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Reliability Databases: State-of-the-Art and Perspectives

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Abstract The report gives a history of development and an overview of the existing reliability databases. This overview also describes some other (than computer databases) sources of reliability and failures information, e.g. reliability handbooks, but the main attention is paid to standard models and software packages containing the data mentioned. The standards corresponding to collection and exchange of reliability data are observed too. Finally, perspective directions in such data sources development are shown.

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Preface

The present report has been written as part of the collaborative work between Risø National Laboratory and Ufa State Aviation Technical University (Russia).

1 Introduction

The fundamental works on reliability theory have established the mathematical basis for the evaluation of the reliability of complex systems computed from the knowledge of component reliability and also for the construction of reliable systems from relatively unreliable components.

Today reliability and safety analysis becomes an important part of each technological system design or investigation process.

Problems to be solved can be divided into two main groups:

1. reliability and safety analysis of hazardous plants, comparing the values of their reliability and safety parameters, increasing safety level of the plant, etc;
2. prognoses of the values of reliability and safety parameters for new plants which are to be constructed.

So, the necessity exists to obtain complete and exact data concerning equipment functioning, accidents and their consequences, maintenance operations and their costs that can be used for the solution of problems from the first group in the classification mentioned above. The best case would be if such information were collected from the same equipment (specific failure data) or from analogous equipment in similar conditions.

In the case of the second group of problems we must use the information on equipment to be planned for implementation combined with expert judgements on new equipment reliability parameters or using standard values or standard reliability models (e.g. MIL-217 or Bellcore).

So, there is a need for reliability data collection in relation to all types of components from the field records of installations and operations, in order to allow us to analyse, compare, or predict the reliability levels of complex systems.

We can define at least three categories of users of reliability databases [1]:

- risk and reliability analysts for analysing and predicting a reliability of complex systems;
- maintenance engineers for measuring and optimising the maintenance performance;
- component designers for analysing and optimising the component performance.

All of these specialists need different types of data.

The risk analyst needs to compute system availability or probability of mission success or failure. For this he needs to know the availability of components and failure rates. Availability can be estimated from failure on demand if downtime has been properly included in the database.

The maintenance engineer needs to measure maintenance performance. The operational data conflates the effects of maintenance and the intrinsic reliability of the component. Also he wants to know what the failure behaviour of the component would be in the case it were not maintained.

The component designer is primarily interested in failure mechanisms that reveal the weak points of design. Hence he is interested in distinguishing failure modes according to failure mechanisms. Where this is not possible, engineering knowledge is used to infer failure mechanisms from other information.

The scope of this survey is description of the data sources that can be used for the analysis of reliability of hazardous industrial plants and installations.

2 Historical review

Collection of necessary empirical data for the prediction of future event probabilities has a long history [2]. Architects used design rules of thumb to capture experience of the ages and thereby produce buildings of incredible longevity and reliability. At least before the 17^{th} century the safe passage events and mortality events were collected and analyzed to uncover prospective underlying classes; then associated class attributes formed a basis for the insurance industry.

One of the first designs for which reliability and risk databases may have been developed were that of the automobile and aircraft when they were converted from a plaything of the rich to means of transport for a broad spectrum of population. Such transport must be reliable and safe, and this fact becomes a basis for gathering of maintenance statistics and attempts at redesigning or replacing of frequently failed items.

2.1 First generation of failure data source

The earliest broad-based published source of reliability data may well have been the "Martin Titan Handbook" [3]. This widely distributed source contained generic failure rates on a wide range of electrical, electronic, electromechanical, and mechanical 'parts and assemblies'. The Titan Handbook was the first known source to standardise the presentation of failure rates in terms of failures per 10^6 hours eliminating the necessity for conversions.

2.2 Reliability data, second generation

The Titan Handbook sets the stage for more ambitious programs to collect and organise reliability data. The brightest examples of these efforts are:

1) MIL-Handbook-217 [4]
2) Failure Rate Data Bank (FARADA) [5]
3) RADC Non-Electronic Reliability Notebook [6]

All of these second-generation sources were built upon the experience of the Titan Handbook (using the constant hazard exponential model and base failure rates per 10^6 hours) and have survived in some form to the present day.

When the computer-aided systems appeared, special databases being managed by software tools became the areas for reliability data collections. Computer utilisation permits the user to recover data more rapidly and to analyse them statistically. The first computer aided database was GIDEP (Government Industry Data Exchange Program) also known as FARADA created under the sponsorship of US Army Material Command, Air Force Logistic Command, and Air Force Systems Command.

2.3 Third generation

The main deficiency of the previous generation of reliability data source was represented by the constant failure rates and non-adequacy of the hazard model to the whole spectrum of environmental conditions and possible reasons of failure. Researchers began to seek improvements by designing new databases that addressed these problems. Range estimations were introduced for estimated mean values to address the problem of heterogeneous sub-populations. These estimates attempted to gauge the actual uncertainty of the underlying mixture distributions through various percentile grouping approaches, thereby preserving the dispersion in the data and reducing the possibility for misuse. Failure rate estimates were separated into time-related and demand-related categories. The failure modes were divided into catastrophic, degraded, and incipient; efforts moved into the commercial nuclear power industry [7-9] and to the offshore oil [10] and chemical industry [11].

The improvement of data analysis techniques and also of hardware and software tools has initiated the growth of database performances. It should be noted that the extent to which a database has been developed varies according to the domain of its application.

3 Types of reliability data

This section of the report contains the definitions of typical data types (classification has been introduced by the report author).

Plant-specific operational data are the data reflecting any event which can occur with equipment (this term covers installation and modification) and which have to be monitored, including the background of data source (environmental conditions, age of equipment, specific features, etc);

Operational data are the data derived from the plant-specific operational data with respect to comparable equipment parameters;

Equipment data are the data describing the "life" of some equipment notably related to failures and maintenance.

Event data are the data describing all events concerning the system functioning, maintenance, etc. These data can be divided into classes:

- *failure data* – information about all accidents/incidents (time of happening of event, site, conditions, consequences, persons involved, etc)
- *maintenance data* – information about corrective and preventive maintenance (time, duration, conditions, cost, etc);

Processed reliability data include failure rate in operation (λ), probability of failure on demand (γ), average repair time, and their confidence intervals, etc;

Reference data are the data being used as standard ones or as a basis for prediction or for comparison with observed data.

The main stages of data collecting and interpreting are illustrated by Figure 1.

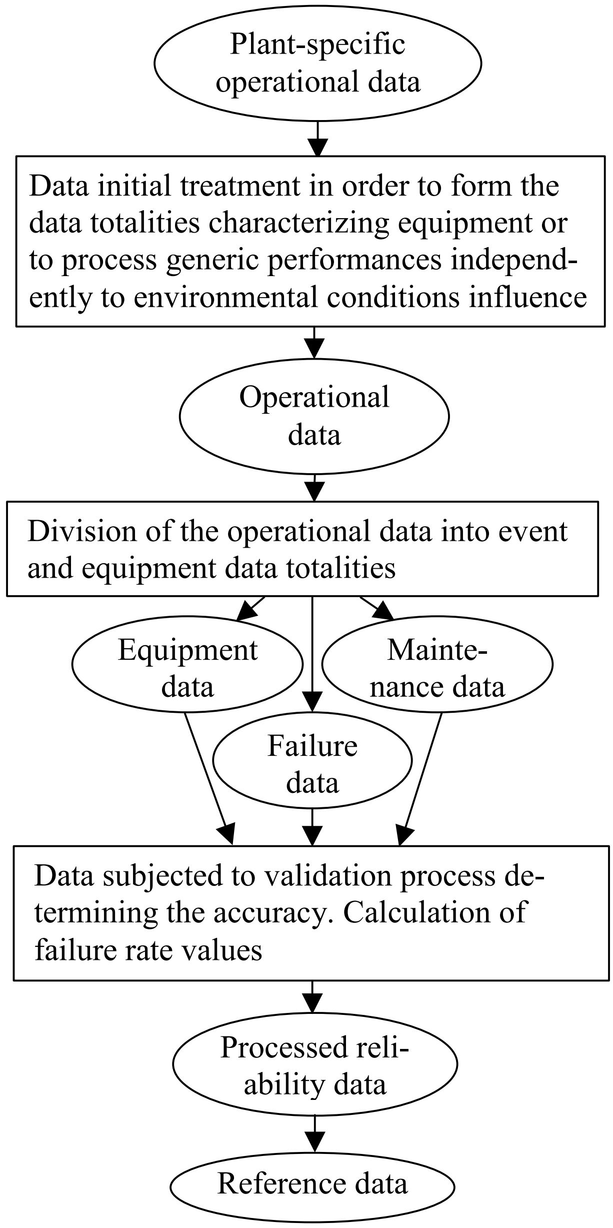

Figure 1

4 Reliability data sources

The following databases are best known. These databases are always under development and being updated (increasing the number of components, involving new analysis methods and techniques, improving the computer tools, etc).

4.1 Databases of equipment data

OREDA (Offshore REliability DAta)

OREDA is a project organisation sponsored by nine oil companies (see list of participants below) with worldwide operations. OREDA's main purpose is to collect and exchange reliability data among the participating companies and act as the forum for co-ordination and management of reliability data collection within the oil and gas industry. OREDA has established a comprehensive databank with reliability and maintenance data for exploration and production equipment from a wide variety of geographic areas, installations, equipment types and operating conditions. Offshore, subsea, and topside equipment are primarily covered, and onshore equipment is also included. The data are stored in a database, and specialised software has been developed to collect, retrieve, and analyse the information.

OREDA Participants:

BP Amoco p.l.c.
Chevron Petroleum Technology Company
TotalFinaElf
ENI S.p.A./AGIP
ExxonMobil
Norsk Hydro ASA
Phillips Petroleum Company Norway
Den norske stats oljeselskap (Statoil) a.s
Shell International Exploration and Production B.V.

OREDA taxonomy and data

The OREDA taxonomy and specification concept has been used as a basis for the development of ISO standard No. 14 224 "Petroleum and natural gas industries - Collection and exchange of reliability and maintenance data for equipment" which was issued by ISO July 1st 1999.

The complete list of equipment taxonomies available for phase V data collection is:

1. Battery & UPS
2. Combustion engine
3. Compressor
4. Control logic
5. Control system
6. Disconnectable turret
7. Electric generator
8. Electric motor
9. Fire & Gas detector
10. Gas turbine
11. Heat exchanger
12. Heater & Boiler
13. Nozzle
14. Pedestal crane
15. Permanent turret
16. Pipeline
17. Process sensor
18. Production riser
19. Pump
20. Running tool
21. Steam turbine
22. Swivel
23. Template & manifold
24. Turboexpander
25. Valves
26. Vessel
27. Wellhead & X-mas tree

Non-OREDA members may get access to this database when doing contract work for any of these member companies (see name of contact persons on the OREDA Website/Participants).

Additionally, data have been issued in generic form in Reliability Handbooks. Three handbooks have been issued since 1984, the last edition (No. 3) early 1998. These handbooks are sold in public for a price of NOK 3000 ($ 330).
OREDA website:
http://www.sintef.no/units/indman/sipaa/prosjekt/oreda/index.html

GIDEP

See [4]. GIDEP members are having electronic access to the types of documents listed below. The proper utilization of GIDEP data can improve quality and reliability while reducing costs in the development, manufacture, and support of complex systems and equipment. The GIDEP database has both equipment and failure parts. In particular, GIDEP documents include:
Reliability and Maintainability (R&M) Data contains failure rate, failure mode, and replacement rate data on parts, components, and subsystems based upon field performance and demonstration tests of equipment, subsystems, and systems. This also includes reports on theory, methods, techniques, and procedures related to reliability and maintainability practices.
Accessibility: http://www.gidep.corona.navy.mil/gidep.htm

Other US governmental organisations providing reliability data

AMSAA's Physics of Failure - Information on the physics-based approach to electronic equipment reliability and other reliability related information including links to reliability related sites.
Accessibility: http://amsaa-web.arl.mil/rad/pofpage.htm
JPL/NASA WWW Radiation Effects Database - Radiation effects test data for total ionizing dose and single event effects.
Accessibility: http://radnet.jpl.nasa.gov/search.htm
JPL's Commercial Off-The-Shelf (COTS) - Allows access to technical reports on COTS/microelectronics used in space programs, COTS risk mitigation methods, and links to other COTS sites.
Accessibility: http://cots.jpl.nasa.gov/
NASA/GSFC Radiation Effects and Analysis site - Test results of the effects of radiation on electronics & photonics.
Accessibility: http://flick.gsfc.nasa.gov/radhome.htm
Product & Technology Surveillance - Information on various military technology issues including product life cycle data and COTS evaluation data hosted by NSWC, Crane Division.
Accessibility: http://pats.crane.navy.mil/pub.htm
Sandia National Laboratories Quality/Reliability Center - A wide range of information on electronics reliability and failure analysis.
Accessibility: http://www.sandia.gov/eqrc

US Industry Companies providing reliability data

Automotive Engineering Council - Automotive part qualification and quality system standards.
Accessibility: http://aecouncil.com/
Harris Semiconductor - Access to many documents and publications including product data sheets, component test reports, and technical papers written by Harris Semiconductor.
Accessibility: http://rel.semi.harris.com/

Hewlett-Packard Laboratories - Provides abstracts of HP Labs Technical Reports.
Accessibility: http://www.hpl.hp.com/search/index.html
Relex Software Corp - Specializes in software analysis, tools, training seminars in reliability engineering.
Accessibility: http://relexsoftware.com/
Reliability Analysis Center - Information in the engineering disciplines of Reliability, Maintainability, Supportability and Quality.
Accessibility: http://rac.iitri.org/
Xilinx Quality & Reliability Programs - Xilinx qualification requirements, results of their reliability monitor program of all product families and all package families.
Accessibility: http://www.xilinx.com/products/qa_data/rel_prog.htm

Non-governmental US organisations providing reliability data

Engineering Statistics Handbook - Goal is to help scientists and engineers incorporate statistical methods in their work as efficiently as possible.
Accessibility: http://www.itl.nist.gov/div898/handbook/index2.htm
IEEE Reliability Society
Accessibility: http://www.ewh.ieee.org/soc/rs/
International Society of Logistics Engineers
Accessibility: http://www.sole.org/
Reliability, Availability, Maintainability Symposium
Accessibility: http://www.rams.org/

TUD database

Earlier the ATV database. This data source is operated and owned by the NPP operators in Sweden and by the operator of the TVO in Finland. The database was designed and taken into service already in the mid-seventies and today stores more than 160,000 failure reports.

BASEXP (Base de donnees informatique en expertise electronique i.e. computer database of electronic expertise)

Created by the CNES (National Centre for Space Studies) in 1992, is a database centred on the analysis of electronic component failures. The content of BASEXP is based on reports issued by the analytical laboratories of the CNES and articles in the specialised literature. Its originality resides in the facility which it provides for the consultation of documents since it allows users to access scanned documents in real time. The nature of consultation depends on the client/server architecture (users not being computer specialists, the database has to be easy to use).

SRDF (Sisteme de recueil de donnees-de fiabilite)

SRDF is the database of EDF (Elictricite de France) which deals with equipment used in nuclear plants. It was put into service in 1978. Data present in the database relates to electrical, mechanical, and electronic equipment. The purpose of this system is to enable the in-service behaviour of a certain number of items of equipment, chosen according to their importance with respect to safety or perhaps the availability of particular units, to be monitored in as much detail as possible. The items of equipment monitored consisted of approximately 1,100 per couple of nuclear units in 1988. Approximately 70,000 reports of failure were added between 1978 and 1992 and 20,000 between 1992 and 1997.

EIREDA.PC (European Industry Reliability Databank)

This is a computer version of the EIREDA data bank. Data therefore relate to the electrical, mechanical, and electromechanical equipment of nuclear plants. This database was created in 1990 and regrouped data drawn from SRDF and other database of EDF (AMPERE Data Bank for example).
Contact: http://www.vtt.fi/aut/tau/network/esreda/esr_home.htm

SADE (Systeme d`analyse des defaillances en explotation i.e. system for analysis of failures in service)

The computer database was developed in 1976 by the CNET (Centre d`etudes des telecommunications i.e. national centre for telecommunications studies) and has been operational since 1978. This database is largely oriented towards electronic equipment (integrated circuits, transistors). For this type of equipment, failure rates are given in a form of analytical relationships and diagrams that allow technological characteristics, operation conditions and environmental factors to be entered. Computer calculation of failure rates is possible. The number of items of electronic equipment was approximately 9 million in 1993 and 180000 reports of failure are recorded each year.

ZEDB (Zentrale Zuverlässigkeits- und Ereignisdatenbank)

ZEDB is a centralized database, in which 20 nuclear power plants (19 German and 1 Dutch) feed design, operational and event data of components that are important with respect to probabilistic safety assessment (PSA). These are mechanical and electronic components, including component specific electronic control equipment.

CORDS (Nuclear Component Reliability Data System)

PC based multi-purpose data system written in Foxpro for Windows and has been operational since 1990. This database contains reliability data from 4 Canadian Nuclear Power Stations (20 reactor units totally).

CCPS/AIChE – Equipment Reliability Database Project

The purpose of the Process Equipment Reliability Database is to provide high quality, valid, and useful data pertaining to the hydrocarbon and chemical process industries. These data can support equipment availability analyses, reliability and design improvements, maintenance strategies, quantitative risk analyses, and life cycle cost determinations.

Participating Companies

Air Products & Chemicals Inc	HSB Energy Division
BOC Group	Hercules, Inc
BP/Amoco	ICI

Citgo Corpus Christi Refinery	Intevep S.A. (Venezuela)
The Dow Chemical Company	Mitsubishi Chemical Corporation
DuPont Engineering	Rosemount Inc.
Equilon Enterprises LLC	Rohm and Haas Company
Factory Mutual Research Corporation	Shell Oil
General Physics	Texaco

Database Features

Although based on published OREDA concepts and evolving ISO database standards, the taxonomies, types of equipment, and equipment boundary conditions in the CCPS database have been modified, when necessary, to be relevant and useful to the Chemical and Hydrocarbon Processing Industries.

Published in September 1998, the book, *Guidelines for Improving Plant Performance through Data Collection and Analysis*, describes the essential elements and information involved, including failure modes, equipment boundaries, and software to house the data. This book also contains examples of how the data can be used to perform value-added analysis to support maintenance optimisation, improved design, and quantitative risk analysis.

The example of the data sheet (from [9]) is presented in the Appendix A.
This project is not finished yet.

4.2 Databases of failure data

GIDEP

See [4]. GIDEP database includes:
Failure Experience Data (FED) consists of objective failure experience data in five types of reports:

1. ALERTs (AL)
2. SAFE-ALERTs (SA)
3. Problem Advisories (PA)
4. Agency Action Notices (AN)
5. Lessons Learned (LL)

These reports are used to notify GIDEP participants about non-conforming parts, components, chemicals, processes, materials, specifications, test instrumentation, safety, and hazardous situations including health hazards. This data also includes failure analysis and problem information submitted by laboratories. Lessons Learned reports shares useful accident prevention information.

Accessibility: http://www.gidep.corona.navy.mil/gidep.htm

NUREG (Nuclear Regulatory Commission)

The NRC's Incident Response Operations (IRO) has published over 500 reports on a broad range of operational experience since 1980. Some of them have been published as NUREGs, including the NUREG-1275 series of Operating Experience Feedback Reports. These reports have been broadly disseminated throughout the nuclear community and to the public. Most reports can be found in the NRC's Public Document Room, and the Nuclear Documents (NUDOCS) database under the *Task Identifier* AE, followed by the report number.
Accessibility: http://www.nrc.gov/NRC/reactors.html

PC-FACTS

A database with more than 20,000 entries to accidents with hazardous materials created and provided by TNO (Nederlandse Organisatie voor **t**oegepast-**n**atuurwetenschappelijk **o**nderzoek i.e. the Netherlands Organisation for Applied Scientific Research)

The database contains more than 20,000 descriptions of accidents with hazardous materials.

Sources are reports from government agencies, publications and technical periodicals.

All data are coded in abstracts for further analysis.

Users are:

- Engineering companies.
- Chemical and petrochemical industry and energy sector.
- Companies storing, transporting, and transferring goods.
- Consultants.
- Authorities.
- Universities and research institutes.
- Insurance companies.
- Fire brigades and safety training centres.

Retrieval of data

Information on accidents can be retrieved by using specified key words.

The programme Friends can be used to specify the search profile, to obtain a price quotation and an order form.

Three options are offered for information presentation of the selected accidents

1) Accident tables: An overview of the main features
2) Accident abstract: Coded identification and a short description of the accident
3) Extended abstract: Complete text as far as available

NB Information may be limited for reasons of confidentiality.

Information can be delivered on hard copy, diskette, or CD-ROM.

Accessibility:
TNO: http://www.tno.nl
PC-FACTS:
http://www.mep.tno.nl/wie_we_zijn/organisatie/afdelingen/industriele_veiligheid/productbladen/productblad_PCFACTS_IV.html

SKI-PIPE

Database on piping failures in commercial nuclear power plants worldwide.
Contact: www.ski.se

Organisations and private companies possess their own databases but the information contained in these ones is confidential and public access is forbidden in order to protect information from competitors.

4.3 Handbooks (reference data)

Military Handbook 217

The first version was published in 1962 and it is regularly revised. This document relates to electronic components used in military equipment.
See also http://www.relexsoftware.com/reference/pdffiles.htm

OREDA Handbook

The data presented are on maintenance, equipment availability and safety improvement needs on offshore oilrigs.

The example of the OREDA data sheet is presented in Appendix A.
Contact: http://www.sintef.no/sipaa/prosjekt/oreda/handbook.html

EIREDA (European Industry Reliability Data Bank)

Data relating to failures of components which play a role in the safety of EDF nuclear plants (34 units), and in the 1998 version, failures in relation to maintenance, and as a general rule, failures of thermal hydraulic, electric and electronic equipment and components.

The example of the EIREDA data sheet is presented in Appendix A.
Contact: http://www.vtt.fi/aut/tau/network/esreda/e_cont.htm

T-Book (TUD System)

The main objective of this databank is to provide failure data for reliability computation which is part of safety analysis of the Nordic Nuclear Power Plants (14 units). Information is automatically collected from the Computerized Plant Maintenance Systems. Reliability parameters are updated with Bayesian techniques, and results are coherent with EDF data.
Contact: www.ski.se

I-Booken (TUD System)

This edition presents the actual Swedish and Finnish transient data and "recommended" frequencies to be used in PSA studies of the Nordic countries. The first version was published during the spring of 1993.

This handbook is available only in Swedish but the table of content, the summary of the report, tables, diagrams are translated and prepared with English text.
Contact: www.ski.se

IEEE Std 500

IEEE Guide to the Collection and Presentation of Electrical, Electronic, Sensing Component, and Mechanical Equipment Reliability Data for Nuclear Power Generating stations. This data book contains expert estimations for the abovementioned equipment failure rates.

The example of the IEEE-500 data sheet is presented in Appendix A.

Handbook of Reliability Data for Electronic Components RDF 93 (France Telecom National Telecommunications Research Center – CNET)

This handbook is the result of the following contributions:
- reliability results concerning equipment in operation, in particular concerning telecommunications equipment (results supplied by manufacturers ALCATEL-CIT, CROUZET and by FRANCE TELECOM), railway equipment (GEC-ALSTHOM) and computer hardware (BULL).
- Component test results (constructors, manufacturers, CNET).
- The experience of a number of experts gleaned from failure and construction analysis on new and used components (constructors, manufacturers, CNET).

The reliability data contained in the handbook is taken mainly from field data concerning electronic equipment operating in three kinds of environment:
- “Ground; stationary; weather protected” i.e. equipment for stationary use on the ground in weather protected locations, operating permanently or otherwise. This applies mainly to telecommunications equipment and computer hardware.
- “Ground; non-weather protected” i.e. equipment for stationary use on the ground in non-weather protected locations. This relates for example, to public payphones.
- “Ground; non stationary; benign” i.e. equipment for non-stationary use on the ground in benign conditions of use. This concerns mainly transport equipment.

British Handbook of Reliability Data for Components used in Telecommunications Systems (HRD5, last issue)

This document is produced from field data supplied by British Telecom’s Materials and Components Centre.

Guidelines for Quantitative Risk Assessment (Purple Book)

This handbook is prepared and published by the Committee for the Prevention of Disasters under the supervision of the Dutch Government. It documents the methods to calculate the risks due to dangerous substances in the Netherlands using the models and data available. Calculation of the risk relates, on the one hand, to stationary installations and, on the other, to transport and related activities.

4.4 Standard models of reliability

MIL-HDBK-217

MIL-HDBK-217 was the original standard for reliability. It was designed to provide reliability math models for nearly every conceivable type of electronic device. It is used by both commercial companies and the defence industry, and is accepted and known world-wide. The most recent revision of MIL-HDBK-217 is Revision F Notice 2, which was released in February of 1995.

MIL-HDBK-217 includes the ability to perform a 'parts count' analysis or a 'part stress' analysis. A 'parts count' analysis provides a simpler reliability math, and is normally used early in a design when detailed information is not available, or a rough estimate of reliability is all that is required. A 'part stress' analy-

sis takes into account more detailed information regarding the components, and therefore offers a more accurate estimate of failure rate.
See also http://www.relexsoftware.com/reference/pdffiles.htm

Bellcore

The Bellcore reliability prediction model was originally developed by AT&T Bell Labs. Bell Labs modified the equations from MIL-HDBK-217 to better represent what their equipment was experiencing in the field. The main concepts between MIL-HDBK-217 and Bellcore were very similar, but Bellcore added the ability to take into account burn-in, field, and laboratory testing. This added ability has made the Bellcore standard very popular with commercial organisations. The most recent revision of the Bellcore Reliability Prediction Procedure, TR-332, is Issue 6 dated December 1997.

Bellcore also supports the ability to perform a 'parts count' or 'part stress' analysis. In Bellcore, however, these different calculations are referred to as Calculation Methods. Bellcore offers ten different Calculation Methods. Each of these methods is designed to take into account different information. This information can include stress data, burn-in data, field data, or laboratory test data.

5 Standardisation of the data collection and exchange

5.1 ISO standard: Gas and Oil - Collection of Reliability and Maintenance Data for Equipment

Based on OREDA Guideline for Data Collection. The scope for the standard is to establish the basis for a consistent approach to data collection for the petroleum and natural gas industry. The main objectives are:

A) to specify the data to be collected for analysis of:
- system design and configuration;
- safety, reliability and availability of systems and plants,
- life cycle cost,
- planning, optimization, and execution of maintenance.

B) To specify data in a standardised format in order to:
- permit exchange of RM data between plants, owners, manufacturers, and contractors,
- ensure that RM data are of sufficient quality for the intended purpose.

Data collection must be fulfilled according to the standard (the requirements are given in the normative part of the standard). The normative part includes the fundamental requirements to ensure that collected data meet the scope. These requirements are related to:
- classification of equipment to technical, operational, and environmental parameters
- failure related parameters describing the maintenance performed
- maintenance related parameters describing the maintenance performed.

5.2 EDF standard for collection of reliability and maintenance data for equipment (also called MCD – Mode et Cause de Defaillance module i.e. failure mode and cause module)

This standard regulates the data collection in the nuclear and electricity generation domains.

Some information about the ISO and MCD comparison is in the Appendix A.

5.3 Other related standards

5.3.1. International standards

ISO6527

International Organisation for Standardisation, ISO 6527, Nuclear power plants; Reliability data exchange; General guidelines, October 1982.

Identifies the typical parameters of a component that permit it to be characterised unequivocally and to allow the corresponding reliability data to be associated with those of other components having equivalent typical parameters. Parameters refer to technical characteristics including the physical principle of operation and quality level and to actual operating conditions and maintenance and test intervals. Data may be represented both in a historical and in a statistical form.

ISO7385

International Organisation for Standardisation, ISO 7385, Nuclear power plants; Guidelines to ensure quality of collected data on reliability, August 1983.

The output of a data collection system is strongly dependent on the quality of the information collected. Before starting such a system it is necessary to clearly define the following items: overall goal, suppliers of field data, users of processed data, terms and expressions to be used, means used to collect data and to treat them, questions to be answered by field data, and field data needed. The standard gives a comprehensive guidance to ensure quality of availability and reliability data collected in nuclear power plants.
Accessibility: http://www.iso.ch

IEC0300-3-2

International Electrotechnical Commission, IEC 300-3-2, Dependability management; part 3: application guide; section 2: collection of dependability data from the field, October 1993.

IEC0319

International Electrotechnical Commission, IEC 319, Presentation of reliability data on electronic components (or parts), 1978.

IEC0706-3

International Electrotechnical Commission, IEC 706, Part 3, Guide on maintainability of equipment; Sections Six and Seven - Verification and collection, analysis and presentation of data, 1987.

IEC0362

International Electrotechnical Commission, IEC 362, Guide for Collection of Reliability, Availability and Maintainability Data from Field Performance of Electronic Items, 1971. (Currently under revision as TC56(Secretariat)267).
Accessibility: http://www.iec.ch

EURO12418

EURO PSC/83/12418, Supply of Basic Maintainability and Reliability Data.

5.3.2. Australian standards

AS2529

Standards Australia, AS2529, Collection of reliability, availability, and maintainability data for electronic and similar engineering use, 1982.

Provides guidance on the collection of reliability data on the field performance of electronic components, equipment and systems to provide data for the comparison of actual and predicted reliability, the improvement of achieved reliability, and the derivation of availability and maintainability information. The Standard can be applied to any other field of engineering for which such data are requested. Technically identical with IEC 362.
Accessibility: http://www.standards.com.au

5.3.3. British standards

BS 5760-11:1994, IEC 60300-3-2:1993

Reliability of systems, equipment, and components. Collection of reliability, availability, maintainability and maintenance support data from the field
Handbook 22:Part 2:1992
Handbook 22. Reliability & maintainability
Accessibility: http://www.bsi-global.com/group.html

MOD00-44/1

UK MoD Directorate of Standardization, Defence Standard 00-44, Reliability and Maintainability Data Collection and Classification; Part 1: Maintenance Data & Defect Reporting in the Royal Navy, the Army and the Royal Air Force, Issue 1, March 1993. (Supersedes Def Stan 05-59).

MOD00-44/2

UK MoD Directorate of Standardization, Defence Standard 00-44, Reliability and Maintainability Data Collection and Classification; Part 2: Data Classification and Incident Sentencing, Issue 1, April 1994. (Supersedes Def Stan 05-59).

Accessibility: http://www.dstan.mod.uk

5.3.4. Dutch standards

NEN10319

Nederlands Normalisatie Instituut, NEN 10319, Presentation of reliability data on electronic components (or parts), July 1980.

This standard is intended to provide guidance for presenting data necessary to distinguish the reliability characteristics of a component. The data may be that relating to failures and failure rates or it may be data on changes (or drift) of characteristics. Such factual information should be available to the circuit and equipment designer to enable him to correctly assess the reliability of his circuits and units. This information will be obtained from reliability test made on the electronic components in laboratories and should be presented as indicated herein.
Accessibility: http://www.nen.nl

5.3.5. Turkish standards

TS5580

Turkish Standards Institution, TS 5580, Nuclear Power Plants - Reliability Data Exchange General Guidelines, 14 March 1988.

TS5581

Turkish Standards Institution, TS 5581, Nuclear Power Plants - Guidelines To Ensure Quality of Collected Data On Reliability, 14 March 1988.
Accessibility: http://www.tse.org.tr

5.3.6. US standards

EIA JEP70

Electronics Industry Association, EIA JEP70, Quality and Reliability Standards.

EIA RB4-A

Electronics Industry Association, EIA RB4-A, Reliability Quantification.
Accessibility: http://www.tiaonline.org/standards/

RAC EEMD-1

RAC, EEMD-1, Electronic Equipment Maintainability Data.

RAC NPRD

RAC, NPRD, Nonelectronic Parts Reliability Data.

This document provides failure rate and failure mode information for mechanical, electromechanical, electrical, pneumatic, hydraulic, and rotating parts. The assumption that the failures of nonelectronic parts follow the exponential distribution has been made because of the virtual absence of data containing

individual times or cycles to failure. Generic failure rate tables include environment; application (military or commercial); failure rate; number of records; number failed; and operating hours. A 60 percent confidence interval is used.
Accessibility: http://rac.iitri.org

IEEE0493

Institute of Electrical and Electronics Engineers, ANSI/IEEE-Std-493, Recommended practice for the design of reliable industrial and commercial power stations, 1990.

Scope: The fundamentals of reliability analysis as it applies to the planning and design of industrial and commercial electric power distribution systems are presented. The presentation is self-contained and should enable trad-off studies during the design of industrial and commercial power systems.

Principal topics:

- Basic concepts of reliability analysis by probability methods
- fundamentals of electric power systems
- reliability evaluation
- economic evaluation of reliability
- cost of power outage data
- equipment reliability data
- evaluation and improving the reliability of an existing plant
- preventive maintenance
- emergency and standby power
- examples of reliability analysis and cost evaluation.

Keywords: Designing reliable industrial and commercial power systems, equipment reliability data, industrial and commercial power systems reliability analysis, reliability analysis.

IEEE0500-P&V

Institute of Electrical and Electronics Engineers, IEEE 500 P&V, Standard Reliability Data for Pumps and Drivers, Valve Actuators, and Valves.

IEEE1046

Institute of Electrical and Electronics Engineers, IEEE 1046, IEEE Application Guide for Distributed Digital Control and Monitoring for Power Plants, 1991
Issuing agency: Professional society, IEEE Power Engineering Society
Type: Guide
Level: Computer system
Size: 105 pages
Scope: Use of digital computers in power plants other than nuclear power plants. Only the specific control aspects of fossil-fuel power plants have been included; apparently also excludes hydroelectric power plants. This guide presents alternative solutions, with comments on them.

Principal topics:

- Objectives of distributed control and monitoring systems
- Dependability
- Plant efficiency

- Improved response time
- Extended equipment life
- Improved operation
- Improved operator interface
- Accessibility of plant data
- Cost-related factors
- System application issues
- Integrated versus segregated systems
- Functional and geographic distribution
- Hierarchical architecture and automation
- Control and protection functions
- Input and output systems
- Environmental considerations
- Documentation
- Data communications structure
- Data communications functions
- Data communications structures
- Control data communication requirements
- Architectural view
- Remote intelligence in distributed control systems
- Single linear network topology
- Special features of proprietary control networks
- Hierarchical network architecture's
- Data acquisition and monitoring
- Man/process and man/ system interfaces
- Reporting functions
- Monitoring functions
- Operating functions
- Diagnosing functions
- Plant performance functions
- Optimisation
- Processing
- Reliability, availability, and fault tolerance of distributed systems
- Reliability
- Software/ hardware/ human reliability
- Partitioning, redundancy, and fault tolerance
- Reliability and availability in distributed control systems

Accessibility: http://standards.ieee.org

6 Related software products

6.1 Reliability Analysis Centre (RAC) products

NPRD-95

Extensive collection of reliability data on mechanical, electromechanical and electronic part types and assemblies. Contains failure rate data on over 25,000 individual parts. Includes part summaries, part details, data sources, part number/mil number index, national stock number index with federal stock class prefix, national stock number index without federal stock class prefix, and part description index. Is a complement to MIL-HDBK-217 in performing reliability analyses of system designs.

MDR-21A Data

This program contains electronic field experience data. Database allows user to conduct custom searches on selected fields and either display or print the results. Files are in dBase III format.

FNPRD-3 (Nonelectronic Parts Reliability Data)

This program allows searches to be conducted on various data fields with the results of searches either displayed or printed. Files are stored in a dBase III format. The use of dBase III allows the user to modify the database if necessary.

VPRED (VHSIC Reliability Prediction Software)

Reliability prediction tool addressing VHSIC and VHSIC-like large-scale CMOS devices. VPRED is based on models presented in RADC-TR-89-177, "VHSIC / VHSIC-like Reliability Prediction Modelling".

Addition (from the RAS homepage):
RAC is renowned worldwide as a source for reliability data. It maintains extensive quantitative and qualitative databases on components/assemblies and makes these data available through several data products. Data is collected from numerous industry and government test and field sources and is updated on a continual basis. Below is a listing of RAC data products.

- Data Sharing Consortium
- Electronic Parts Reliability Data
- Non-electronic Parts Reliability Data
- Non-operating Reliability Data
- Failure Mode Distributions
- Electrostatic Discharge Susceptibility Data

Contact: http://rac.iitri.org

6.2 Relex Software Corporation products

Relex Calculs Simplifies

Electronic reliability analysis based upon prediction models from the French Centre National D'Etudes Des Telecommunications standard. Uses simplified reliability analysis with average data values.

Relex CNET

Performs reliability analyses on electronic systems per the French document "Recueil de donnees de fiabilite du CNET". It provides a state-of-the-art user interface with extensive hypertext help, bar, pie, and line scientific graphics, large parts libraries, CAD interface, defaults and derating analysis, system modelling and redundancy capabilities.
Contact: http://www.relexsoftware.com

6.3 BQR Reliability Engineering Ltd. products

CARE® FTA - Fault/Event Tree Analysis

Handles Hardware/Software Fault and Event trees (no limit of functional levels, number of assemblies, faults or events. The FTA tree can be built-up from the project tree assemblies or components and/or from the functional FMECA tree and/or from the RBD model tree. Different Gates options such as OR, AND, NOT, XOR, K-out-of-N. FTA analyses common mode failures. There is a really simple on screen presentation of the tree using + and - to expand and collapse trees.
Only up and down scroll - no need to scroll right and left for large trees.
Quick and accurate calculation of probability and rates for all events.
Conditional effects probability may be given under OR gates.

CARE® RBD Basic Model

The CARE® RBD module is the ultimate tool for the project management and system engineering personnel for reliability Allocation and reliability Calculation. The RBD tool provides six basic model types that provide engineering personnel with capability to model the functionality of ANY complex system (electronic, mechanical and software).

RBD Basic includes the following item types: Simple, Serial - The block fails when a sub block fails, Parallel - The block fails when all sub blocks fail. All sub blocks operate simultaneously until failure, K out of N - The block fails, when any K sub blocks fail from N, Stand By - The block fails when all sub blocks fail. Only one sub block operates each moment. The rest are spares or in failure.

The software provides the following results: MTBF\FPMH, Reliability, Availability, Down Time (Hrs), MTTR (Min).

CARE® RBD Network Model

The CARE® RBD module is the ultimate tool for the project management and system engineering personnel for reliability Allocation and reliability Calculation.

The Network Reliability Analyzer helps systems and networks designers to evaluate the Reliability, Availability, and Down Time of the Network, from the concept design to the completion of the full-scale development.

The entire network fails only if there are no valid (operational) paths from the Input to the Output. Any network configuration may be build where every sub-block (connection) can be composed from any of the Basic and Markov models. If the network may be split to some sub networks with a few connections between them, each sub block can be replaced by "multipin" block, simplifying the common solution. Each sub-block can also be composed from any of the Basic and Markov models.

The software provides the following results: MTBF\FPMH, Reliability, Availability, Down Time (Hrs), MTTR (Min).

MTBF Prediction :

- Predict Failure Rates of components in accordance with the following standards :
    - Parts-Count and Stress of MIL-HDBK-217F1
    - HRD5 of British-Telecom
    - CNET95 of France-Telecom
    - BellCore
    - Non-Operating of MIL-HDBK-217E1
    - User Defined prediction methods
    - Mechanical Failure Rates based on NPRD-95
    - FARADIP - Failure Rates Data in Perspective
- Combination of different Prediction-Methods and Environments in one project
- Failure Rates allocation from system to lower levels
- Graphical MTBF Project Tree Editor
- CAD/CAE interfaces
- 30,000 Components Library
- BQR provides services to prepare customized components libraries
- Mission Reliability calculation
- Global change, Optimization and Curve Sensitivity facility for : Ambient/Case Temperatures, Quality-Levels, Environments and Prediction-Methods
- 3 Failure Rates PARETO tables by: Reference-Designators, Part-Numbers and Part-Categories

Electronic Libraries

Military Components Library

Available data for 6,000,000 military components, such as: MIL-C-39014, MIL-C-39006, MIL-C-39001, MIL-C-20, MIL-C-5, MIL-R-55182, MIL-R-39017, MIL-R-39008, MIL-R-39007, MIL-C-39003, MIL-R-22684, MIL-R-10509, MIL-R-26, MIL-R-11 and others.

Industrial Components Library
This library contains new State-of-the-Art 5,000 components from different manufacturers sorted by Part Numbers. The library includes reliability and thermal attributes.
Contact: http://www.bqr.com/

6.4 Aralia/SimTree program
A powerful and user-friendly tool for creating, presenting and processing fault trees for Windows. Aralia-SimTree has developed by two laboratories of the University of Bordeaux: the Laboratory for Computer Research (LaBRI) and the Laboratory of Analysis for System Dysfunction (LADS). Aralia-SimTree is distributed by IXI.

Aralia-SimTree has a hierarchically organised reliability database which is independent from projects.
Contact: http://www.ixi.fr/tools/

6.5 RAM Commander
This is a software for Reliability and Maintainability engineers, including following libraries:

- Extensive Component libraries with more than 20000 components produced by world-leading manufacturers
- User Component libraries
- Utility for uploading Component libraries from external sources
- User-defined Failure Rate library with field data

Contact: http://www.ingenieurwerkstatt.de

7 Summary
The completed analysis and description of the state-of-the-art in the field of reliability databases shows that this type of activity progresses rapidly. From the first generation of the data sources accumulating some reliability indices [3] such databases have gone a long way in order to obtain essential new performances which allow the users to solve a lot of practical problems within safety or reliability level assessment.

The modern reliability databases are characterised by the following specific features:

(i) the great number of equipment and failure reports included into the database (up to 9 million reports in SADE database);
(ii) the wide scope of the information to be involved: namely failure numerical data, maintenance parameters, climate conditions, etc (OREDA, SADE, PC-FACTS and other databases);
(iii) the reflection of real uncertainty corresponding to initial data, in particular by giving the lower and upper bounds for failure rate estimates (IEEE-500, T-Book, OREDA, EIREDA, CCPS Guidelines);
(iv) orientation towards definite types of equipment or separate branches of industry:
  - nuclear power plants (T-Book, NUREG Reports, ZEDB, CORDIS);
  - chemical industry (CCPS);
  - offshore gas and oil industry (OREDA);

- electronic components of technical systems (BASEXP, SRDF, EIREDA) etc.

Sometimes computer implementation of reliability databases contains additional details that give a possibility to consider them as data banks (e.g. EIREDA 2000 besides datasheets includes additional tools for Bayesian analysis accomplishment and some results visualisation).

Application of reliability databases to the investigation of technological systems performances normally allows:

- to reduce the time for resulting indices computing;
- to accomplish computer-aided analysis of safety, reliability, and maintainability by means of widely used methods (fault trees or event chains construction, Monte Carlo simulation, maintenance planning for critical failures prevention);
- to provide a possibility of repeated computations with the same initial data brought from the same information source (this is important for the results verification).

The properties of the databases mentioned above allow us to expect an essential effect from their implementation into projects being accomplished by the Department of Systems Analysis at Risø, especially in the framework of the programs concerning industrial risk assessment, safety provision for technological processes in nuclear and chemical industry, maintenance of power sources, and many others.

Meanwhile it becomes clear that the complexity of situations for which reliability databases have to be applied also causes the necessity to implement the new investigations in order not only to promote the existing databases but also to construct new (in principle) information stores. Here we outline the following directions of the future activity:

(i) it can be observed that many databases contain information obtained by different procedures for its extraction, so the comparison of databases contents shows sometimes a great variation in the parameter values; consequently the problem appears how to provide a consensus between the data from different sources. The reasons of the differences are the following (see Fig.2):

1. differences in the conditions of work and maintenance,
2. differences in the data collection procedures,
3. differences in the procedures of data presentation and visualisation;

Possible solutions to this problem are:

1. more detailed analysis of different data collection and exchange standards for the definition of main sources of differences (for example via preparation the “test set of data” and investigation of data collection results),
2. investigation of used data analysis procedures for the definition of main sources of differences and interpretation of their results (can be used the same way as in the previous part),
3. definition of “typical” set of reliability data presentation that can be used in the wide spectrum of applications.

(ii) today the special types of databases for reliability analysis and for industrial risk analysis usually are created as different independent ones, meanwhile a correct risk analysis must give an opportunity to see the whole “chain” of events (from the equipment failures to the accidents with definite consequences); as a result, combined hierarchical databases are needed, where reliability databases can play a role of an important subsystems;

(iii) the fact that reliability databases are considered the tools for effective decision making support makes it inherent to compose datasheets with necessary algorithms for information treatment, intermediate results visualisation, and preliminary conclusion formulation; in fact this means that the great majority of such databases transform into the data banks.

The implementation of the activity that aims at building the foundations for new types of data sources forming requires both research and development.

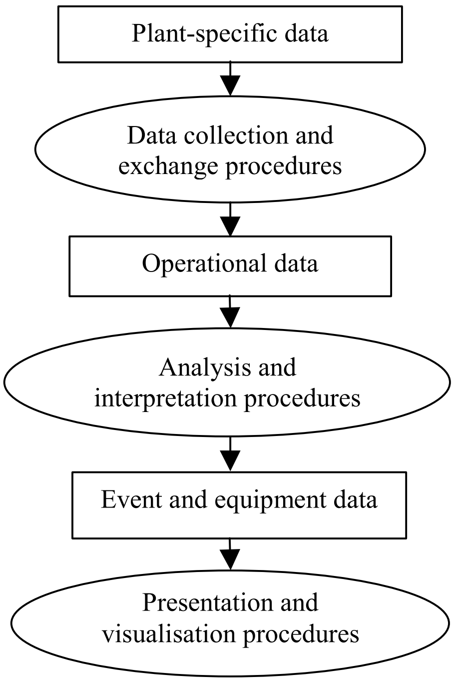

Figure 2

8 Acknowledgements

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9 References

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Appendix

1. OREDA data

The data in the Handbook represent the North Sea (Norwegian and UK sector) and the Adriatic Sea. Data have been collected for altogether 7,629 equipment units. The data represent a total observation period of 22,373 years, and 11,154 failures have been recorded.

The data are presented in approximately 250 data sheets for various functions, applications, capacities, fluids, sizes etc. of the equipment. An example of such a data sheet is shown below:

Taxonomy no		**Item**		
1.1.1.1.1		Machinery Compressors Centrifugal Electric Motor Driven (100-1000) kW		
Population	**Installations**	**Aggregated time in service (10^6 hours)**		**No of demands**
5	2	**Calendar time *** 0.1248	**Operational time †** 0.0832	

Failure mode	**No of fail.**	**Failure rate (per 10^6 hours). Lower**	**Upper**	**SD**	**MLE**	**Active rep. hrs**	**Repair (manhours) Min**	**Mean**	**Max**
Critical	**23* 23†**	**1.31 2.02**	**827.93 1806.90**	**304.49 665.33**	**184.33 276.36**	**10.0**	**0.5**	**24.3**	**186.3**
Failed to start	1* 1†	0.94 0.29	22.20 61.58	7.02 22.41	8.01 12.02	-	13.0	13.0	13.0
Fail while running	14* 14†	0.97 1.28	499.13 1093.54	183.39 402.61	112.20 168.22	10.0	0.5	24.0	186.3
Unknown	1* 1†	0.94 0.29	22.20 61.58	7.02 22.41	8.01 12.02	-	11.4	11.4	11.4
Vibration	7* 7†	0.71 0.70	243.34 538.64	89.14 198.24	56.10 84.11	-	0.5	28.5	117.5
Degraded	**6* 6†**	**0.67 0.62**	**206.78 459.35**	**75.67 169.04**	**48.09 72.09**	-	**9.7**	**27.4**	**75.4**
Other	6* 6†	0.67 0.62	206.78 459.35	75.67 169.04	48.09 72.09	-	9.7	27.4	75.4
Incipient	**29* 29†**	**1.54 2.51**	**1047.12 2282.45**	**385.22 840.47**	**232.42 348.45**	**4.1**	**2.0**	**16.2**	**173.6**
External leakage	4* 4†	0.60 0.46	133.63 300.70	48.67 110.60	32.06 48.06	2.5	3.0	21.3	51.7
Overheated	1* 1†	0.94 0.29	22.20 61.58	7.02 22.41	8.01 12.02	-	173.6	173.6	173.6
Other	21* 21†	1.23 1.85	754.87 1648.38	277.58 606.95	168.30 252.33	4.4	2.0	9.0	62.3
Overhaul	1* 1†	0.94 0.29	22.20 61.58	7.02 22.41	8.01 12.02	2.0	3.0	3.0	3.0
Vibration	2* 2†	0.54 0.32	60.26 141.78	21.46 52.04	16.03 24.03	-	4.9	9.4	14.0
All modes	**58* 58†**	**2.64 4.90**	**2106.50 4580.93**	**775.38 1686.97**	**464.83 696.91**	**4.4**	**0.5**	**20.6**	**186.3**
Comments									

2. Comparison between ISO Standard Draft and MCD Module

		ISO	MCD
Domain		Offshore (petroleum, natural gas) Possible extension to other sectors	Nuclear Electricity generation
Scope		Technical Committee ISO/TC 67 IEC collaboration International Working Group (Italy, Norway, Netherlands, UK, US)	EDF Analysis of the needs of different users: Local sites, Central Services, Engineering Department, Research and Development
State		Draft Standard, published Final document in 1997/98	Published in May 1995 Limited to EDF
Terminology	Origin	IEC and specific	PSA and RCM terminology
	Correspondences	Critical failures Non-critical failures No safety critical Failures Failure cause (IEC 50-191) Failure descriptor Failure mechanism (IEC 50-191)	Failures with mission loss Degradations Safety Critical Failures Not in MCD but in SAPHIR Measurable effect Process leading to failure
Selected equipment		No information, criticality is not a criterion Pipes are noted	Representative sampling of PSA and RCM critical equipment Pipes can also be recorded
Equipment description		Detailed More complete than MCD relative to: +environment +system architecture +operation mode Generic operating data (to be confirmed)	Information given in other EDF plant data bases. Relative to families of similar equipment Less precise Annual recording of operating data
Boundaries – Failure logical analysis Functional Group (FG) Technological Assembly (TA) Subtechnological Assembly (STA)		3 levels: FG/TA/STA Failure mode severity at the level of the FG Available breakdowns for: engine, compressor, logical units, generator, electric motor, fire and gas detector, gas turbine, heat exchanger, sensor, pump, valves, tanks and reservoir submarine equipment, pipes 6 recorded data: FG/FG mode/ FG severity/TA/STA Measurable effect	Specific breakdown of equipment into 4 to 6 levels (most often: 4 levels) Failure mode severity recorded at the level of the FG and the TA Generic Breakdown for more than 100 Functional Groups 10 recorded data (corresponding to 4 levels)

Data Format	Coded data, few possible choices for a specific field Free text recommended: Complementary information (circumstances, causes, corrective measures) Essential for quality Imperative data: possible to fill with “other” unknown for some data like mode, measurable effect, maintenance performed, method of detection, cause	Coded data, few possible choices for a specific field Free text essential: Synthesis Complementary information (measurable effect, corrective measures) Essential for quality Imperative data
Elementary fields	Specific ISO fields: Maintenance action Date Failure Cause (different from measurable effect) Man hour per utilization Consequence on installation safety (≠ of PSA criticality) Cost are not normalized	Specific MCD fields: Failure or operating shutdown date Consequence on the unit Origin of the failure (direct or consequence) State of the equipment (in operation, on demand, stopped) Dosimetry Cost (man hour, spare part, total)
Functionality	Only data quality aspect is mentioned	MCD seems more complete

Analogies

- Events to be recorded: both standards recommend recording every maintenance action, preventive and corrective.
- Elementary fields: several identical fields are found in both documents: installation-unit, form codification, maintenance reference, observation date, recorder, controller, consequence on the unit, detection method, FG, TA, STA, FG severity, measurable effect, maintenance performed, maintenance type, unavailability, repair time, manhours, … Complementary tables associated to certain fields are identical.
- Logical analysis of the failure: in both standards, breakdown trees are recommended to obtain quality data, to specify equipment boundaries, to aid the recorder

The ISO breakdown is simpler with only 3 levels: FG, TA, STA. Fifteen generic equipment breakdowns are necessary in the ISO standard, and 6 elementary fields relative to the logical analysis of the failure are recorded: FG/FG mode/FG severity/TA/STA/Measure effect.

Differences

- Selected equipment: the ISO selection is generic; MCD can be generic, but generally, the description of the component is specific to each type of equipment.
- Equipment breakdown: 3 levels in ISO, at least 4 levels in MCD; 15 breakdowns in ISO, close to 100 breakdowns in MCD.
- Failures, some nuclear-specific data in MCD: safety critical failure, dosimetry consequences, state and situation of the equipment at the moment of the failure; 6 data field in ISO as against 10 in MCD for failure analysis; free text considered essential for quality and analysis in MCD; total cost in MCD.
- Failure modes: more possibilities in MCD; both standards have failure modes specific to equipment families.

3. The EIREDA data sheet example

THIRD EDITION	**RELIABILITY DATA HANDBOOK** Source: PRA/PSA	1996 table 54 of 418

COMPONENT :	**PUMP** (Feedwater)	EPS

SAMPLE:	78/87: plant*year:	103	No eqts/plant:	2
	88/93: eqts*year:	180		

Failure Mode	Failure Rate λ (E-6/h)			Probability of Failure on Demand γ/d (E-3)			Mean Active Repair
Prior (78/87)	λ/h		EF	γ/d		EF	Mttr/h
Critical failures	8.6•		1.4	0.3		2.1	13
Likelihood (88/93)	No Failure(s) 15		Cum. Time 1.176 E+6 h	No Failure(s) 1		No Demands 19.95 E+3	Mttr/h 13
Post. Probability Interval: % — mean	90 %	10.5		60 %	0.19		Man*h
		7.4	14.0		0.11	0.27	46
Posterior pdf Parameters	Gamma λ (26.8 ; 2.56 E+6)			Beta γ (8.29 ; 4.41 E+4)			
Mode 1: Ext. leak: 40%				Mode 2: Loss of performance: 18%			

Other Sources		λ /h. E-6	EF	γ /d.E-3	EF	Mttr/h
WASH	Critical	50		1		
	All					
	Sample					
RRA••	Critical					
	All	220				
	Sample					
NUREG	Critical					
	All	1200				
	Sample					
ESReDA 92•••	Critical	14				
	All	57				8
	Sample					

Comments: Common Cause Failure : $\beta = 0.05$

- Rupture or severe leak 3 E-9 /h ; EF = 10

Main turbine (not included): $\hat{\lambda}$ =18.7 E-6/h; EF= 1.8

$\hat{\gamma}$ =1.4E-3/d; EF=1.6

MTTR=20h, Man*hour=59h

Turbine Regulation and security systems: $\hat{\lambda}$ =34.2E-6/h

••Generic failure rate, process equipment - boiler feed.

•••LPG generic failure, pump and motor

Turbine driven oil pump: 3/12 MW : $\hat{\lambda}$ = 900 E-6/h, MTTR = 32 h

4. The CCPS Guideline data sheet example

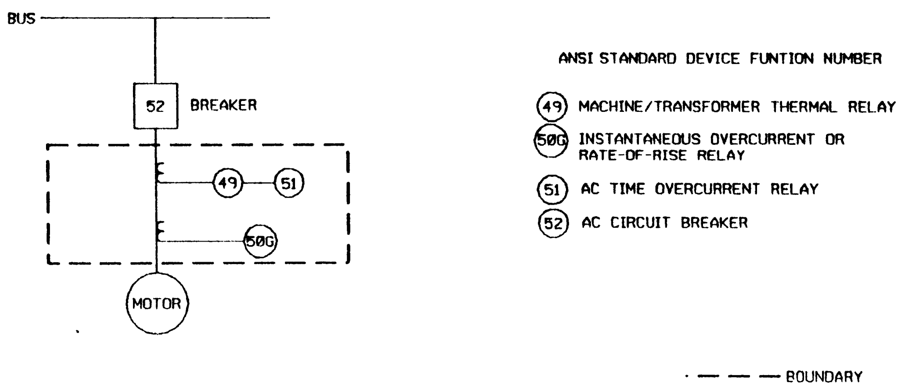
DATA ON SELECTED PROCESS SYSTEMS AND EQUIPMENT

Taxonomy No.	1.2.7.2	**Equipment Description**	RELAYS - PROTECTIVE
Operating Mode		**Process Severity**	UNKNOWN

Population	**Samples**	**Aggregated time in service (10^6 hrs)**		**No. of Demands**
		Calendar time	**Operating time**	

Failure mode	**Failures (per 10^6 hrs)**			**Failures (per 10^3 demands)**		
	Lower	**Mean**	**Upper**	**Lower**	**Mean**	**Upper**
CATASTROPHIC	1.79	1.91	2.04			
a. Fails to Close on Demand						
b. Fails to Open on Demand						
c. Spurious Operation	0.00104	0.06	0.232			
d. Delayed Change of State	0.0015	0.00288	0.00486			
e .Premature Change of State	0.00387	0.00598	0.0087			

Equipment Boundary



Data Reference No. (Table 5.1): 8.2, 8.5, 8.7

5. The IEEE-Std-500 data sheet example

(Composite of Ref 19 and 10.1.X)

CHAPTER: 9 Conductors SECTION: 9.1 Cables SUBSECTION:

ITEM OR EQUIPMENT DESCRIPTION

FAILURE MODE	FAILURE RATE								(*) OUT OF SERVICE (†) REPAIR TIME OR (§) RESTORE (HOURS)			
	FAILURES/10^6 HOURS **				FAILURES/10^6 CYCLES ††							
	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF	LOW	REC	HIGH	REF
ALL MODES	0.71	7.54	200.0		0	19.38	96.30					
CATASTROPHIC	0.71	7.54	200.0		0	19.38	96.30					
Open					0	2.32	11.60					
Short Line to Ground					0	10.70	53.0					
Short Line to Line					0	6.40	32.0					

** Per Power Plant Unit

†† Per 1000 Circuit Feet

Bibliographic Data Sheet **Risø-R-1235(EN)**

Title and authors

Reliability databases: state-of-the-art and perspectives

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Abstract (max. 2000 characters)

The report gives a history of development and an overview of the existing reliability databases. This overview also describes some other (than computer databases) sources of reliability and failures information, e.g. reliability handbooks, but the main attention is paid to standard models and software packages containing the data mentioned. The standards corresponding to collection and exchange of reliability data are observed too. Finally, perspective directions in such data sources development are shown.

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