

Process Instrumentation Reliability Terminology

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PROCESS INSTRUMENTATION RELIABILITY TERMINOLOGY

1. SCOPE AND PURPOSE

1.1 This standard offers guidance concerning definitions associated with *reliability*, *maintainability* and *availability* of industrial process instrumentation or systems.

1.2 The purpose of this standard is to establish common terminology for use by manufacturers, vendors and users to describe system or product *reliability*, *maintainability* and *availability*.

2. INTRODUCTION

2.1 The manufacturer of process instrumentation or systems may be required to offer adequate assurance as to continuity of performance to specifications. Such assurance utilizes *reliability* definitions contained in this standard.

2.2 *Reliability* statements by manufacturers shall include:

EITHER

- a. Confidence level used in presenting the numeric (*reliability*, *availability*, *maintainability*, etc.) and whether it is one-sided or not, and the distribution used.
- b. Number of units tested or in the field sample.
- c. Cumulative unit hours of operation.
- d. Number of failures.
- e. Type of failures which occurred.
- f. Environmental conditions.
- g. Model used for extrapolations of accelerated tests and supporting test information for model selected, when applicable.

OR

- h. Discrete component failure rate source and the assumption made for each piece part failure rate. An acceptable source is Military Handbook 217, Reliability Prediction of Electronic Equipment.

3. SOURCES AND REFERENCES

In the preparation of this standard, the standards and related publications issued by technical societies and organizations were reviewed. Existing terms and definitions have been used wherever suitable. Definitions used verbatim are followed by the source document number, e.g., IEC PUB. 271. Where definitions have been modified in accordance with customary reliability practices in process instrumentation, the designation REF. is used, e.g., REF. IEC PUB. 271. The documents pertaining to this standard are referenced below:

American National Standard C42.100-1972**Dictionary of Electrical and Electronics Terms**

Copies of the ANS Publication referred to above may be purchased from the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018

British Standards Institution BS 4200 Parts 1-1967, 3-1971, 4-1971, 5-1968, 6-1971, 7-1973

Guide on the Reliability of Electronic Equipment and Parts Used Therein

Copies of the BS Publications referred to above may be purchased from the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018

Institute of Electrical and Electronics Engineers (IEEE) Standards:

380-1972—Definitions of Terms Used in IEEE Nuclear Power Generating Station Standards

352-1975—Guide for General Principles of Reliability Analysis of Nuclear Power Generating Stations Protection Systems

Copies of the IEEE Standards referred to above may be purchased from The Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, N.Y. 10017

International Electrotechnical Commission (IEC)

Publication 271, 2nd Edition, List of Basic Terms, Definitions, and Mathematics for Reliability—1974

Copies of the IEC Publication referred to above may be purchased from the American National Standards Institute, Inc., 1430 Broadway, New York, N.Y. 10018

Military Handbook 472**Maintainability Prediction****Military Handbook 217B****Reliability Prediction of Electronic Equipment**

Copies of the MIL Publications referred to above may be purchased from the Commanding Officer, Naval Publication & Forms Center, 5801 Tabor Avenue, Philadelphia, Pa. 19120

Scientific Apparatus Makers Association (SAMA)

Documents are no longer available from this organization

Society of Automotive Engineers, Inc. (SAE) Aerospace Recommended Practice ARP926-1967**Design Analysis Procedure for Failure Mode, Effects and Criticality Analysis (FMECA)**

Copies of the SAE Publication referred to above may be purchased from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pa. 15096

4. DEFINITIONS OF TERMS

accelerated test

See test, accelerated

acceleration factor

The ratio between the times necessary to obtain a stated proportion of failures for two different sets of stress conditions involving the same *failure modes* and/or mechanisms.

IEC PUB. 271

accuracy

Conformity of an indicated value to an accepted standard value, or true value.

PMC 20.1—1973

availability, steady state; (A)

Ratio defined as $A = M / (M + R)$ where M is *mean time between failures* and R is the mean downtime for repair.

availability, transient; [A(t)]

A(t) = probability that a *system* is in operating state at time t; it is a function of time and is dependent on the initial conditions.

censored data

Data representing incomplete life tests.

Note 1: During testing, some *modules* will have failed, and the time of *failure* can be determined. For those *modules*, however, which are still operational, the *failure* point is some time in the future. Censored data are thus incomplete life testing results.

Note 2: Censored data can also be data from which *module failures* have been removed from final test data to insure homogeneous data for analysis purposes.

consecutive testing

The testing of a series of *modules* one after the other.

Note: This may or may not involve a time interval between the completion of the test on one *module* and the starting of the test on the next *module*.

convenience function

See function, convenience

degradation factor

Factor by which actual *system* operational or use *reliability* is less than *predicted reliability*.

derating factor

Ratio of *module* operating stress to rated stress.

design basis event

Postulated event used in the design to establish the performance requirements of the *module* and *system*.

REF. IEEE STD. 380-1972

design basis event conditions

Conditions calculated to occur as a result of the *design basis event*.

REF. IEEE STD. 380-1972

effectiveness

The product of *reliability* times *availability* for a given level of performance under specified operating conditions.

essential function

See function, essential

failed state

The condition of a *module* during the time when it is not capable of performing its intended *function*.

failed time

The time during which a *module* remains in the *failed state*.

failure

The termination of the ability of a *module* to perform its required *function*. Note: Failures may be unannounced and not detected until the next test (unannounced failure), or they may be announced and detected by any number of methods at the instant of occurrence (announced failure).

REF. IEEE STD. 380-1972

failure, catastrophic

The sudden and complete *failure* of a *module* in which the particular performance characteristic moves completely to one of the extreme limits outside the normal specification range.

failure, chance

See failure rate period, constant.

failure, critical

A *failure* of a functional entity which causes total loss of the use of an *essential function*.

failure, degradation

See failure, parametric

failure, early

The *failure* of a *module* which occurs during the initial life phase of such devices and which is generally caused by initial production, assembly, test, installation or commissioning errors.

See Figure 1—Page 6

failure, independent

Failure which is free from influence of *failure modes* of another *module* or on other *modules*.

failure, intermittent

Failure of a *module* persisting for a limited period of time and following which the *module* recovers its ability to perform its required *function* without being subjected to any external corrective action.

Note: Such a *failure* is often recurrent.

REF. IEC PUB. 271

failure, major

A *failure* of a functional entity which causes degraded operation of any *essential function*, but does not cause total loss of the use of the *essential function*.

failure, minor

A *failure* of a functional entity which causes the loss of a *convenience function* only.

failure, misuse

Failure attributable to the application of stresses beyond the stated capabilities of the *module* or *system*.

REF. IEC PUB. 271

failure mode

The malfunction symptom after *failure*.

failure modes and effects analysis (FMEA)

A design evaluation procedure which documents all conceivable potential *failures* in a *module* design, determines by analysis of a single *failure* the effect of each *failure* on *module* operation, identifies *failures* critical to operational success or personnel safety, highlights *failure* causes that require special handling procedures during manufacturing and usage.

REF. SAE ARP 926

failure modes, effects, and criticality analysis (FMECA)

A design evaluation procedure which documents all conceivable potential *failures* in a *module* design, determines by analysis of a single *failure* the effect of each *failure* on *module* operation,

identifies *failures* critical to operational success or personnel safety, highlights *failure* causes that require special handling procedures during manufacturing and usage, and ranks each potential *failure* according to the combined influence of *failure* effect severity and probability of occurrence.

REF. SAE ARP 926

failure, parametric

The condition of a *module* whereby one or more performance characteristics have moved outside the assessed specification range in such a way that a *module* no longer performs in the desired manner.

NOTE: An example is a *module* drifting outside of specifications limits.

failure, primary

Failure of a *module*, not caused either directly or indirectly by the *failure* of another *module*.

REF. BRITISH STD. GUIDE BS 4200

failure, random

See failure rate period, constant

failure, secondary

Failure of a *module*, caused either directly or indirectly by the *failure* of another *module*.

REF. BRITISH STD. GUIDE BS 4200

failure, wear-out

Failure following the *constant failure rate period*, which occurs as a result of deterioration processes or mechanical wear and whose probability of occurrence increases with time.

REF. BRITISH STD. GUIDE BS 4200

See Figure 1—Page 6

failure mechanism

The cause of the malfunction symptom.

failure rate (λ)

The expected number of *failures* of a given *module*, in a given time interval under specified conditions.

REF. IEEE STD. 380-1972

failure, rate, assessed

The *failure rate* of a *module* determined as a limiting value or values of the confidence interval with a stated probability level, based on the same data as the *observed failure rate* of nominally identical *modules*.

Note 1. The source of the data should be stated.

Note 2. Results can be accumulated (combined) only when all conditions are similar.

Note 3. Probability level is synonymous with confidence level.

Note 4. It should be stated whether one-sided limits are being used.

Note 5. The assumed underlying distribution should be stated.

Note 6. Where one limiting value is given this is usually the upper limit.
REF. BRITISH STD. GUIDE BS 4200

failure rate, extrapolated

Extension by a defined extrapolation or interpolation of the *assessed failure rate* for durations and/or stress conditions different from those applying to the conditions of that *assessed failure rate*.

BRITISH STD. GUIDE BS 4200

failure rate, observed

The number of *failures* in a population in the total cumulative observed time on that population.

Note: Stress conditions should be stated.

failure rate, predicted

For the stated conditions of use and the design considerations of a *module*, the number of *failures* in a stated period of time, based on the *observed, assessed or extrapolated failure rates* of its parts.

Note: Engineering and statistical assumptions should be stated.

REF. BRITISH STD. GUIDE BS 4200

failure rate period, constant

That period during which the *failures* occur to the *modules* concerned at an approximately uniform rate.

Note: A constant failure rate assumes that random *failures* occur at the statistically expected value.

REF. BRITISH STD. GUIDE BS 4200

See Figure 1—Page 6

fault tree analysis (FTA)

A design evaluation procedure which logically identifies all event sequences which can lead to a specified event. FTA involves generation of event sequences that begins with the final event and works backwards to initiating events.

Note: FTA is a procedure, usually graphical, that is used for analyzing logical dependence of events which can lead to a stated system fault.

function

An action or operation.

function, convenience

A helpful but dispensible action or operation.

function, essential

An indispensable or absolutely necessary action or operation.

Note: Loss or removal would completely interrupt the action or operation.

function time

The time during which the operation or action must be performed without interruption.

improvement factor

Factor by which actual *system reliability* is greater than *predicted reliability*.

independent failure

See failure, independent

infant mortality

See failure, early

See Figure 1—Page 6

limit design

Provision to allow for the "worst case" of stresses that might occur, considering safety-factor allowances.

maintainability

The probability that a *module* will be restored to a specified operable condition within a given period of time when the *maintenance* action is performed in accordance with prescribed procedures and resources.

REF. MIL HDBK 472

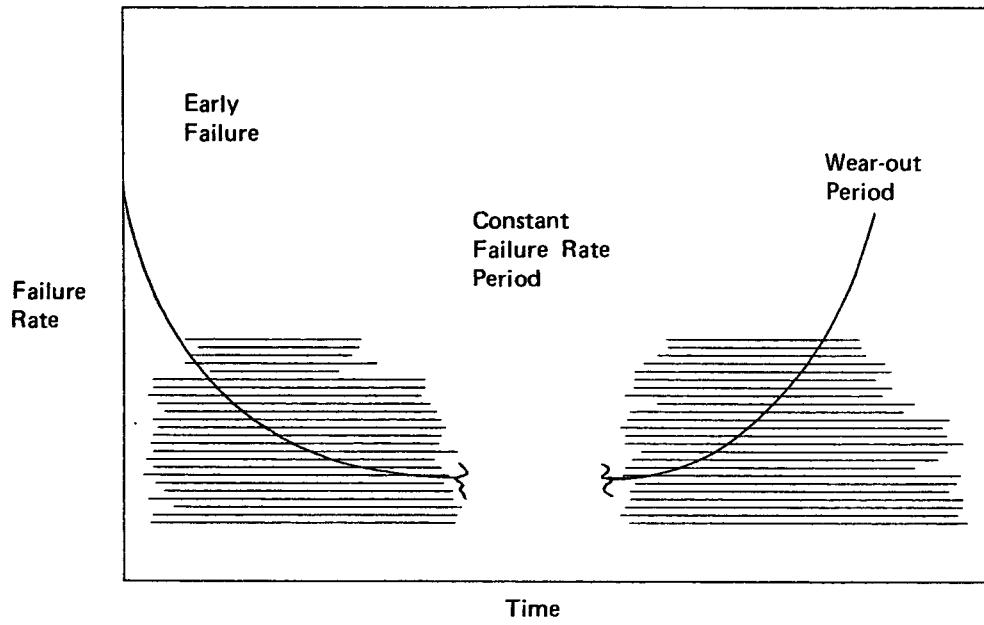


FIGURE 1 – EXAMPLE OF FAILURE RATE/TIME PATTERN

maintenance

Any activity intended to keep equipment in satisfactory working condition, including tests, measurements, replacements, adjustments, and repairs.

maintenance capability

The facilities and trained personnel, as well as the engineering support and spare parts availability, to keep a *system* in operable condition.

maintenance, corrective

Maintenance required as a result of a *failure*.

maintenance, preventive

A procedure of periodically reconditioning a product in accordance with specific instructions and scheduling to prevent or reduce the probability of *failure* or degradation while the product is in service.

maintenance ratio

The average number of *maintenance* hours required to support each hour of operation.

mean failure rate, observed

The total number of *failures* in a single population in the total cumulative observed time on that population.

Note: The observed mean failure rate is to be associated with particular, and stated, time intervals (or summation of intervals) and stress conditions.

REF. BRITISH STD. GUIDE BS 4200

mean life

The arithmetic mean of the time to *failure* of a group of nominally identical items.

ANSI C42.100

mean life, assessed

The *mean life* of a *module* determined as a limiting value or values of the confidence interval with a stated probability level based on the same data as the observed mean life of nominally identical *modules*.

Note 1. The source of the data shall be stated.

Note 2. Results can accumulated (combined) only when all conditions are similar.

Note 3. Probability level is synonymous with confidence level.

Note 4. It should be stated whether one-sided or two-sided limits are being used.

Note 5. The assumed underlying distribution should be stated.

Note 6. Where one limiting value is given this is usually the lower limit.

REF. BRITISH STD. GUIDE BS 4200

mean life, extrapolated

Extension by a defined extrapolation or interpolation of the *assessed mean life* for stress conditions different from those applying to the conditions of that *assessed mean life*.

BRITISH STD. GUIDE BS 4200

mean time between failures (MTBF, M, θ)

The average time interval between *failures* for repairable *modules*, usually measured in terms of operating hours.

mean time between failures, assessed

The mean time between *failures* of a *module* determined as a limiting value or values of the confidence interval with a stated probability level, based on the same data as the *observed mean time between failures* of nominally identical *modules*.

Note 1. The source of the data should be stated.

Note 2. Results can be accumulated (combined) only when all conditions are similar.

Note 3. Probability level is synonymous with confidence level.

Note 4. It should be stated whether one-sided or two-sided limits are being used.

Note 5. The assumed underlying distribution should be stated.

Note 6. Where one limiting value is given this is usually the lower limit.

REF. BRITISH STD. GUIDE BS 4200

mean time between failures, extrapolated

Extension by a defined extrapolation or interpolation of the *assessed mean time between failures* for durations and/or stress conditions different from those applying to the conditions of that *assessed mean time between failures*.

BRITISH STD. GUIDE BS 4200

mean time between failures, observed

For a stated period in the life of a *module*, the mean value of the lengths of observed times between consecutive *failures* under stated stress conditions.

Note 1. The criteria for what constitutes a *failure* shall be stated.

Note 2. This is the reciprocal of the *observed mean failure rate* during the period.

REF. IEC PUB. 271

mean time between failures, predicted

For the stated conditions of use and the design considerations of a *module*, the computed mean value of the length of time between consecutive failures in a stated period of time, based on the *observed, assessed or extrapolated failure rates* of its parts.

Note: Engineering and statistical assumptions should be stated including:

1. Confidence level
2. Failure rate data source
3. Failure criteria
4. Conditions—environmental, and define function
5. Distribution—assumed underlying

mean time to failure (MTTF)

The mean average time until a non-repairable *module* fails, measured in operating hours.

mean time to failure, assessed

The mean time to failure of a *module* determined as a limiting value or values of the confidence interval with a stated probability level, based on the same data as the *observed mean time to failure* of nominally identical *modules*.

Note 1. The source of the data should be stated.

Note 2. Results can be accumulated (combined) only when all conditions are similar.

Note 3. Probability level is synonymous with confidence level.

Note 4. It should be stated whether one-sided or two-sided limits are being used.

Note 5. The assumed underlying distributions should be stated.

Note 6. Where one limiting value is given this is usually the lower limit.

REF. BRITISH STD. GUIDE BS 4200

mean time to failure, extrapolated

Extension by a defined extrapolation or interpolation of the *assessed mean time to failure* for durations and/or stress conditions different from those applying to the conditions of that *assessed mean time to failure*.

REF. BRITISH STD. GUIDE BS 4200

mean time to failure, observed

For *truncated tests* for a stated period and under stated stress conditions, the total cumulative observed time divided by the total number of *failures* in the population during the period.

Note: This is the reciprocal of the *mean failure rate observed* during the period.

REF. BRITISH STD. GUIDE BS 4200

mission

The singular objective, task, or purpose of a *module* or *system*.

REF. IEEE STD. 352-1975

module

A component or any assembly of interconnected components which constitutes an identifiable item, device, instrument, or piece of equipment.

Note: A *module* can be disconnected, removed as a unit, and replaced. It has definable performance characteristics which permit it to be tested as a unit.

REF. IEEE STD. 380-1972

non-redundant elements

A configuration of elements which can only produce a correct *function* when each element in the configuration is operating correctly.

probability of survival, P_s

See *reliability*

redundancy

A configuration of multiple elements which can still produce a correct output when one or more elements is not functioning correctly.

redundancy, active

That *redundancy* wherein all means of performing a given *function* are operating simultaneously.

BRITISH STD. GUIDE BS 4200

redundancy, standby

That *redundancy* wherein the alternative means of performing a given *function* are inoperative until needed.

REF. BRITISH STD. GUIDE BS 4200

reliability [R(t)]

The characteristic of a *module* expressed by the probability that it will perform a required *function* under stated conditions for a stated period of time.

Note 1: The probability of a *module* not failing prior to time *t* is

$$R(t) = \int_t^{\infty} f(t) dt$$

f(t) = density function
of time to failure

Note 2: When the probability of *failure* is independent of age, the *failure rate* is considered constant and

$$f(t) = \lambda e^{-\lambda t}$$

also

$$R(t) = P_s = e^{-\lambda t} = e^{-t/M}$$

P_s = probability of survival

t = time

M = mean time between failure

λ = failure rate

e = 2.7183

REF. IEEE 352-1975

reliability, assessed

The reliability of a *module* determined within stated confidence limits from tests or field *failure* data on nominally identical *modules*.

Note: The source of the data shall be stated. Results can be accumulated (combined) only when all the conditions are similar. Alternatively, point estimates may be used, the basis of which shall be defined.

REF. IEC PUB. 271

reliability demonstration

Tests and/or operating history with documentation which demonstrate the *reliability* achievement of a *module* or *system*.

reliability documentation

The written procedures, tests, assumptions, references, data and calculations supporting *reliability* statements.

reliability, extrapolated

Extension by a defined extrapolation or interpolation of the *assessed reliability* for durations or stress conditions different from those applying to the conditions of that *assessed reliability*.

IEC PUB. 271

reliability, predicted (theoretical)

The *reliability* of an equipment computed from its design considerations and from the *reliability* of its parts in the intended conditions of use.

REF. IEC PUB. 271

reliability block diagram

A success-oriented diagram which represents pictorially the logic of a *system*. *Reliability* block diagrams are developed through analysis of the functional relationships among *modules* shown by functional block diagrams and circuit schematics. The interrelation of events is expressed by the way that the blocks are interconnected in the block diagram.

REF. IEEE STD. 352-1975

repair

Act of restoring a failed *module* or *system* to a specified operable condition.

repairability

Probability that a failed *system* will be restored to a specified operable condition within a specified period of active *repair* work.

repair, mean time to

The average time required to *repair* a *failure* under the operating conditions encountered.

repair time

The time spent replacing, repairing, or adjusting all items suspected to have been the cause of the malfunction.

REF. MIL-HDBK-472

repair rate

The expected number of *repair* actions of a given type completed per unit of time.

IEEE STD. 352-1975

serviceability

Those properties of design that make a *module* or *system* easy to service and repair.

state transition rate analysis

A *system* design evaluation procedure that can be used to obtain theoretical quantitative *reliability* and *availability* information. The underlying mechanism for this procedure is a mathematical model based on a Markov process. To use the method one must determine that a *system* can attain a definite number of states. Each state is defined in terms of whether particular *functions* are active, or failed and under *repair*. There is no general rule for the number of states that are of interest for a *system* with N sub-functions. There is one assumption and that is: At any one time, t, the state of the *system* is a random variable which takes on one, and only one, of the states.

system

An assembly of interconnected *modules*.

test, accelerated

A test in which the applied stress level is chosen to exceed that stated in the reference conditions in order to shorten the time required to observe the stress response of the *module*, or magnify the response in a given time.

Note: To be valid, an accelerated test must not alter the basic modes and/or mechanisms of *failure*, or their relative prevalence.

REF. IEC PUB 271

test, stress step

A test consisting of several stress levels applied sequentially for periods of equal duration to each *module* in the sample. During each period, a stated stress level is applied and the stress level is increased from one step to the next.

IEC PUB. 271

test, system performance

Tests performed on complete *systems*, including all electric, electronic, instrumentation, controls, fluid, and mechanical subsystems under normal or simulated process conditions of temperature, flow, level, pressure, etc.

REF. IEEE STD. 380-1972

test, truncated

The termination of testing at a given time with the possibility that some *modules* may not have failed or tests may be terminated at some preassigned number of *failures*.

unavailability

The numerical complement of availability.

REF. IEEE STD. 352-1975

useful life

1. Repairable: The period from a stated time, during which under stated conditions a *module* has an acceptable *failure rate*.

REF. BRITISH STD. GUIDE BS 4200

2. Non-Repairable: The time to *failure* for a specific service condition.

Note: If it does not exceed the time during which non-repairable *modules* have an acceptable *failure rate*.

REF. IEEE STD. 352-1975

wearout period

The time interval, following the period of *constant failure rate*, during which *failures* occur at an increasing rate.

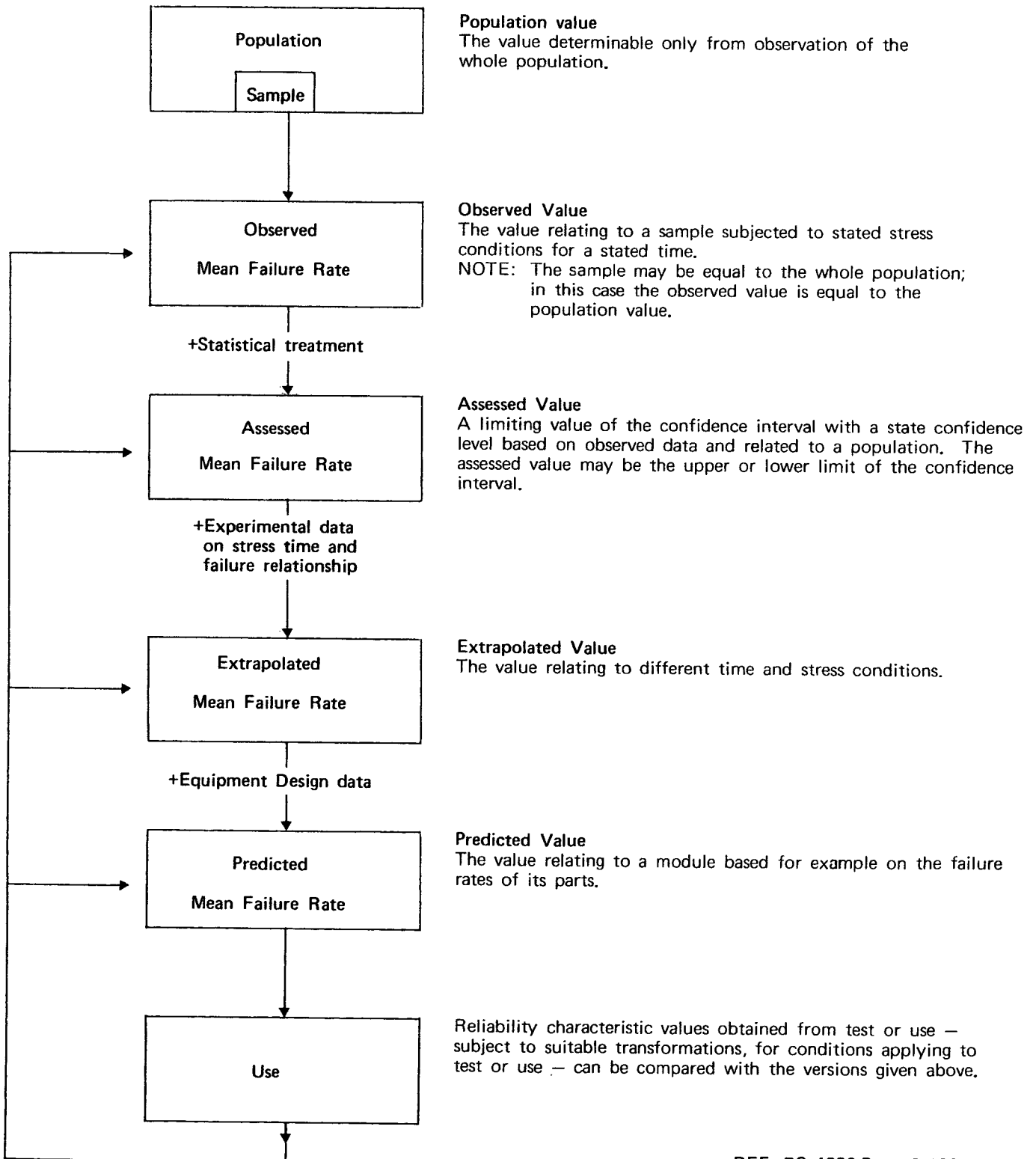
See Figure 1—Page 6

IEEE STD. 352-1975

Figure 2.

GENERAL RELATIONSHIP BETWEEN RELIABILITY TERMS

The following diagram shows the general relationship between reliability terms and their variants, for example, the possible versions of *failure rate*, *mean time between failures*, *mean time to failure* and *mean life*. Illustrated are the "mean failure rate" relationships.



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