolation class	
08 Construction type	
09 Protection type	
10 Cooling type	
11 Power factor	
12 Inrush current	A
13 Rotor PD2 mass-moment of inertia	$kg \cdot m^2$
14 Temperature class	
Electronic relays	
01 Manufacturer reference	
02 Relay functions	
03 Direct connection, transformers, converters	
04 Rated voltage current	V, A
05 Converters; signal range; measuring unit	

Table 5 *(continued)*

Component characteristics	Units
Thermal relays	
01 Manufacturer reference	
02 Number of poles	
03 Current range	A
04 Automatic, manual reclosing	
05 Normal, micrometric locked setting	
06 Number and type of contacts	
07 Indoor, outdoor, flameproof, tropical type	
08 Normal, ambient temperature compensation	
Electrical actuators	
01 Manufacturer reference	
02 Rotary, linear movement	
03 Maximum torque	Nm
04 Maximum strength	N
05 Maximum angle	(°)
06 Maximum stroke	mm
07 Absorbed power : continuous, three-phase, single-phase	W
08 Supply voltage	V
09 Positioning signal range; measuring unit	
10 Opening, closing-torque limiter	
11 Position transmitter, built-in indicator	
12 Number and type of limit switches	
13 Indoor, outdoor, flameproof, tropical type	
Gate valves	
01 Manufacturer reference	
02 Rated pressure	MPa
03 Rated diameter	mm
04 Actuation type	
05 Endfittings type	
06 Body material	
07 Steam and plug material	
08 By-pass diameter	mm
09 Rated temperature	
Ball valves	
01 Manufacturer reference	
02 Rated pressure	MPa
03 Rated diameter	mm
04 Actuation type manual, pneumatic, electrical	
05 Endfittings type	
06 Body and seat material	
07 Plug and steam material	
08 Rated temperature	
Check valves	
01 Manufacturer reference	
02 Rated pressure	MPa
03 Rated diameter	mm
04 Pneumatic drive	
05 Balanced	
06 Rated temperature	

Table 5 (*concluded*)

Component characteristics	Units
Safety relief valves	
01 Manufacturer reference	
02 Rated inlet, outlet pressure	MPa
03 Rated inlet, outlet diameter	mm
04 Self-actuated, controlled drive	
05 Orifice area	mm^2
06 Endfittings type	
07 Body and seat material	
08 Steam and plug material	
09 Spring material	
10 Rated temperature	
Rotary pumps	
01 Manufacturer reference	
02 Driven fluid	
03 Axial, centrifugal	
04 Rated flow	m^3/h
05 Rated head	m
06 Rated power	kW
07 Rotational frequency	r/min
08 Number of stages	
09 Mechanical, labyrinth, packing seals	
10 NPSH	
11 Shut-off head	
12 Maximum pumping temperature	°C
13 Vertical, horizontal shaft	
Heat exchangers	
01 Manufacturer reference	
02 (Single, double pass)	
03 Heater, coolant fluid	
04 Horizontal, vertical	
05 Fluid on tube side; number of pass	
06 Fluid on shell side	MPa
07 Pressure tube/shell side	
08 Exchange surface	m^2
09 Number of tubes; diameter, thickness	mm
10 Tube material	
11 Shell material	
12 Desuperheater, saturated, sub-cooling section	