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Overview of NPPs component reliability data collection with regards to time-dependent reliability analysis applications.

EC JRC Network on Use of Probabilistic Safety Assessments (PSA) for Evaluation of Aging Effects to the Safety of Energy Facilities.
Task 4.

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Abstract

This report presents the state of the art of existed NPPs component reliability data collection systems which aimed to elaborate components reliability parameters to be used in Probabilistic Safety Assessements (PSA). A specific emphasis was done to the possible application of data in time-dependent reliability analysis.
The report was prepared by JRC IE in the frame of EC JRC Ageing PSA Network Task 4 activities and is based on analysis of responses of Network participants to the questionnaire.
Main conclusions and recommendations are presented in the report and they addressed to the data availability and accessibility, as well as to possible improvements of data collection and important issues to be considered in Ageing PSA Network work plan.

Acknowledgements

The author would like to thank to all EC JRC Ageing PSA Network partners, who contributed to this study by responding to the Questionnaire, as well as to the Task Group 4 experts Dr. Dana Kelly from INL, USA and Dr. Jens-Uwe Klugel from Gosgen NPP, Swiss for valuable comments and remarks on the conclusions of the study.

Context

1. Introduction

This overview is prepared in the frame of Task 4 “Reliability and data analysis for active components” of EC JRC Ageing PSA Network activities [1].

Task 4 is aimed to demonstrate the methods and approaches for time-dependent reliability analysis and to classify and characterise the data needed.

It is expected that the results of this task would help
- to improve reliability and maintenance data collection system,
- to choose the appropriate reliability model for the parameters estimation,
- to address ageing and maintenance effects in component failure models,
- to evaluate the model uncertainties.

Performed Case Studies on time-dependent reliability analysis [2, 3] identified two types of initial reliability data which could be used to constract age-dependent reliability models :
- times to failure data,
- binned data on failure intensities or failure rates.

In addition, certain information is needed to make an important assumption about component renewal process.

Concerning initial reliability data needed for elaboration of times to failure or binned failure rates statistics, the main problem relates to the initial data availability and accessibility, i.e. cost of the data. These issues are addressed in the following chapters.

Background

In case of sufficient reliability data, age-dependent reliability models could be constructed and introduced into Probabilistic Safety Assessment (PSA) models.

For active components the age-dependent reliability parameters could be considered on the level of Fault Tree (FT) by assigning the time-dependent unavailabilities for correspondent Basic Events (BE).

The Fault Trees included component time-dependent unavailability could be used as for calculation of probability of functional events, as well as for estimation of initiating event frequencies. Both of the cases have to be considered for input parameters specification.

Depending of available PSA code and expected applications the technique for introduction of time-dependent unavailability on the level of Basic Events could be different.

The general process of elaboration of age-dependent input data consists of four steps:
1 Specification of unavailability type and attributes associated with BE,
2 Choose the model to be applied and data categories needed for parameters estimation,
3 Perform data collection and processing,
4 Estimate time-dependent unavailability factors to be considered in PSA.

Schematically this process is presented on the figure 1.

This report discusses the issue related to available data sources specified on figure 1 as Step 2 : “Choose the model to be applied and data categories needed for parameters estimation”.

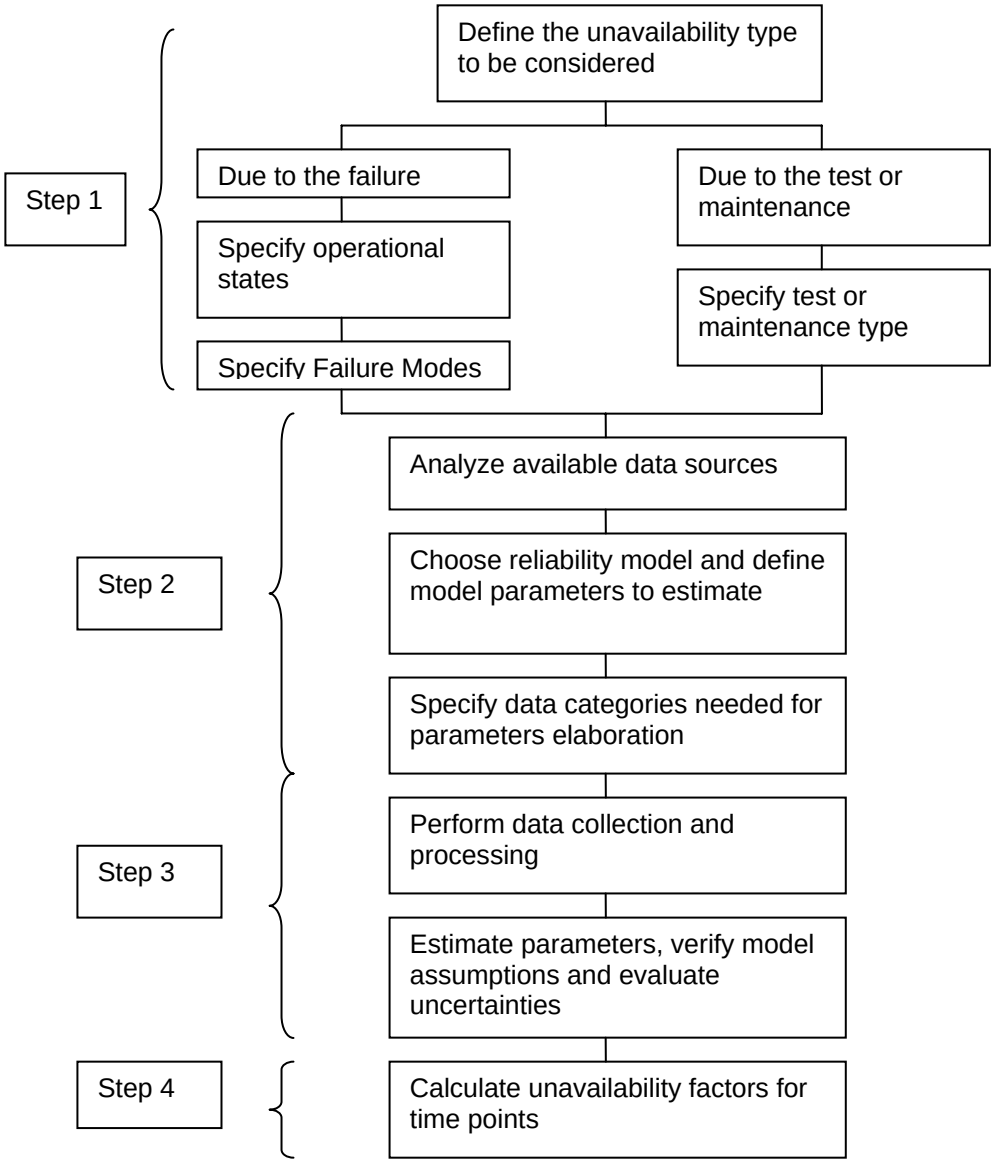

Figure 1 : General process of elaboration of age-dependent input data for PSA

2. Questionnaire about reliability data collection and availability

In order to understand the state of the art with reliability data collection, identify and characterize available data sources, JRC IE prepared a questionnaire about reliability data collection and availability, Annex 1.

Objectives of the questionnaire are :

- To collect and summarize the information about available PSA component reliability data and raw data collection systems,
- To understand the availability, accessibility and completeness/exhaustivity of information registered in raw data collection systems needed for ageing and maintenance advanced evaluations,
- To propose the recommendations what data could be used for age-dependent reliability models elaboration and the way to improve data collection for the purpose of ageing/risk assessments.

Content : all questions could be divided in two parts :

- Available PSA component reliability data
    - Level of data assessment,

    - Types of data available,
    - Data needed for ageing reliability assessment,
- Data needed to characterize uncertainties and quality of results
    - Processed reliability data for parameters elaboration,
    - Raw data collection.

Limits : the questionnaire is focused mainly on active mechanical, electrical and I&C components modelled in PSA level 1. The initial considerations concerning the data and models needed to asses ageing into PSA are taking form the presentation on Ageing PSA 2006 Workshop, Bucharest, October 2006 [4].

Contributions : the questionnaire was distributed to the Task Group 4 participants (IRSN/FR, CNE/RO, INPE/RU, LEI/LT, JSI/SL) and to some of Ageing PSA Network partners (VEIKI-Paks NPP/HU, KGG/Swiss, KAERI/Korea, CNSC/Canada, NRI/ Czech Republic, Novator/Ukraine).

Following 10 organizations answered to the questionnaire :

- CNSC/CA,
- CNE/RO,
- KKG/SW,
- KAERI/KO,
- LEI/LT,
- NRI/CZ,
- Novator/UA,
- JSI/SL,
- INPE/RF,
- Paks NPP/HU.

This list includes one regulator (CNSC/CA), three utilities (CNE/RO, Paks NPP and KKG/SW) and regulatory or utility support organizations dealing with PSA and data collection). So it was expected that the responses would provide quite good and representative picture of the state of the art.

To make easier the comparison and checking of the responses from different participants a short summary of all answers is provided in a table of Annex 2.

3. Summary and analysis of responses

3.1. Reliability data collection description

As it is mentioned in previous section, the questionnaire deals with several types of data. Figure 2 presents in very schematic way relations between three types of data considered potentially available for age-dependent reliability analysis :

- PSA reliability data,
- Others reliability data,
- Raw data.

The engineers involved in PSA development and application familiar with PSA reliability data, which include Initiating Events (IE) frequencies and component reliability parameters. These data are directly used in PSA Event Trees and Fault Trees models.

Most important information collected and treated during parameter's elaboration normally documented in IE frequencies and Component Reliability Parameters Evaluation task reports and/or databases. These processed data are usually well structured and have a high quality. Processed data about failures and component performance could be certainly used for age-dependent reliability analysis. An example of PSA Component Reliability Data structure is presented in Annex 3.

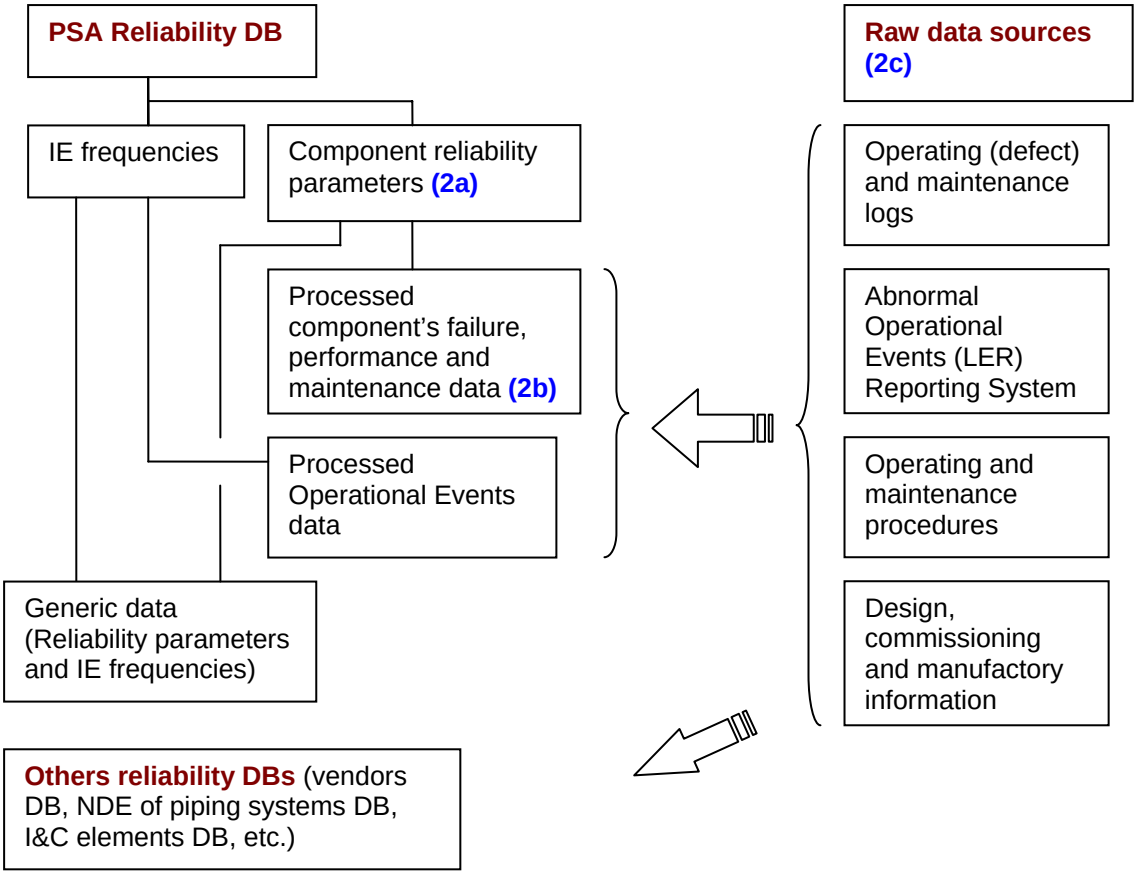

Figure 2. Potential data sources for age-dependent reliability analysis.

Another potential data source presented on Figure 2 is non-PSA reliability DBs. These data cover the component types, which not included in PSA model. It could be of interest in case if some component has to be modeled in PSA or if it will be necessary to enlarge statistic for similar PSA component group.

Third type of data, could be used for age-dependent reliability analysis, are the raw data collected on the plant, as well as operational, maintenance and design documentation.

Nota : the data concerning IE and non-PSA reliability DBs are not explicitly discussed in the questionnaire, so some additional clarification could be needed in the future.

The examples of data recorded in operating logs and processed failure data considered for parameters estimation are provided by the participants.

Annex 4 provides an example of data recorded in operating logs (CNE/RO). Then Annex 5 gives an example of processed failure data considered for parameters estimation (NRI/CZ).

For example, if ones will be interested to calculate the failure rate of fire protection system isolation valves, he will search first the record in "Summary of System / Equipment Status" : "During OMT 67147.2 isolating valve V291 for VEM 337/338 is not holding, rest of OMT aborted until V291 problem is solved. V109 developed seal leakage; WR filed." This information has to be completed by data from other different sources to put it in a format presented in Annex 5. In particular, the analyst has to define failure mode, failure degree (criticity factor), operating state when failure occurred, repair time, etc. Then cumulated number of hours or demands has to be defined and for this purpose another data sources have to be analyzed…

It has to be recognized that there is considerable amount of efforts to process data available in operational logs to the format needed for parameters estimation. At all, it makes data collection process quite expensive and resources consuming.

However, to perform age-dependent reliability analysis additional data have to be elaborated as well.

It could be specified what data are needed for construction of time-dependent reliability model, but it is not clear

- if those data are available in any of listed sources,
- how easy it will take to extract and process them
- and what will be the quality/completeness of obtained information.

Analysis of responses to the questionnaire provides some clarifications on these issues.

3.2. PSA component reliability data.

It was supposed that all participants have some kind of PSA Reliability Data Collection system. Also, it is known that PSA reliability data are usually a good quality and well documented. These statements are confirmed by most of the participants. So, in most of the cases, PSA Reliability Data are ***available in electronic or DB forms*** (see answers to Q2). Collection and treatment of data are performed in accordance to correspondent written procedure (see answers to Q5). In most of the cases the data are updated regularly with the periodicity of PSA updating : usually each 5-10 years (see answers to Q7). In addition, the participants who apply "living PSA" or some specific reliability programs update data on annual basis (see answers to Q7).

Remark/conclusion/proposal 1. *In the most of the cases, PSA Reliability Data have a good quality, are available in electronic or DB forms and updated regularly. Collection and treatment of data are performed in accordance to the written procedure. It should be a good basis for the following ageing reliability analysis and improvement of data collection system.*

Form other hand all of the participants, except KKG/SW, stated that the procedure does not include any requirement to perform a statistical validation of the assumption about constant failure rate (see answers to Q6). That means that up to now there are no formal requirements for trend analysis, methods of assessments and data needed. It could be certainly the areas where Ageing PSA network could provide a real contribution to the plant performance and safety improvements.

Remark/conclusion/proposal 2. *As soon as PSA Reliability Data Collection procedures does not specify formal requirements for exponential or binominal models validation, as well as for verification of ageing trends. It could be recommended to include such an analysis into the procedure. Corresponded guideline with methods and approaches could be proposed by Ageing PSA network.*

It will be also interesting to learn recent KKG/SW experience concerning this subject.

As it was mentioned in Task 4 specification (see Ageing PSA Terms of References [5]) age-dependent reliability models require more data than actually applied PSA component reliability models. 'More data" means not only nomenclature (additional data about maintenance, operational and environmental stressors, etc.), but also more large statistic and especially data for long-term operated components (covered age windows).

It is important point to see the possible sources of "generic" data or possible ways of cooperation between Ageing PSA partners to get more large statistical samples, because it could be very difficult or even impossible to build any age-dependent reliability model by using only plant specific data collection. From the answers of the participants, it is appeared that except KAERI/Korea, all participants have plant specific data collections (see answers to Q1). Total cumulated operating experience could be presented by reactor types as follows :

- PWR about 145 r.y. (KKG/SW - 24 r.y. + KAERI/KO – 101 r.y. + JSI/SL – 20 r.y.),

- VVER about 402 r.y. (NRI/CZ – 90 r.y. + NOV/UA – 240 r.y. + Paks NPP - 72 r.y.),
- CANDU – not clear but has to be quite large if take into account Canadian experience,
- RBMK about 20 r.y. (LEI/LT).

It was not asked in the questionnaire, but it is important to mention that 7 form 18 PWR reactors and 14 from 21 VVER reactors presented by participants are already (or will be at the end of this year) more than 20 years old (see IAEA PRIS database at http://www.iaea.org/programmes/a2/).

Remark/conclusion/proposal 3. *Taking into account actual state and availability of PSA Reliability Data collection it would be interesting to specify and to perform some case studies in order to demonstrate possible ways to enlarge statistical base for age-dependent models construction using different sources of primary data by organizing exchanges between the Ageing PSA participants. It could help for understanding the differences and to formulate the requirements to improve data collection.*

3.3. Data availability and accessibility (difficulty to extract and process)

From the responses to the questions it follows that in most of the cases scope of the reliability data collection is limited by PSA-related components. In some of the cases, for example KKG/SW, the statistical samples include others (non PSA) components. In some case (KAERI/KO) safety related components of secondary systems also are within the scope of reliability data collection. There is only one response about collection of information for all safety and safety related components at Ukrainian NPPs, but the actual status of this data base has to be clarified.

It is assumed that for ageing assessment applications PSA models would include (or at least some preliminary analysis and selection has to be done) some passive components and active components which are not presently modeled in PSA (in some cases, for example, I&C components).

Remark/conclusion/proposal 4. *The reliability data collection systems do not cover passive components and active components which are not presently modeled in PSA, but would be modeled in Ageing PSA. Some additional efforts could be needed to collect and process the data for these types of components.*

In this perspective, some effort have to be done to evaluate possible generic data sources (like OCDE/NEA Piping Reliability DB, etc.) and others (non-PSA) reliability data collected on the plants.

Figure 3 presents an example of PSA Component Reliability Data categories. However, these data are not enough to perform ageing trend or reliability analysis and, consequently, different additional data categories are needed.

Taking into account the variety of time-dependent reliability models proposed in recent publications (see overview provided in [2], the following additional data categories were proposed for evaluation :

3a - Component commissioning date (age 0).
3b - Failure/censoring times (age in the moment of failure/censoring).
3c - Component replacement – date and cause of replacement (corrective maintenance, preventive maintenance, modifications/design changes).
3d - Characteristics of applied tests and maintenance strategy – type and periodicity.
3e - Degree of component renewal during the maintenance (corrective maintenance, preventive maintenance).
3f - Component lifetime (design/manufacture specification, qualification tests results).
3g – real cumulated number of hours in operation, number of demands.

3h – information about average and extreme levels of operating stressors (pressure, temperature, mechanical loads, vibration, water chemistry, neutron flow, current intensity, frequency, voltage, etc.)
3i - information about of average and extreme levels of environmental stressors (pressure, temperature, humidity, neutron flow, etc.)

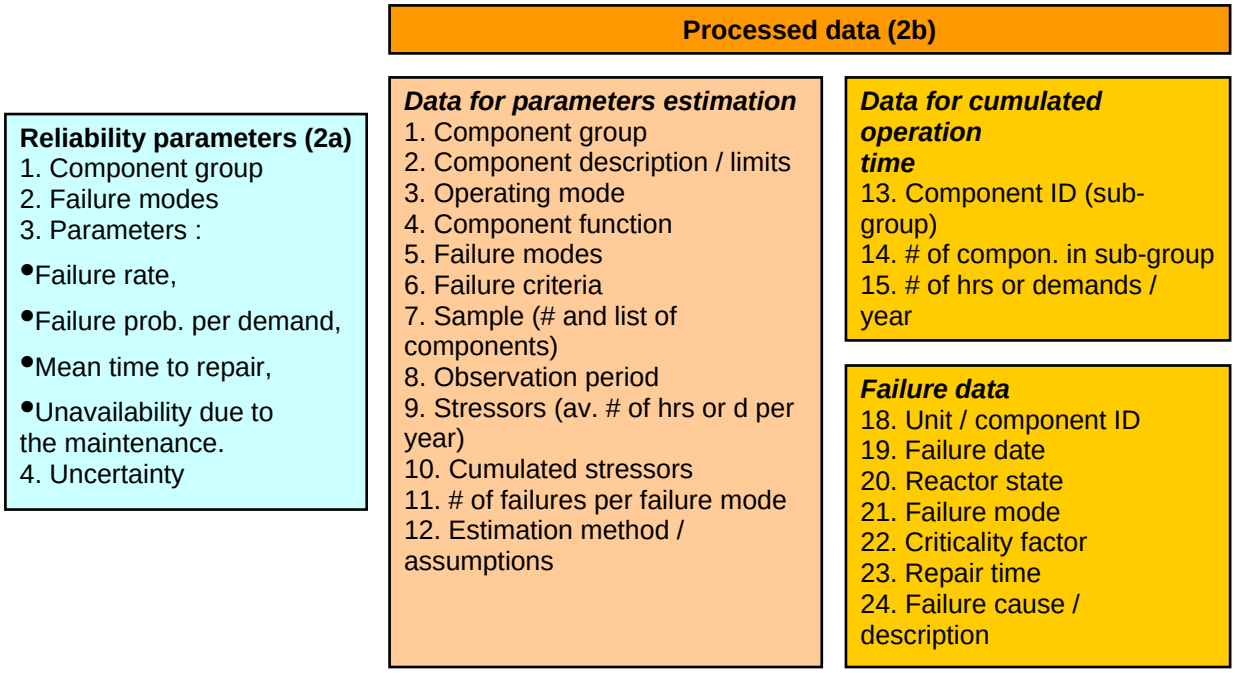

Figure 3. Nomenclature of PSA Component Reliability Data.

Table 1 present an evaluation from given responses concerning the availability and degree of accessibility of data (how easy it to extract and to process) for each category (see responses to Q3-Q4).

Table 1. Additional data categories availability and accessibility.

Data category	Availability								K1	Accessibility (easy to extract and process)								K2
3a - Component commissioning date (age 0)	1	1	1	1	1	1	1	0	87%	0	0	1	0	1	1	1	0	50%
3b - Failure/censoring times	1	1	1	1	1	1	1	0	87%	0	0	0	0	1	1	1	0	37%
3c - Component replacement – date and cause	1	1	1	1	1	1	1	1	100 %	0	0	0	0	1	0	1	0	25%
3d - Characteristics of applied tests and maintenance strategy – type and periodicity	1	1	1	0.5	0.5	1	0,5	0,5	56%	0	0	0,5	0	0	0	0	0	0%
3e - Degree of component renewal during the maintenance	1	1	0	0	0,5	0	0,5	0,5	25%	0	0	0	0	0	0	0,5	0	0%
3f - Component lifetime	1	1	1	0	1	1	1	0,5	75%	0	0,5	0	0	0	0	0	0	0%
3g – real cumulated number of hours in operation, number of demands	1	1	1	0,5	1	1	0,5	0,5	62%	0	1	0,5	0,5	0	0	0,5	0	12%
3h – information about average and extreme levels of operating	0	0,5	0,5	1	1	0,5	0,5	0,5	25%	0	0	0	0	0	0	0	0	0%

stressors																	
3i - information about of average and extreme levels of environmental stressors	0	0,5	0,5	1	1	0	0,5	0,5	25%	0	0	0	0	0	0	0	0%

Response of each expert was evaluated by three degrees : 1 – clear positive statement, 0,5 – partial answer or different cases exists, 0 – negative or unclear answer.

The coefficients K1 and K2 represent the ratios of positive responses in total number of answers and they basically reflect some “average” situation. For example, for data category 3c all participants answered that data are available (K1 = 100%), but in most of the cases it very difficult (means quite costly) to extract and to process them form existed data sources (K2 = 25%).

The results presented in the table show that in exception of data related to degree of component renewal during the maintenance (3e) and information about operational and environment stressors (3h, 3i), all others data needed for ageing reliability analysis are available in many cases. Surprising foundlings are that data about component commissioning date (3a) and component lifetime (3f) are considered as highly available (K1 is 87% and 75%).

Unfortunately, all these data are not easily extractable. In exception of failure/censoring times and component commissioning dates (K2 is 37% and 50% correspondently), all others data categories are rather difficult to access and to process.

Some of participants indicate that recent data often more available and accessible because of computerized data collection and processing systems are implemented last years. In these cases, old data for earlier periods of operation of NPP are very difficult to extract.

Remark/conclusion/proposal 5. *From the statistical point of view the fact of unavailability of data for the beginning of operation, means that we deal with left censored data and it has to be considered for the parameters estimation technique.*

From applications point of view, availability and accessibility of data for different types of reliability models are shown on the figure 4.

Three cases are specified on the figure :

- Case 1 : simple age-dependent reliability model or trend analysis. Types of data needed are 3a, 3b, 3c.
- Case 2 : age-dependent reliability models including test and maintenance evaluations. Types of data needed are the data for Case 1 and 3d, 3e (evaluation given only for additional data).
- Case 3 : comprehensive age-dependent reliability models. Types of data needed are the data for Case 1 and Case 2, and 3f, 3g, 3h, 3i (evaluation given only for additional data).

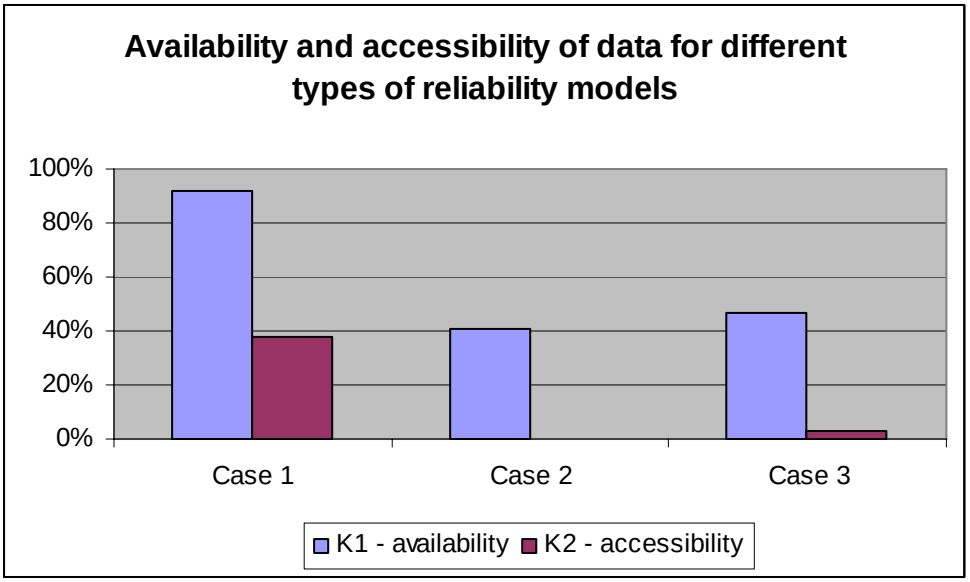

Figure 4. Availability and accessibility of data for different types of reliability models

Remark/conclusion/proposal 6. *This diagram demonstrate that even for simple age-dependent reliability assessments for which most of the data are available, the cost of data processing could be quite high. If ones would apply reliability models for maintenance analysis and optimization, or for lifetime evaluation and prediction, a large additional investment for data collection and processing have to be envisaged.*

This remark has to be taken into account as for further Ageing PSA activities on models development, as for the specification of additional efforts needed in data collection.

Answering to the questionnaire participants proposed additional data categories needed for ageing evaluation. Some of this categories have normally to be addressed in PSA reliability data analysis, as for example :

- for each component failure, information on failure mechanism and cause,
- component type : active or passive components,
- type of failure: incipient (degradation) or sudden failure (failure).
- suspicion of common cause failure mode (CCF-candidate).

Others are more specific to the ageing characterization and surveillance activities :

- component life cycle or ageing management strategy (for instance, monitoring and inspections are missing in 3d and 3e),
- information on component degradation mechanisms,
- information on component failure precursors (prevented before the component really failed as a result of preventive inspection/maintenance),
- results of non-destructing testing of passive components
- plant history of component failures of all component types, aging is planned being considered for, including date of failures.
- relation between random failures and ageing dependent failures,
- number of failures per component on one-year interval.

Remark/conclusion/proposal 7. *Relevance, availability and accessibility of data from proposed categories have to be discussed and evaluated within Task 4 working group. Results of this evaluation have to be considered for the case studies specifications and for data collection improvements recommendations.*

3.4. Raw data quality and availability

It was shown in previous section that most of the data needed for ageing assessment are not easily accessible. In general, that means that some information is collected and stored as raw data and requires additional efforts to process it. If ones will decide to work with raw data he has to understand first if those data are available and if he could obtain useful information from processing.

As stated in the responses to the questions all participants have written requirements for raw data collection. Table 2 presents an evaluation of answers given to question about requirements for raw data collection. Supposing that formal requirements could, in certain way, assure some availability and quality of collected data, coefficient K3 provides some idea about how often we can find available and good quality raw data of each category.

Table 2. Availability and quality of raw data.

Data category	Availability K1	Accessibility K2	Required by Data Collection Procedure								Availability / Quality K3
3a - Component commissioning date (age 0)	88%	50%	0	0	1	0	0	1	1	0	38%
3b - Failure/censoring times (age in the moment of failure/censoring).	88%	38%	0	1	1	0	0	1	0	0	38%
3c - Component replacement – date and cause	100%	25%	0	1	1	1	0	1	1	0	63%
3d - Characteristics of applied tests and maintenance strategy – type and periodicity	56%	0%	0	1	1	0	0	1	1	0	50%
3e - Degree of component renewal during the maintenance (corrective maintenance, preventive maintenance).	25%	0%	0	1	1	0	0	0	0	0	25%
3f - Component lifetime (design/manufacture specification, qualification tests results).	75%	0%	0	0	1	0	0	1	1	0	38%
3g – real cumulated number of hours in operation, number of demands	63%	13%	0	1	0	1	0	1	1	0	50%
3h – information about average and extreme levels of operating stressors	25%	0%	0	0	0	0	0	0,5	1	0	13%
3i - information about of average and extreme levels of environmental stressors	25%	0%	0	0	0	0	0	0,5	0	0	0%

Two participants provided their expert evaluation in more comprehensive way by answering to the question about availability and quality of raw data (see answers to the question Q15). The results of these evaluations (with some adaptations done for easier comparison) are provided in Table 3.

Table 3. Availability and quality of raw data (plant specific evaluations).

Category	NRI/CZ (availability and quality by component type)			CNE/RO (all types of components)	
	Mechanical components	Electrical components	I&C components	Availability	Quality
3a - Component commissioning date (age 0)	low	very low	very low	low	medium
3b - Failure/censoring times (age in the moment of failure/censoring).	very low	very low	very low	low	medium
3c - Component replacement – date and cause	good	medium	medium	medium	very good
3d - Characteristics of applied tests and maintenance strategy – type and periodicity	very good	good	good	very good	very good
3e - Degree of component renewal during the maintenance (corrective maintenance, preventive maintenance).	very good	good	medium	medium	very good
3f - Component lifetime (design/manufacture specification, qualification tests results).	good	medium	low	good	good
3g – real cumulated number of hours in operation, number of demands	very good	good	medium-low	good	medium
3h – information about average and extreme levels of operating stressors	medium	good	medium-low	low	good
3i - information about of average and extreme levels of environmental stressors	good	good	medium	medium	good
History of component failures of all component types	medium	medium	low	-	-

Table 3 reflects the situation with raw data collection at two different utilities. It seems like both of them have rather intensive data collection process. The results show high availability and good quality for the data categories of 3d, 3e, 3f (except I&C components), 3g and 3i. For the categories of data as 3a, 3b, it rather opposite situation is reported. Of cause, these evaluations correspond to the specific situation on particular power plant and it sometimes not confirms the foundlings presented in previous sections. But this reflects also the diversities in raw data collection processes.

Remark/conclusion/proposal 8. *Taking into account a diversity of responses and uncertainty with the availability, accessibility and quality of raw data it could be proposed to apply the following scheme for case studies specification :*

1. *Specify PSA model possible modifications related to ageing consideration,*
2. *Propose reliability models to apply and specify parameters needed,*
3. *Formulate requirements for data for parameters estimation,*
4. *Perform data collection and processing to demonstrate the feasibility,*

5. *Characterize availability, accessibility and quality of data for each case and provide recommendations for data collection improvements.*

4. Final conclusions and recommendations

Remark/conclusion/proposal 1. *In the most of the cases, PSA Reliability Data have a good quality, are available in electronic or DB forms and updated regularly. Collection and treatment of data are performed in accordance to the written procedure. It should be a good basis for the following ageing reliability analysis and improvement of data collection system.*

Remark/conclusion/proposal 2. *As soon as PSA Reliability Data Collection procedures does not specify formal requirements for exponential or binominal models validation, as well as for verification of ageing trends. It could be recommended to include such an analysis into the procedure. Corresponded guideline with methods and approaches could be proposed by Ageing PSA network.*

It will be also interesting to learn recent KKG/SW experience concerning this subject.

Remark/conclusion/proposal 3. *Taking into account actual state and availability of PSA Reliability Data collection it would be interesting to specify and to perform some case studies in order to demonstrate possible ways to enlarge statistical base for age-dependent models construction using different sources of primary data by organizing exchanges between the Ageing PSA participants. It could help for understanding the differences and to formulate the requirements to improve data collection.*

Remark/conclusion/proposal 4. *The reliability data collection systems do not cover passive components and active components which are not presently modeled in PSA, but would be modeled in Ageing PSA. Some additional efforts could be needed to collect and process the data for these types of components.*

In this perspective, some effort have to be done to evaluate possible generic data sources (like OCDE/NEA Piping Reliability DB, etc.) and others (non-PSA) reliability data collected on the plants.

Remark/conclusion/proposal 5. *From the statistical point of view the fact of unavailability of data for the beginning of operation, means that we deal with left censored data and it has to be considered for the parameters estimation technique.*

From applications point of view, availability and accessibility of data for different types of reliability models are shown on the figure 4.

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- Case 3 : comprehensive age-dependent reliability models. Types of data needed are the data for Case 1 and Case 2, and 3f, 3g, 3h, 3i (evaluation given only for additional data).

Remark/conclusion/proposal 6. *This diagram demonstrate that even for simple age-dependent reliability assessments for which most of the data are available, the cost of data processing could be quite high. If ones would apply reliability models for maintenance analysis and optimization, or for lifetime evaluation and prediction, a large additional investment for data collection and processing have to be envisaged.*

This remark has to be taken into account as for further Ageing PSA activities on models development, as for the specification of additional efforts needed in data collection.

Remark/conclusion/proposal 7. *Relevance, availability and accessibility of data from proposed categories have to be discussed and evaluated within Task 4 working group. Results of this evaluation have to be considered for the case studies specifications and for data collection improvements recommendations.*

Remark/conclusion/proposal 8. *Taking into account a diversity of responses and uncertainty with the availability, accessibility and quality of raw data it could be proposed to apply the following scheme for case studies specification :*

- *Specify PSA model possible modifications related to ageing consideration,*
- *Propose reliability models to apply and specify parameters needed,*
- *Formulate requirements for data for parameters estimation,*
- *Perform data collection and processing to demonstrate the feasibility,*
- *Characterize availability, accessibility and quality of data for each case and provide recommendations for data collection improvements.*

References

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Annex 1 : Questionnaire about reliability data collection and availability

Background
This questionnaire is prepared in the frame of Ageing PSA Task 4 in accordance with results of discussions during Ageing PSA Network Steering Committee (20/02/07). The initial considerations concerning the data and models needed to assess ageing into PSA are taken from the presentation on APSA Workshop in Bucharest last October "Age-dependent reliability models. Statistical data analysis and parameters estimation (unit I)"
http://www.energyrisks.jrc.nl/APSA/PDF/APSA%20Workshop%202-5%20October%202006/M3-2_Rodionov.pdf
Objectives of the questionnaire:

- To collect and summarize the information about available PSA component reliability data and raw data collection systems,
- To understand the availability, accessibility and completeness of information registered in raw data collection systems needed for ageing and maintenance advanced evaluations,
- To propose the recommendations what data could be used for age-dependent reliability models elaboration and the way to improve data collection for the purpose of ageing/risk assessments.

Limits: the questionnaire is focused mainly on active mechanical, electrical and I&C components modeled in PSA level 1.
Expected contributions: the questionnaire is addressed first to the participants from TG 4 (IRSN/FR, CNE/RO, INPE/RU, LEI/LT, JSI/SL). Outputs from VEIKI-Paks NPP/HU, KGG/Swiss, KAERI/Korea, CNSC/Canada will be welcome.
Available PSA component reliability data.
Level of data assessment
Q1. On which level component reliability data were collected and elaborated? What is a total operating experience considered (in reactor-years) ?
1a - national / reactor type data,
1b - plant / unit specific data.
Types of data available
Q2. Which type of data are available and in what storage format (paper, electronic, database)?
2a - component reliability parameters (failure rates or failure probabilities per demand by failure mode and component group),
2b - processed reliability data for parameters elaboration (specification of statistical samples and available statistical data, list of considered failures, cumulated operating time or number of demands by failure mode and component group)
2c - raw data (defect and maintenance logs, unit/system/components performance data acquisition system, etc.).
Data needed for ageing reliability assessment
Q3. What are possible sources of data for each listed category? What data are available or could be easily extracted and processed from raw data (2c) or from processed reliability data (2b)?
3a - Component commissioning date (age 0).
3b - Failure/censoring times (age in the moment of failure/censoring).
3c - Component replacement – date and cause of replacement (corrective maintenance, preventive maintenance, modifications/design changes).
3d - Characteristics of applied tests and maintenance strategy – type and periodicity.
3e - Degree of component renewal during the maintenance (corrective maintenance, preventive maintenance).
3f - Component lifetime (design/manufacture specification, qualification tests results).
3g – real cumulated number of hours in operation, number of demands.
3h – information about average and extreme levels of operating stressors (pressure, temperature, mechanical loads, vibration, water chemistry, neutron flow, current intensity, frequency, voltage, etc.)

3i - information about of average and extreme levels of environmental stressors (pressure, temperature, humidity, neutron flow, etc.)

Q4. In your opinion, what kind of data needed for ageing reliability assessment is missed in this list?

3j -

3k –

…

Data needed to characterize uncertainties and quality of results

Processed reliability data for parameters elaboration (2b)

Q5. Do you have formal written procedure for PSA data collection and processing applicable on plant/utility level?

Q6. Does this procedure require to perform a statistical validation of the assumption about constant failure rate? If yes, what methods are applied and for which type of components?

Q7. What is a periodicity of data updating, is it related to PSA updates or to other requirements?

Q8. What type of data listed in 3 formally required to collect by data collection procedure?

Q9. Does reliability data collection process include only PSA-related components, components important to safety, safety related components, others components?

Q10. Does for each component group from mechanical, electrical and I&C types, following data could be easily extracted from PSA component reliability data set?

10a - Sample size.

10b - Period of observation and covered age window.

10c - Total cumulated operating time/number of demands.

10d - Censoring rate (number of failures per component during period of data collection).

Q11. Does data collection and processing is a part of day-to-day (permanent) responsibility of assigned staff?

Raw data collection (2c)

Q12. For better understanding of data contents and structure, could you provide some examples of operating and maintenance records/reports which include data listed in 3 ?

Q13. Do you have formal written procedure for failure and maintenance data collection and processing applicable on plant/utility level?

Q14. What type of data listed in 3 formally required to collect by raw data collection procedure?

Q15. Could you characterize for each data category (3) availability and quality of raw data for mechanical, electrical and I&C component types?

Annex 2 : Summary of responses

Responses from CNSC/CA	Responses from CNE/RO	Responses from KKG/SW	Responses from NRI/CZ	Responses from LEI/LT
Q1. On which level component reliability data were collected and elaborated? What is a total operating experience considered (in reactor-years) ? *1a - national / reactor type data,* *1b - plant / unit specific data.*				
Utility level : 2 of the utilities have a large number of reactors (8, 12), while 2 others have just 1 reactor each.	Plant specific data. CNE Unit 1. Data for period 10/2005 – 12/2006 are processed.	Plant specific data Goesgen NPP – 24 r-y Others NPPs about the same situation (National Reliability DB ?)	Plant specific data. NPP Dukovany : 4 units / 80 r-y NPP Temelin : 2 units, 10 r-y will be available in 2008	Plant specific data unit I : 1983 – 2004.12.31 (closed) unit II : 1987 – till now
Q2. Which type of data are available and in what storage format (paper, electronic, database)? *2a - component reliability parameters* *2b - processed reliability data for parameters elaboration* *2c - raw data*				
2c data is available at the plants mostly in the electronic form. 2a, 2b – no answer	2c is available mostly in electronic format, except the Maintenance Work Reports. 2b electronic (DB?) format, 2a – DB format.	2a – available 2b – available in DB format, 2c – available in paper format	2a is available in paper, electronic and database format (for Dukovany NPP only) 2b paper, electronic (DB?) from last update in 2004 (Dukovany NPP) 2c available at NPPs, good quality of data since the middle of 90s	2a is available in electronic form (PSA report, Risk Spectrum model data base), 2b - electronic form (PSA report), 2c – defect /maintenance data before year 2000 are available in paper version, after 2000 in DB format

Responses from KAERI	Responses from Novator/UA	Responses from JSI/SL	Responses from INPE/RU	Responses from Paks NPP/HU
Q1. On which level component reliability data were collected and elaborated? What is a total operating experience considered (in reactor-years) ? *1a - national / reactor type data,* *1b - plant / unit specific data.*				
Plant specific data for Kori 1 (1/90 – 12/99) 10 r*y; Kori 2 (1/92 – 12/2001) 10 r*y ; Kori 3, 4 (1/91 – 6/2002) 23 r*y (accessible); Yonggwang 1, 2 (1/90 – 12/2001) 24 r*y (accessible); Yonggwang 3, 4 (4/95 – 12/2002) 14,7 r*y (KAERI); Ulchin 1, 2 (2/94 - 1/2004) 10r*y ; Ulchin 3, 4 (8/98 - 12/2002) 9,4 r*y (KAERI); Wolsong 1 (1/92 – 12/2001) 10 r*y (CANDU)	1b - PSA component reliability data were collected and elaborated on the plant level (Ukraine has 15 reactors in operation with over 240 r.y. of experience)	Plant specific data – 20 r-y	Bilibino NPP. Plant specific data were collected. Total operating experience is considered during 33 years (since 1974).	<u>Mechanical components:</u> PSA data collection since 1989. 4 units - 72 r.-y. Collection is started with 400 components and now about 2400 components. <u>I&C and electrical components:</u> data collection are performed on the needs of different operational and maintenance departments.
Q2. Which type of data are available and in what storage format (paper, electronic, database)? *2a - component reliability parameters* *2b - processed reliability data for parameters elaboration* *2c - raw data*				
2c was collected in paper format before 2000. After 2000 defect/maintenance logs are computerized. 2a, 2b : KAERI process reliability data for parameter elaboration.	2a, 2b, 2c data are available in PSA reports (electronic and paper copies). Ukrainian reliability database (URDB) on safety-related equipment, incl. mechanical, electrical, and I&C comp. (2c)	2a, 2b and 2c are available in paper, electronic and database format	2b –paper format (yearly reports).	2a - Available in electronic format. 2c - Operator logs Maintenance logs

Responses from CNSC/CA	Responses from CNE/RO	Responses from KKG/SW	Responses from NRI/CZ	Responses from LEI/LT
Q3. What are possible sources of data for each listed category? What data are available or could be easily extracted and processed from raw data (2c) or from processed reliability data (2b)?				
3a - Component commissioning date (age 0).				
Available (2c?) / not easy to extract	Available in commissioning docs (2c) / not easy to extract	Available (2b?)	At disposal in plant documentation. Cannot be directly easily extracted or processed from 2b.	Source: FOBOS DB (2c)/ Extract: Easy
3b - Failure/censoring times				
Available (2c?) / not easy to extract	Failure date and duration are available (2b), but failure times couldn't be calculated without info about commissioning date	Available (2b?), but may have to be processed to detailed analysis.	Would have to be derived. Can not be directly easily extracted or processed neither from 2b, nor from 2c	Source: FOBOS DB (2c)/ Extract: Easy
3c - Component replacement – date and cause of replacement				
Available (2c?) / not easy to extract	Available in Work Reports (2c) / not easy to extract	Available (2b?), but may have to be processed to detailed analysis.	At disposal in plant documentation, partly in the records corresponding to 2c. Cannot be directly easily extracted or processed from 2b	Source: FOBOS DB (2c)/ Extract: Easy
3d - Characteristics of applied tests and maintenance strategy – type and periodicity				
Available (2c?) / not easy to extract	Operational Tests and Work Request Application (2c) / not easy to extract	Available (2b?)	Completely at disposal in plant documentation (out of reliability data collection). Many (PSA related) characteristics may be available in the processed data (type 2b) here	Source: reports (out of reliability data collection)/ Extract: difficult
3e - Degree of component renewal during the maintenance				
Available (2c?) / not easy to extract	Operator Logs, Work Request Applications (2c) / not easy to extract	No evaluation performed – complete functional renewal assumed	In general, some data are at disposal (2c?), but it may no way be guaranteed that the data are complete or that the data for all most important components are at disposal.	Source: FOBOS DB (2c) or reports (out of reliability data collection) / Extract: difficult

Responses from KAERI	Responses from Novator/UA	Responses from JSI/SL	Responses from INPE/RU	Responses from Paks NPP/HU
Q3. What are possible sources of data for each listed category? What data are available or could be easily extracted and processed from raw data (2c) or from processed reliability data (2b)?				
3a - Component commissioning date (age 0).				
Available (2b?)/ easy to extract	URDB (2c)	Not clear	Not clear	Not available.
3b - Failure/censoring times				
Available (2b?)/ easy to extract	URDB (2c)	Not clear	Failures and renewals logs / difficult to extract	Just for few components (but not easily processed from raw data)
3c - Component replacement – date and cause of replacement				
Available (2c?) / not easy to extract	URDB (2c), preventive maintenance – CAESAR ? (2c)	Available	Failures and renewals logs /difficult to extract	Just for few components (individual investigation is required).
3d - Characteristics of applied tests and maintenance strategy – type and periodicity				
Available (2c) TecSpec and component test procedures/ Not easy before computerization of reporting method	Technical specifications, operating and service instructions, PSA reports.	Available for certain type of components	Failures and renewals logs / difficult to extract	Available.
3e - Degree of component renewal during the maintenance				
We can hardly extract this type of data because plant operators don't mention it	URDB (2c), preventive maintenance – CAESAR ? (2c)	Available for certain type of components	Not clear	Systematic search is not available (mainly in paper format).

Responses from CNSC/CA	Responses from CNE/RO	Responses from KKG/SW	Responses from NRI/CZ	Responses from LEI/LT
3f - Component lifetime				
Available (2c?) / not easy to extract	easily to collect for Environmental Qualified (EQ) equipments only (out of reliability data collection)	Available (2c) / not easy to extract (for electro-technical equipment, has to be processed from 2c).	No info. The availability will differ from type to type.	Source: reports (out of reliability data collection)/ Extract: difficult
3 g – real cumulated number of hours in operation, number of demands				
Available (2c?) / not easy to extract	Partly available in 2b / easy to extract Preventive/Corrective Maintenance docs, Registrations of Risk Monitor Database (2c) / not easy to extract	Available (2b)	For NPP Dukovany, regarding number of hours, good estimates are at disposal for many component populations (2b). Number of demands are not considered so far for Dukovany NPP (2a, 2b) / not easily available For Temelin will be available in 2b	Source: reports (out of reliability data collection ?)/ Extract: difficult
3h – information about average and extreme levels of operating stressors				
Not always available	Design Manuals, Operating Manuals (out of reliability data collection) / not easy to extract	Only qualification, normal operational conditions and theoretical accident conditions are available, (out of reliability data collection) / not easy to extract	Information about average levels of operating stressors may be taken relatively easily from plant procedures (out of reliability data collection) But the info about extreme levels would have required new special analysis	Source: reports (out of reliability data collection ?)/ Extract: difficult
3i - information about of average and extreme levels of environmental stressors				
Not always available	Design Manuals, Operating Manuals (out of reliability data collection) / not easy to extract	Only qualification, normal operational conditions and theoretical accident conditions are available, (out of reliability data collection) / not easy to extract	Information about average levels of operating stressors may be taken relatively easily from plant procedures (out of reliability data collection) But the info about extreme levels would have required new special analysis	Source: reports (out of reliability data collection ?)/ Extract: difficult

Responses from KAERI	Responses from Novator/UA	Responses from JSI/SL	Responses from INPE/RU	Responses from Paks NPP/HU
3f - Component lifetime				
Available (2c?) / not easy to extract	URDB (2c), Technical specifications, operating and service instructions ?	Available for certain type of components	Design docs / difficult to extract	Systematic search is not available (mainly in paper format).
3 g – real cumulated number of hours in operation, number of demands				
Not easy. We use an estimated cumulative operation time by operation/test process guidance.	PSA reports.	Available for certain type of components	Not clear	Partially available (e.g. for diesel generators, but in paper form).
3h – information about average and extreme levels of operating stressors				
Not easy except for a failure during a surveillance test	Technical specifications, operating and service instructions, PSA reports.	Not clear/ difficult to extract	Not clear	Not available
3i - information about of average and extreme levels of environmental stressors				
Not available / Difficult to extract	Technical specifications, operating and service instructions, PSA reports.	Not clear/ difficult to extract	Not clear	Not available

Responses from CNSC/CA	Responses from CNE/RO	Responses from KKG/SW	Responses from NRI/CZ	Responses from LEI/LT
Q4. In your opinion, what kind of data needed for ageing reliability assessment is missed in this list?				
3j - component life cycle or ageing management strategy (for instance, monitoring and inspections are missing in 3d and 3e) 3k - for each component failure, information on failure mechanism and cause 3l - information on component degradation mechanisms 3m - information on component failure precursors (prevented before the component really failed as a result of preventive inspection/maintenance)	**3j -** Active/ Passive components? **3k -** What failure modes?, Type of failure: incipient (degradation) or sudden failure (failure)	3j –Suspicion of common cause failure mode (CCF-candidate)	3j - plant history of component failures of all component types, aging is planned being considered for, including date of failures.	No answer
Q5. Do you have formal written procedure for PSA data collection and processing applicable on plant/utility level?				
Yes, all licensees have such procedures, but CNSC has currently a regulatory improvement program requiring a number of enhancements in these procedures	Yes	Yes in the format of an internal concept description	Since 2003, such explicit procedure has been at disposal for NPP Dukovany in written form.	No
Q6. Does this procedure require to perform a statistical validation of the assumption about constant failure rate? If yes, what methods are applied and for which type of components?				
No, but If an unsafe trend is identified (usually a 10% increase in failure rate over last 3 years comparing to the data in PSA models), CNSC requires compensatory measures	No	Yes Introduced recently. Statistical models were used – Nelson-Aalen – estimator, Laplace-Test, direct assessment of parameters of an exp. distribution (lambda=const) and NHPP (2 parametric Weibull)	No, but the idea has been discussed several times, found useful and may be applied in future.	No

Responses from KAERI	Responses from Novator/UA	Responses from JSI/SL	Responses from INPE/RU	Responses from Paks NPP/HU
Q4. In your opinion, what kind of data needed for ageing reliability assessment is missed in this list?				
No answer	No answer	3j – relation between random failures and ageing dependent failures 3k – results of non-destructing testing of passive components	3j - number of failures per component during year	No answer
Q5. Do you have formal written procedure for PSA data collection and processing applicable on plant/utility level?				
Yes	Yes. There is one for each PSA study	Yes	No. Procedures for PSA data collection is provided by GOSATOMNADZOR	Yes, for the mechanical components.
Q6. Does this procedure require to perform a statistical validation of the assumption about constant failure rate? If yes, what methods are applied and for which type of components?				
No	No, but Trend assessement for I&C equipement is an essential element of lifetime management.	No	No, but statistical validation is performed during data processing. We used Kendal criterion for this validation	No

Responses from CNSC/CA	Responses from CNE/RO	Responses from KKG/SW	Responses from NRI/CZ	Responses from LEI/LT
Q7. What is a periodicity of data updating, is it related to PSA updates or to other requirements?				
The data are updated on the ***annual*** basis and show degradation trends. (PSA updates and reliability program requirements for systems important to safety).	***Yearly***, related to PSA updates	Update for Living PSA - ***annual*** for most critical components and an full update with data processing to the VGB database ***once in 5 years***.	***5 years*** at NPP Dukovany However, in some specific cases are solved within the Living PSA project on a ***year-by-year*** basis. Not defined for NPP Temelin.	***Not clear***
Q8. What type of data listed in 3 formally required to collect by data collection procedure? **Processed reliability data for parameters elaboration (2b)**				
As stated in response to Q3, most of the data are available, but are difficult to extract, because the recording process is governed by different procedures and different recording tools.	See response to question Q3	All besides 3g and 3h (do not change) are reviewed or updated	The following types, using the codes in Q3, are required in some way nowadays: 3c, 3g, 3j. Since also analysis of failure cause is required, data types determined in 3h, 3i are frequently available.	All activities related to maintenance/repair
Q9. Does reliability data collection process include only PSA-related components, components important to safety, safety related components, others components?				
The data collection process include data on multiple different components, but the level of rigor, details, and tools used depend on whether the component is important to safety, safety related, or other.	It includes PSA related components and other systems necessary in future development of PSA (Level II).	It contains all PSA related components, samples on electro-technical and I&C equipment. The PSA-related components at Goesgen include partially balance of plant equipment ?	The reliability data collection process is oriented particularly to PSA-related components. However, some steps of the process are integral parts of maintenance evaluation	No answer

Responses from KAERI	Responses from Novator/UA	Responses from JSI/SL	Responses from INPE/RU	Responses from Paks NPP/HU
Q7. What is a periodicity of data updating, is it related to PSA updates or to other requirements?				
It is related to PSA updates. PSA update is related to PSR (every ***10 years***). ***Not clear***	Concerning data for PSA it is related to PSA updates.	***Not clear***	Yearly updated	The data update is related to the PSA update. Mainly, attached to PSR
Q8. What type of data listed in 3 formally required to collect by data collection procedure? **Processed reliability data for parameters elaboration (2b)**				
3a, 3b, 3c. For 3g, Utility uses computerized data input S/W after 2000 not handwriting, it becomes possible to collect real cumulated number of hours/demands.	3d, 3g, 3h, 3i ?	cumulated number of hours in operation, number of demands (3h) ?	Failure times and number of failures per component during year	PSA relevant data (mainly mechanical components).
Q9. Does reliability data collection process include only PSA-related components, components important to safety, safety related components, others components?				
In KAERI, we collected PSA-related components and other safety related components of secondary systems	Reliability data collection process includes all scope of equipment. Now the database contains data of components important to safety and safety related components	only PSA-related components	PSA-related components, components important to safety, safety related comports. Special attention is paid to I&C components	Only PSA-related components.

Responses from CNSC/CA	Responses from CNE/RO	Responses from KKG/SW	Responses from NRI/CZ	Responses from LEI/LT
Q10. Does for each component group from mechanical, electrical and I&C types, following data could be easily extracted from PSA component reliability data set?				
10a - Sample size.				
Yes	Yes	Yes, from the VGb-database	For NPP Dukovany Yes, for NPP Temelin no, but planed to be solved in the very next future, at disposal next year (2008).	Yes
10b - Period of observation and covered age window.				
Yes	Yes	Yes	For NPP Dukovany, period of observation yes, covered age window not. For NPP Temelin period of observation will be available in 2008	No
10c - Total cumulated operating time/number of demands.				
Yes	Yes, with note is not the total (per plant age) operating time, but the operating time/ number of demands since October 2005.	Yes	See Q3, part 3g. There are no problems with good estimation of cumulated operating time, in general, but the numbers of demands are mostly not collected.	Yes
10d - Censoring rate (number of failures per component during period of data collection).				
Not for a specific component, only for a group of similar components providing one failure rate value.	Yes	Yes	For NPP Dukovany, big volume of such information is at disposal. For NPP Temelin, some information of this type will be ready in 2008	No
Q11. Does data collection and processing is a part of day-to-day (permanent) responsibility of assigned staff?				
Yes	Yes	Raw data collection (2c). Yes, for important equipment, on a regular basis for all components modeled in PSA. Lifetime data and maintenance activity data is collected by the maintenance staff.	Some extent of raw data collection is part of day-to-day responsibility, as it is mentioned in related plant procedures	No for 2b

Responses from KAERI	Responses from Novator/UA	Responses from JSI/SL	Responses from INPE/RU	Responses from Paks NPP/HU
Q10. Does for each component group from mechanical, electrical and I&C types, following data could be easily extracted from PSA component reliability data set?				
10a - Sample size.				
It's easy to extract those items in the case of mechanical components only	Yes	Yes	Yes	No
10b - Period of observation and covered age window.				
Period of observation – yes, covered age window – no It's easy to extract those items in the case of mechanical components only	Period of observation – yes, covered age window – no.	No	Yes	No
10c - Total cumulated operating time/number of demands.				
It's easy to extract those items in the case of mechanical components only	Yes	Yes	Yes	No
10d - Censoring rate (number of failures per component during period of data collection).				
It's easy to extract those items in the case of mechanical components only	Yes	No	Yes	No
Q11. Does data collection and processing is a part of day-to-day (permanent) responsibility of assigned staff?				
Yes	Yes for 2c	Yes	Yes	Yes

Responses from CNSC/CA	Responses from CNE/RO	Responses from KKG/SW	Responses from NRI/CZ	Responses from LEI/LT
Q12. For better understanding of data contents and structure, could you provide some examples of operating and maintenance records/reports which include data listed in 3? **Raw data collection (2c)**				
Not available	Daily operating records as per operating records Shift Supervisor Log and Control Room Log	Not available The general description of collected data can be found in the reference manual of the VGB database	An example of raw data analysis result is given in the table form	Not available
Q13. Do you have formal written procedure for failure and maintenance data collection and processing applicable on plant/utility level?				
A number of procedures governing separately different parts of data collection for different purposes	Yes, the same as that for Q5 ?	Yes	Yes, such procedure does exist for failure data. It does not exist in explicit form for maintenance data	Collection: Yes Processing: No
Q14. What type of data listed in 3 formally required to collect by raw data collection procedure?				
See answer to Q8	3g, for the rest of questions from 3, see the response to Q3	See answer to Q8	See response to Q8. The data collection procedure is mainly oriented to raw data collection.	No answer
Q15. Could you characterize for each data category (3) availability and quality of raw data for mechanical, electrical and I&C component types?				
We expect to have a comprehensive response to this question after completion of the on-going task of the CNSC Ageing PSA research project	On a scale of 1 to 5 for availability(a) and quality(q): **3a:** a. 2, q. 3 **3b:** a. 2, q. 3 (depends on 3a) **3c:** a. 3, q. 5 **3d:** a. 5, q. 5 available in other (than reliability data) plant databases. **3e:** a. 3, q. 5 **3f:** a. 4, q. 4, for Environmentally Qualified equipments only. **3g:** a. 4, q. 3 **3h:** a. 2, q. 4 **3i:** a. 3, q. 4	? Yes, in a qualitative way	Presented in a table form	No answer

Responses from KAERI	Responses from Novator/UA	Responses from JSI/SL	Responses from INPE/RU	Responses from Paks NPP/HU
Q12. For better understanding of data contents and structure, could you provide some examples of operating and maintenance records/reports which include data listed in 3 ? **Raw data collection (2c)**				
Available for sample but in Korean. Structure of data could be provided on demand	URDB structure is presented	Not available	Failure logs contains the info : failure date, component ID, defect description, procedure of defect elimination and etc.	Not available
Q13. Do you have formal written procedure for failure and maintenance data collection and processing applicable on plant/utility level?				
Yes	Yes	Yes	Yes	No
Q14. What type of data listed in 3 formally required to collect by raw data collection procedure?				
3a, 3b, 3c, 3d, 3f and 3g. For 3h and 3i, plant operators collect the data when a failure is severe	3a, 3c, 3d, 3f, 3g, 3h.	See answer to Q8	Not clear	Failure mode, estimated unavailability time, possible root cause, failure identification circumstances.
Q15. Could you characterize for each data category (3) availability and quality of raw data for mechanical, electrical and I&C component types?				
In general, availability and quality of raw data is better in the case of mechanical components than in the case of other type components	Different for each NPP	? No, see Q3	Not clear	See Q1

Annex 3. Nomenclature of PSA Component Reliability Data.

Reliability parameters (2a)

1. Component group
2. Failure modes
3. Parameters :
    - Failure rate,
    - Failure probability per demand,
    - Mean time to repair,
    - Unavailability due to the maintenance.
4. Uncertainty

Processed data (2b)

Data for parameters estimation

1. Component group
2. Component description / limits
3. Operating mode
4. Component function
5. Failure modes
6. Failure criteria
7. Sample specification (number of components in the sample and list of components)
8. Observation period
9. Operating stressors (average number of hours or demands per year)
10. Cumulated number of hours in operation or number of demands
11. Number of failures considered for parameters estimation per failure mode
12. Parameter estimation method / assumptions

Data for estimation of cumulated number of hours in operation or number of demands

13. Component ID (sub-group)
14. Number of components in sub-group
15. Number of hours or demands per year
16. Observation period
17. Total cumulated number of hours in operation or number of demands

Failure data

18. Unit / component ID
19. Failure date
20. Reactor state
21. Failure mode
22. Criticality factor
23. Repair time
24. Failure cause / description

Annex 4. Daily operating records as per operating records Shift Supervisor Log and Control Room Log (sample provided by CNE/RO)

Cernavoda N.P.P
Shift Supervisor Log

Shift: 1 **Date:** 01 / 02-Feb-2006

Crew: D **Supervisors:** A. Tucu/ D. Iancu/ S. Marinescu

Shift Progress / Problems

CONDENSATE SYSTEM: Make-up- 43220

TK02 drained as per CCAR; filing I/P.

TURBINE STEAM: Condensate Return- 43330

43130-P5 tested; S/D due to abnormal noise reported; investigation to follow.

OVERALL PLANT CONTROL- 63710

RP @ 99.94 % FP ; T/G @ 703.3 MW ; Cond. Vac. @ 4.20 kPa ; Aux. Steam @ 48.75 t/h ; EFD 98; COD 75 .

Summary of System / Equipment Status

ELECTRICAL: 24kV- 51400

T04 OI#2006.03 and routine issued for corrective action.T04 oil leak identified, routine revised to allow operation with expansion tank oil level at 1/4.

ELECTRICAL: UPS- 55000

1-55420-INV 1C placed in service under test.

STANDBY DIESELS- 52300

DG#3 isolated for maintenance; glycol and oil drained. Portable heaters installed to SDG rooms from T/B plugs, to increase glycol/lube oil temperature.

FIRE DETECTION- 67147

5112-T01/ T02 fire signal trip jumpered as per PDD, recorder installed in PL2 (US01-19), monitoring and fire watch in progress. PDD revision in progress.

FIRE PROTECTION- 71400

During OMT 67147.2 isolating valve V291 for VEM 337/338 is not holding, rest of OMT aborted until V291 problem is solved. V109 developed seal leakage; WR filed.

U0 BOILERS- 72100

ABA isolated for maintenance and ISCIR authorization.

Cernavoda N.P.P
Control Room Log

Shift: 1 **Date:** 01 / 02-Feb-2006

Crew: D **Operators:** D. IANCU/D. IVAN/B.D. OMER

Time	Unit	BSI	Equipment	Event
20:25	0	71620	l#6	SOS 71620.13 issued to wash in closed circuit the line.
20:26	0	71620	l#7	SOS 71620.14 issued to wash in closed circuit the line.
20:27	0	71620	l#6	SOS 71620.8 issued to regenerate the line.
20:28	0	71660	tk 5.1	SOS 71660.8 issued to prepare FeCl3 solution.
20:29	0	71620	l#7	OO issued to place i/s the line with IX 4.1.
20:30	0	71630	tk's	OO issued to recirculate NaOH solution in TK2.1/2.3/2.4.
20:31	0	71630	tk 7.3	OO issued to transfer NaOH for 7162-L#6 regeneration.
20:45	1	33330	tk 1	Cover gas purged to lower D2 concentration.
20:58	1	68300	ch j	Channel rejected for scheduled tests.

21:00	1	32310	mcg	O2 added to restore normal concentration.
21:05	1	34810	tk 1	He added to restore normal operating pressure.
21:10	1	38410	tk 106	SOS 38410.04 issued to transfer tank content in 3811-TK 1.
21:30	1	43220	tk 1	Tank placed i/s after filling.
21:50	1	41231	ge 01	Reactive power decreased to -40 MVAR at DEN request.
22:00	1	43220	tk 2	Tank placed in bleed as per chem lab request.
22:40	1	38420	tk 4	OO issued to recirculate, sample and evacuate to S/B active drainage tank content.
22:55	1	43130	p 05	Pump started in test but s/d 15 min. later due to motor ballbearing abnormal noise; pretest conditions to be established.
23:20	1	34320	tk 5	Aprox. 5l of D2O drained to clear high level alarm.
02:00	1	68300	ch j	Scheduled OMT 68300.00J/15J/03J/05J/06J/07J/09J/10J completed OK, channel reset.
06:35	1	43220	tk 2	Tank filling started.

Summary:

MCR ANNUNCIATION:
-PL 12 HS OFF NORMAL: 43130-P 05 isolated.
-PL 16 WN-A2/ B2/ B1: SDG3 isolated; SDG 1 Trouble due to glycol xfer pump isolation for SDG 3 mtce.
-PL 18 WN-A1 DS09 NES unavailable.
WN-A5 STATOR CLG H2 ABN.Generator H2 pressure at normal value.WR & RCA filed.
-PL 19 WN-B1 DG 2 TROUBLE: false low level alarm on 7 days fuel tank, WR#F 1948 filed.
SYSTEM STATUS:
-Th CYCLE DRAIN: P 05 test failed, more investigations to follow..
-FIRE DETECTION: 7140-DV31 & DV33 isolated & JR's #3161(T01 & T02 trip logic) & #2834(recorder) installed as per 67147-P02 PDD. Fire watch established.
-SDG: Temporary heaters installed. Heaters operation & oil/ glycol temperature to be monitored. DG3 isolated, DV isolated , fire watch established.
-RCW: V397 open 60 %. 7134-V046 open 10%.
-RSW:Fans selected Off with C/T.
-CCW DISCHARGE: A1close A2/B2/B1 open ; recirc fraction 70 %.
-ELECTRIC:1-51440-T04 oil leak(~3.2l/h) monitoring I/p; Routine 1-EL-022 issued. WN 19-C8 "Inverter ch C trbl" came in alarm frequentely;investigation in progress;WR#F17505 and RCA filed.
-CHILLED WATER: WR#F17494 filed for CH011 condenser cleaning.CH 009 available only in AUTO.
-COND. STORAGE: TK 2 in feed/bleed as per chem lab request.
-LEPA: #9301/5; #9302/1; #9303/3
-ISOLATION:
0-7161-FR 1.8
1-5623-LP 31
-TEST:
1-5239-HTR 21
-REMOVE:
0-7140-V 111
0-7161-STR 7/8
0-7161-P 6.1
1-5613-LP 32
1-7140-V 149/V 525

Annex 5 : Raw data analysis (example provided by NRI/CZ)

An example of raw data analysis result is given in the following table. The table content is mostly fictive, but the information structure is exactly like in real data analysis. The table deals with analysis of failure events for the component type “invertor” (electric supply systems). Similar table was developed for each component population (type) analyzed.

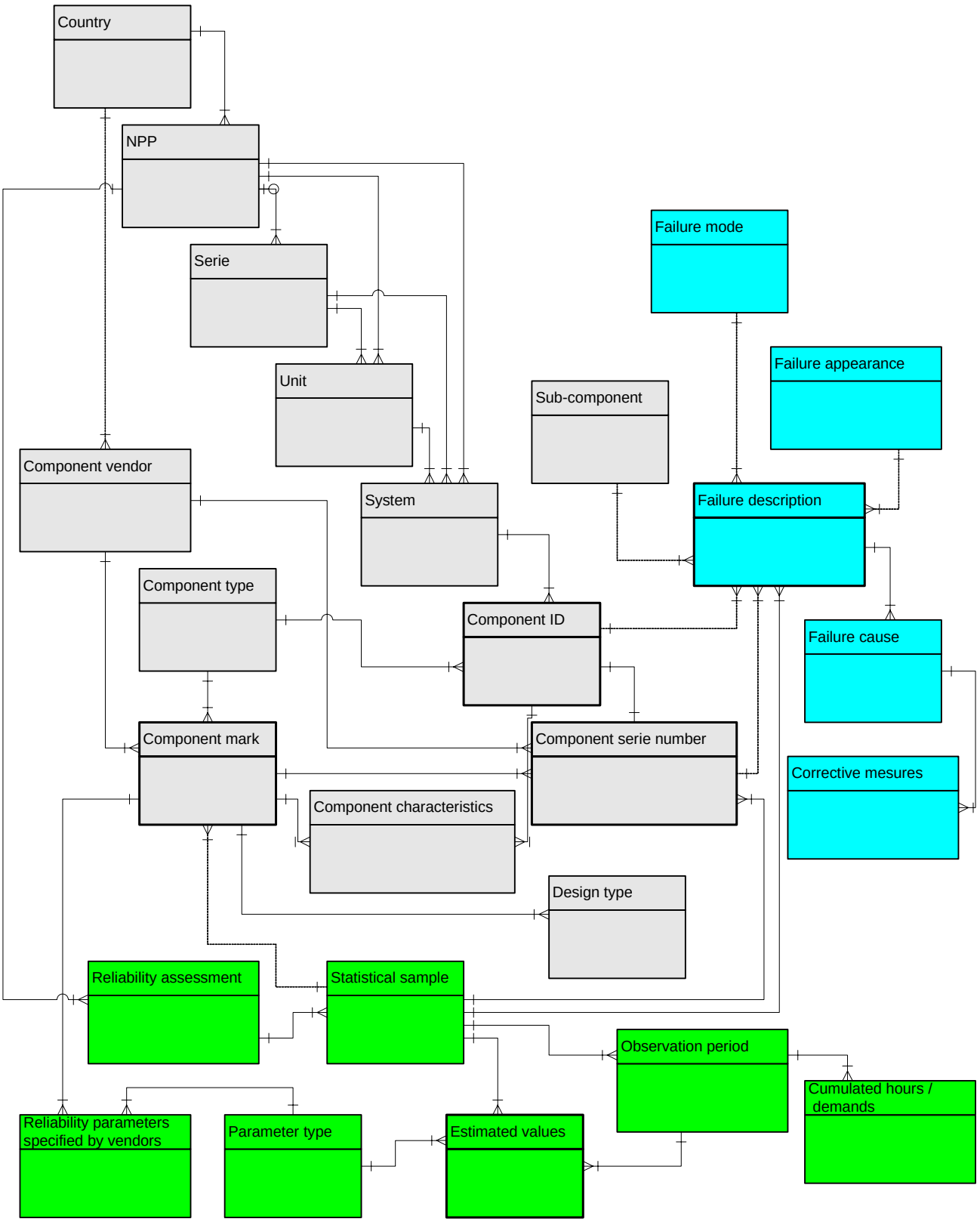
In the first column of the table, number of the event in plant records is specified. Using this number (and year code), detailed comprehensive information about the event can be found.

The second column contains important coefficient “C”, which represent, in fact, real numerical contributor of the event to the statistics for derivation of reliability parameter value. The most typical cases are 1)C=1, real event, full direct contributor to the statistics 2)C=0, for some reason, the event does not contribute to the statistics, but it is useful to present it in the analysis output for the sake of completeness 3)C is higher than 0, but lower that 1 - this case indicates event, where there is uncertainty about predicative value of it, the value of C represent a potential indicated with the event regarding failure possibility of the component, in fact.

The information in the remaining columns is easy understandable.

Ev. No.	**C**	**Unit No.**	**Event date**	**Brief event description.** ***Comment to the result of data analysis.***	**Regime**
-18	1	4	15.03.1997 09:55	Repeated loss of invertor INV03 caused by failure of control circuits. Hardware failure. ***Included into the statistics as fully representative event.***	R1
9	1	2	05.00.1999 11:15	Loss of invertor INV01 - due to failure of tyristor bridge. Consequently, two ESFAS trains were lost. ***Included into the statistics as fully representative event.***	R1
-76	1	3	19.01.1999 19:19	Loss of invertor INV03 caused by failure of control circuits. Hardware failure. ***Included into the statistics as fully representative event.***	R1
-52	0.3	3	07.12.2000 00:07	Spontaneous transfer of power supply for the invertor INV05 to the bus 2CB01. Cause not revealed. ***Does not represent full loss, but there is loss potential connected with consequent dynamic status. The potential has been specified in coefficient C value.***	R1
-112	1	1	00.12.2000 18:42	Loss of invertor INV03 caused by failure of control circuits. Hardware failure. ***Included into the statistics as fully representative event.***	R1
-31	1	3	06.09.2002 13:41	Repeated false indication of invertor INV02 overload supplemented with transfer to electronic bypass due to consequent failure of control unit B142. Hardware failure. ***Included into the statistics as fully representative event..***	R1

Annex 6 : Ukrainian Reliability Data Base (URDB) structure (example provided by NOV/UA)



European Commission

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Abstract
This report presents the state of the art of existed NPPs component reliability data collection systems which aimed to elaborate components reliability parameters to be used in Probabilistic Safety Assessements (PSA). A specific emphasis was done to the possible application of data in time-dependent reliability analysis.
The report was prepared by JRC IE in the frame of EC JRC Ageing PSA Network Task 4 activities and is based on analysis of responses of Network participants to the questionnaire.
Main conclusions and recommendations are presented in the report and they addressed to the data availability and accessibility, as well as to possible improvements of data collection and important issues to be considered in Ageing PSA Network work plan.

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