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LIFE CYCLE DOCUMENTATION - AN ESSENTIAL TOOL FOR PLANT LIFE MANAGEMENT AND AGEING MANAGEMENT

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ABSTRACT

Systems, structures and components (SSC) that are relevant to safety and availability must have a quality level that meets the requirements throughout plant service life. Both in ageing management and in plant life management, based on a proven quality as a starting point (e.g. after design and manufacture) possible damage / degradation mechanisms have to be controlled in operation in order to guarantee or at least maintain this quality status. The intensity of these measures depends on the relevance of the individual SSC.

On the background of actual state of knowledge the efficiency of the procedures has to be checked, regularly and individually, and the actual quality status of every SSC has to be compared to the requirements. This means, system weakness analysis / system health assessments have to be performed; this can only be done, successfully, using a comprehensive data basis on every relevant SSC (knowledge basis).

Life cycle documentation is part of a person-independent knowledge basis about every relevant SSC. Life cycle documentation gives a comprehensive chronological overview of all relevant quality related documentations and reports as well as - on a yearly basis - of every planned activity (like surveillance, maintenance and inspection measures) and of every event / incident (internal and external sources) that may affect quality including the assessments. Actual knowledge is taken into account in life cycle documentation, too.

INTRODUCTION

The main goal of ageing management (AM) in nuclear power plants is to demonstrate that all safety requirements are met throughout plant service life. The purpose of plant life management (PLIM) is to care for safety as well as for availability. Regarding this background AM concentrates on safety relevant systems, structures and components (SSC) and it is a subset of PLIM which includes safety *and* availability relevant SSC, **Fig. 1**.

SSC that are relevant to safety and availability must have a quality level that meets the requirements throughout plant service life. Regarding safety relevant SSC the requirements are fixed e.g. in legislation, standards and specifications, regarding availability there are specifications and commercial requirements.

Both in AM and PLIM, based on a quality after design and manufacture that meets the requirements the actual state of SSC has to be compared to the requirements, regularly. This means, system weakness analysis / system health assessments have to be performed; this can only be done, successfully, using a comprehensive data basis on every relevant SSC (knowledge basis). Part of this data basis is life cycle documentation.

In the paper, a summary of experience with life cycle documentation is given using examples of NPP Neckarwestheim, Germany.

Fig. 1: Scope of ageing management and plant life management

LIFE CYCLE

SSC that are relevant to safety and availability must have a quality level that meets the requirements throughout plant service life.

The initial step to establish a required quality status of SSC is performed during the state of design, **Fig. 2**. One of the main tasks of design is to consider every possible damage mechanism of the future operation (using specifications of loads, medium and environment and the selection of the materials etc.). Damage mechanisms that cannot be controlled (e.g. relevant corrosion, relevant dynamic loads) have to be avoided (using appropriate materials, constructions, environment). In operation it has to be verified that the boundary conditions for these presuppositions are kept. As this is usually done using surveillance, periodic tests, inspections and maintenance these measures have to be planned during design, already. Goal of the design analysis is to demonstrate that every requirement is met and the results are within given limits e.g. regarding safety relevant mechanical SSC by stress, fatigue and fracture mechanics analysis. It is obvious that experience and knowledge in this state determine the reliability of the component.

The manufacturing process is the next important step for the quality status of components. SSC design has to be realized; modifications and repair have to be documented, analyzed and assessed. The required quality can only be achieved if there is a thorough control e.g. of material composition and behavior as well as of construction details. The final state of SSC after the manufacturing process (as built) is aimed to be qualified according requirements and defect-free (mechanical SSC, especially).

Integrity and function of a SSC in operation (safety and availability, remaining life) is determined by the real operation history. In operation, generally, damage mechanisms due to interaction between material, loads and environment act on every SSC and - depending on their relevance - as a consequence there may be degradation with time (physical ageing): As operation experience showed not specified (new) loads, malfunction, failures and defects have been discovered in the past. Additionally, requirements (e.g. fixed in standards) and / or the knowledge base may be changed and / or technology advances (obsolescence).

Obsolescence aspects have to be considered by tracing the state of knowledge, mainly. Physical ageing mechanisms have to be controlled by application of an appropriate set of measures to guarantee / maintain the required quality of SSC in operation. There are a lot of different measures applied in NPP; e.g.

- monitoring of loads and water chemistry
- non destructive testing
- function checks
- inspections / ISI
- maintenance.

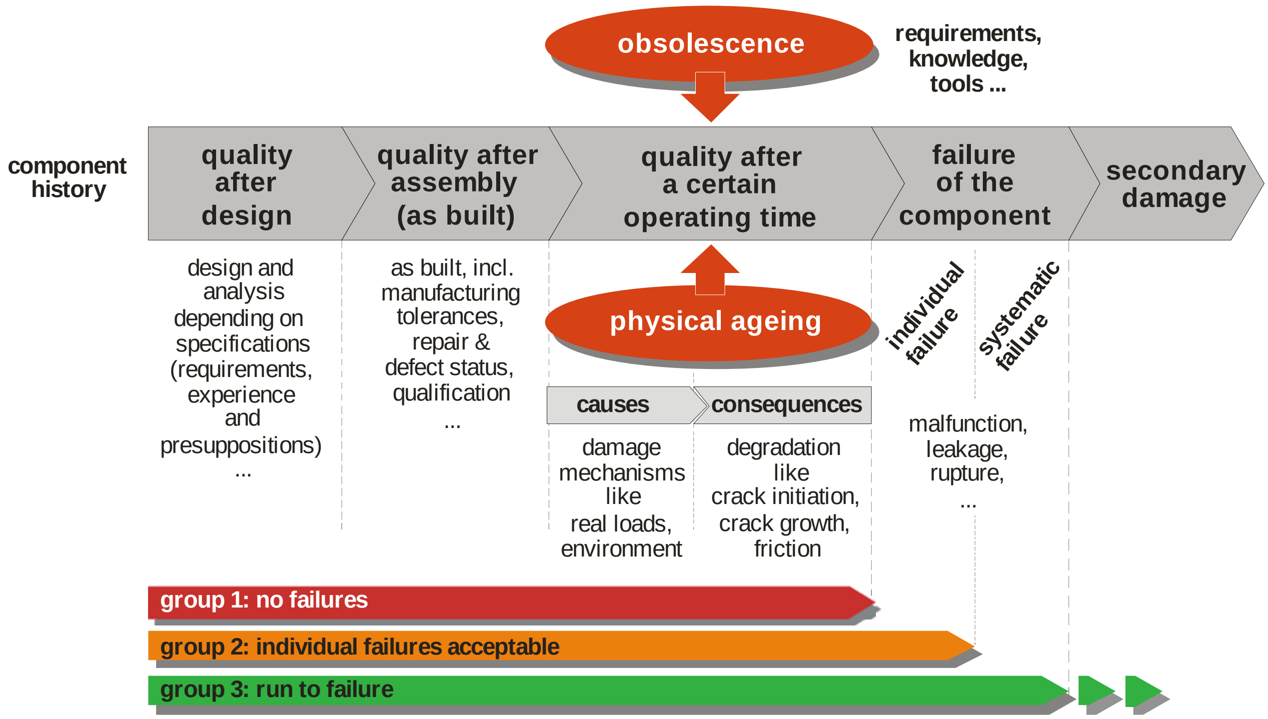

Fig. 2: life cycle of systems, structures and components

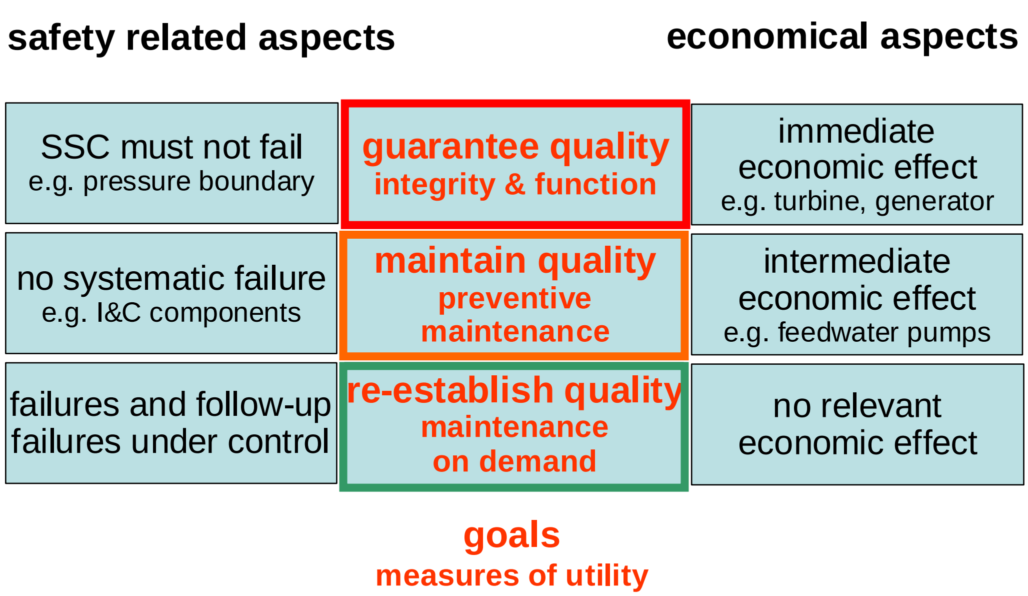

Fig. 3: classification of SSC in AM and PLIM

The overall effort depends on the relevance of the individual SSC. Three groups of SSC usually are defined, ref. to **Fig. 3**:

- group 1: Guarantee integrity
  The quality status of the components in this group has to be guaranteed on a pre-defined (high) level.
- group 2: Prevent systematic malfunction / failures
  The quality status of the components in this group has to be maintained on a required level.
- group 3: Other components with no specific demands on quality.
  The quality status of the components in this group has to be re-established on demand.

Within the integrity concept applied to safety relevant mechanical SSC of group 1 (e.g. SSC of pressure boundary) the possible damage mechanisms have to be controlled; this is done by an extensive monitoring and assessment of the causes of damage (e.g. loads, water chemistry) and - as a redundant measure - of the consequences of damage (e.g. using periodic non-destructive testing). The first priority of the measures is to prevent relevant degradation; integrity and function have to be guaranteed. The same principles can be applied to economically relevant SSC that must not fail (e.g. turbine, generator). As the example of the turbine shows monitoring of the loads is performed as well as monitoring of vibration for example; as a redundant measure comprehensive non-destructive testing is performed.

In the second group of SSC (e.g. main steam and feedwater system outside containment, electrical and I&C components) there is redundancy, in general. Based on this redundancy single malfunctions can be managed but systematic failures have to be avoided both regarding SSC that are relevant to safety and those that are relevant to availability. This means that the sum of measures can concentrate on finding signs of degradation before there are notable consequences. To maintain quality (integrity and function incl. tightness) of this group of SSC inspections, tests and maintenance are performed regularly (time dependant, periodically) or based on monitoring of relevant parameters (predictive). The time dependant process is easier to establish but may be not cost-effective in some cases. The predictive method can only be used if there is enough experience with the component and the dominating damage mechanism. At the end of each cycle, the initial quality status (integrity and function) has to be re-established if necessary.

Regarding the large number of components and systems in group 3 it is sufficient to perform maintenance on demand, i.e. if a failure is detected. However, a failure analysis is recommended to optimize the procedures.

Generally, for all groups of SSC the basis is a good quality after production (design and manufacture). On the basis of an appropriate quality of the SSC (as a starting point) the sum of the measures applied in operation (like surveillance, maintenance and testing) must meet the main goal of AM and PLIM: appropriate control of possible degradation, **Figs. 4 and 5**.

The measures discussed above are performed on a planned basis. The presuppositions of design are verified and it is checked for relevant known damage mechanisms as well as redundantly for potentially “new” damage mechanisms. Additionally, especially regarding potentially “new” damage mechanisms further measures are:

- assessment of not expected events, malfunctions and failures,
- assessment of other plant specific surveillance results,

and

- assessment of the change in knowledge (e.g. experience of other plants, R&D),
- assessment of change in requirements.

The last two topics cover obsolescence, too. The results of these measures contribute to the knowledge basis.

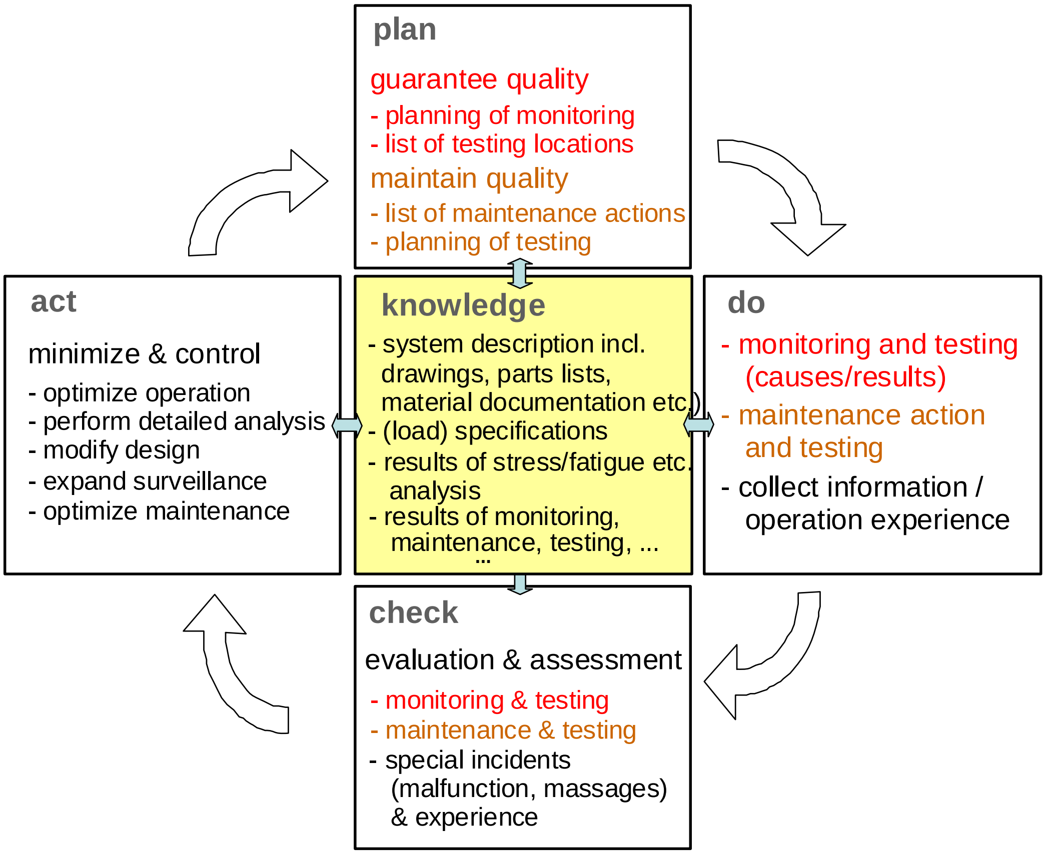

Fig. 4: processing data in AM / PLIM

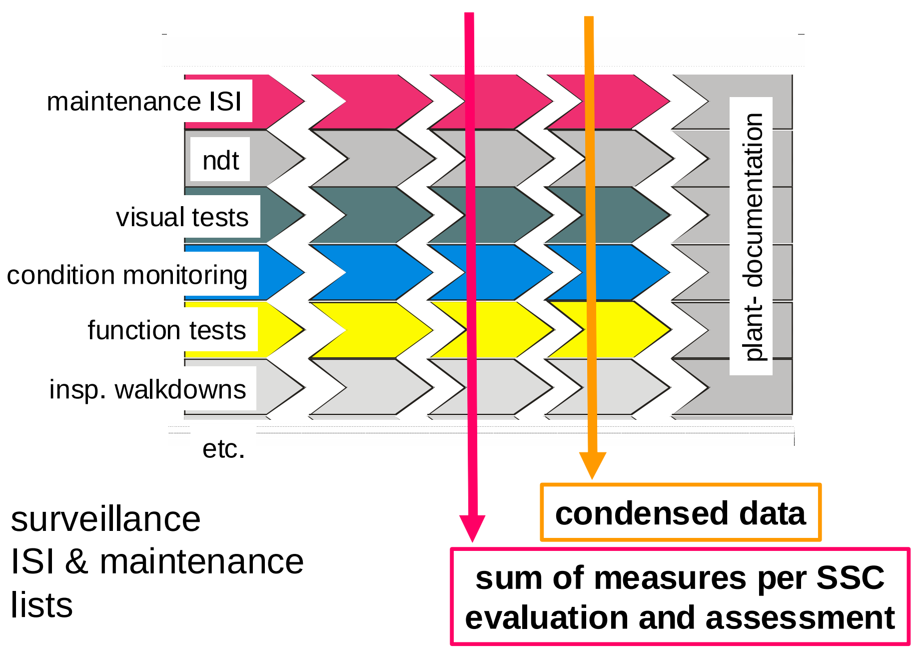

Fig. 5: evaluation and assessment of data per SSC

A procedure (like AM, PLIM) has to be installed that can be modeled in a PDCA-cycle (Plan-Do-Check-Act) for example (ref. to Fig. 4) to ensure steady improvement.

After a certain period of operation the state of quality of every SSC is determined by the

- quality after design and manufacturing and by the
- measures that are applied to guarantee or maintain or re-establish this quality during operation.

Therefore it is necessary to compare the actual quality status of every SSC to the requirements to check the efficiency of every single measure and to check the overall efficiency of the process (AM/PLIM) and to demonstrate this fact, effectively. This means system weakness analysis / system health assessments have to be performed, regularly; this can only be done, successfully, using a comprehensive data basis on every relevant SSC (knowledge basis). Part of this data basis is life cycle documentation.

LIFE CYCLE DOCUMENTATION

Life cycle documentation is part of a person-independent knowledge basis about every relevant SSC. Life cycle documentation gives a

- comprehensive chronological overview

of all relevant

- quality related documents and reports / documentations
- activities / events / incidents that may affect quality

of individual SSC including the assessments. As shown in Fig. 5 this consequent correlation to the individual SSC is one key topic of life cycle documentation. Actual knowledge is taken into account, too. Life cycle begins with design and manufacture, consequently

- documentation of design and manufacture

i.e. the (initial) proof of SSC quality is part of this individual life cycle documentation, see table in **Fig. 6**. If there were relevant modifications and optimization in the time since manufacture the documentations of these measures applied to the SSC have to be included, too. The data in life cycle documentation should summarize the actual quality of the SSC and they should provide an overview about open points. Another special subject concentrates on

- possible damage mechanisms
  including those that have to be excluded e.g. as a presupposition during design.

In operation, a

- bundle of measures

is applied to maintain/guarantee the quality. These measures (as planned) are listed in the database.

	<<< PLIM Plant Life Management >>>	
	< AM Ageing Management >	
	safety relevant	availability relevant
basic data set		
characteristic data (identification, design and operation parameters, ...)	database header per SSC	database header per SSC
actual SSC configuration (materials, design, construction details, ...)	drawing numbers, materials lists, ... remarks, authorities comments	drawing numbers, materials lists, ... remarks
modifications	work order documentation, ... remarks, authorities comments	work order documentation, ... remarks
quality status after design and manufacture	references, ... remarks, authority comments	references, ... remarks
quality status update after modifications	if applicable	if applicable
quality status update after changes in requirements	if applicable	if applicable
actual quality status	references utility/ manufacturer reports ... & remarks comments of licensing authority open points	references utility/ manufacturer reports ... & remarks
relevant damage/degradation mechanisms	list of mechanisms	list of mechanisms
measures to control relevant damage/ degradation mechanisms	list of measures	list of measures
annual data sets		
planned action & results / remarkable results & reaction		
surveillance (monitoring loads, environmental parameters, diagnostics, ...)	activity results / remarks assessment & add. measures (if necessary)	activity results / remarks assessment & add. measures (if necessary)
inspections / ISI incl. special investigations (periodic ndt, vt, ...)	activity results / remarks assessment & add. measures (if necessary)	activity results / remarks assessment & add. measures (if necessary)
function tests	activity results / remarks assessment & add. measures (if necessary)	activity results / remarks assessment & add. measures (if necessary)
preventive maintenance (service & exchange of parts subject to wear and tear, ...)	activity results / remarks assessment & add. measures (if necessary)	activity results / remarks assessment & add. measures (if necessary)
repair	see not expected	see not expected
...	...	...
not planned action / event / experience & results / remarkable results & reaction		
malfunction and failures ("internal" experience) incl. reports of irregularities	reference results / remarks assessment & add. measures (incl. control of efficiency)	reference results / remarks assessment & add. measures (incl. control of efficiency)
external events (reports on generic problems, incidents of other utilities).	reference results / remarks assessment & add. measures (if necessary, incl. control of efficiency)	reference results / remarks assessment & add. measures (if necessary, incl. control of efficiency)
expanded knowledge (research etc.)	references results / remarks assessment & add. measures (if necessary, incl. control of efficiency)	reference results / remarks assessment & add. measures (if necessary, incl. control of efficiency)

Fig. 6: Life cycle documentation – samples of content

While the data discussed to this point are more of static nature (there are only few events that trigger changes) the majority of data in life cycle documentation is extended with operation time (with the years). The results of these planned measures like

- surveillance (like monitoring of loads, diagnostics etc.)
- inspections (like non destructive testing, function checks etc.)
- maintenance (esp. active components)

are stored in the life cycle documentation, regularly. The sum of measures applied provides control of relevant known damage mechanisms as well as redundant check for potentially “new” damage mechanisms. Additionally, regarding potentially “new” damage mechanisms special attention is given to “remarkable” i.e. unexpected results like

- malfunction and failures (“internal” experience).

and

- “external” events (reports on generic problems, incidents of other utilities).

Unexpected results and events are assessed, regularly, and -if applicable- a summary is stored in the life cycle documentation. Finally, the

- assessment of state of knowledge
  (incl. experience of manufacturer and utilities, results of research etc.)
- assessment of changes in requirements

is part of this data basis. Using these data in total a comprehensive chronological overview is provided for every relevant SSC, individually. These data can be printed sorted for each measure applied (documentation of the single stages) and reduced to relevant / remarkable results / events. This overview is the basis of the regular assessment of the existing quality status in AM and PLIM programs. Thus at any time, the sum of data collected in life cycle documentation allows for

- system weakness analysis / system health reports.

Regarding AM in Germany this assessment has to be done once a year; the results have to be presented to the authorities in formal reports. Regarding effective PLIM the same time interval for regular assessments is recommended on the basis of experience. However, reports on the results of availability relevant SSC are internal.

CONCLUSIONS / LESSONS LEARDED

Regular system health reports are essential for plant life time management, ageing management and for periodic safety reports. A comprehensive life cycle documentation of every relevant SSC is the centre tool / basis for these topics.

In the Neckarwestheim AM-program, above procedures and data bases are in use since more than 10 years now. Based on this experience the scope is expanded to availability relevant SSC, too, to enhance plant life management.