

## AGEING MANAGEMENT: CONTROL OF THE KNOWLEDGE DATA BASE

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### ABSTRACT

Ageing management is part of the safety management system in NPP Neckarwestheim, Germany. The central goal of aging management is to increase knowledge about ageing mechanisms acting on systems, structures and components (SSC), steadily. Comprehensive knowledge is a pre-requisite to guard against ageing related systematic failures.

To increase knowledge it is necessary to gather and evaluate data of different departments, systematically. While a nuclear power plant is in service numerous events may occur which are related to aging and may have an influence on the quality of SSC. Relevant events may be malfunction, maintenance results, operational experience, results of surveillance or events in other utilities. It is important to evaluate these events concerning the aspect of aging, regularly, and to decide which measures are required to prevent similar unexpected events in the future. In some cases the new experience has to be assigned to comparable SSC. These evaluations and the necessary measures as well as the tracking of their effectiveness are performed by an aging management team that meets every 3 months.

The resulting knowledge data base supports the application of the PDCA cycle and provides an overview and fast access to all quality documents related to each SSC including surveillance measures and results. It simplifies the generation of annual status reports which demonstrate the efficiency of aging management.

Finally, the procedure can be extended to SSC which are important for the availability of the plant and thus take a step forward from aging management to plant life management.

### INTRODUCTION

The nuclear power plants (NPP) in Neckarwestheim, Germany, have implemented a comprehensive ageing management (AM) in recent years. AM uses both organizational and technical measures to

- control possible ageing phenomena

and thus to ensure the

- availability of the required safety functions

throughout the plant service life.

Safe operation of nuclear power plants highly depends on integrity and function of safety relevant systems, structures and components (SSC) in use. More general, integrity and function can be expressed as “quality”. It is the main task of the design and manufacture process to install SSC in a required quality level. By means of the sum of measures applied in operation (like surveillance, maintenance and testing) the required quality of the safety relevant SSC has to be maintained.

AM concentrates on safety relevant SSC; **Fig. 1** gives examples of SSC out of the mechanical, electrical and I&C as well as building sector. Depending on the quality requirements, three groups of SSC have been defined to classify the scale of the measures applied:

- group 1: SSC must not fail (guarantee SSC integrity – control ageing phenomena)
- group 2: no systematic failure (maintain SSC quality level e.g. by use of preventive maintenance)
- group 3: failure orientated maintenance (re-establish initial quality, if necessary)

Regarding the first group of SSC (guarantee of integrity), gross failures must be prevented in any case (“leak-before-break”). This first group contains all those SSC whose integrity is extremely important for the safety of the plant; most SSC of this group are part of the pressure boundary within the containment.

To guarantee integrity, possible damage (ageing) mechanisms have to be controlled explicitly following a consequent procedure like the one that is given by the German nuclear code KTA 3201.4 (integrity concept for mechanical SSC) [1]. In Neckarwestheim, the key tasks of this procedure in operation are: extensive monitoring and control of the causes of damage (e.g. loads, water chemistry) and – as a redundant measure – monitoring of the results of damage (e.g. using non destructive testing - ndt) – besides the regular assessment of unexpected events and the actual knowledge.

The second group contains all other safety relevant SSC (except those of group no. 1). These systems and components are built in with redundancy; therefore malfunctions or failures may happen as long as these are single incidents and the consequences (like follow-up failures) can be controlled. However, intensive care has to be taken that there are no “common mode” failures, i.e. systematic failures, especially not in more than one redundancy. To maintain SSC quality inspections, tests and maintenance action are performed regularly (time dependant) or based on monitoring of relevant parameters (predictive). These procedures are usually summarized under “preventive maintenance”. As with group 1 all unexpected factors and events as well as the actual knowledge have to be evaluated and assessed.

The majority of SSC in a power plant is classified into group 3. Regarding safety, failures and malfunctions can be accepted in this group 3 of SSC; it is sufficient to perform maintenance on demand, i.e. if a failure is detected. Possible consequences of failures / follow-up failures have to be under control.

All safety relevant SSC belong to groups 1 and 2 – therefore SSC of group 3 are not part of the AM-procedure.

The process of aging management can be modeled in a PDCA-cycle (Plan-Do-Check-Act) to demonstrate the implementation of steady improvement, **Fig. 2**. On the basis of an “installed” quality that meets the requirements the measures to safeguard this quality have to be planned and performed, checked, regularly, and modified, if necessary. Assessments are made on the background of actual knowledge [2]. Knowledge is the center point of the AM procedure and it has to be increased continuously to understand ageing [3].

Within AM the quality of safety relevant systems, structures and components has to be assessed, regularly. Thus the safety margin can be verified (and demonstrated) at every stage of operation and if necessary it can be reacted in time.

This paper concentrates on the features of a knowledge data base that was made to measure for the Neckarwestheim NPP to manage the numerous data that are connected to AM. This data base supports the application of the PDCA cycle and provides an overview and fast access to all quality documents related to each SSC including surveillance measures and results. It simplifies the generation of annual status reports which demonstrate the efficiency of aging management.

## **BASIS: EXISTING QUALITY**

As said above and in Fig. 2 the basis for application of AM to a SSC is a quality status that meets the requirements. The initial step to establish a required quality status of SSC is performed during the state of design. Main goal of the design is to consider every possible damage mechanism of the future operation (by specification of loads, medium and environment and the selection of the materials). The knowledge during the state of design determines the reliability of the component. Goal of the design analysis – regarding mechanical SSC: stress, fatigue and fracture mechanics analysis - is to demonstrate, that the results are within given limits. It is obvious that the design process does not provide conclusions regarding the state of component quality after a given period of operation.

The manufacturing process is important for the quality status of components, too. The required quality can only be achieved if there is a thorough control of material composition and behavior, of constructive details and of the desired fault-free state.

Integrity and function of a component in operation (safety, remaining life) is determined by the real operation history. As operation experience shows, failures, defects and not specified (new) loads are discovered during operation. Additionally, requirements (e.g. fixed in standards) and / or the knowledge base may be changed. Therefore it is obvious that - after a certain period of operation – the state of quality is determined by the

mechanical SSC	electrical SSC and SSC of I&C	building SSC
<ul style="list-style-type: none"> <li>- pumps</li> <li>- valves</li> <li>- piping systems incl. supports up to building</li> <li>- vessels</li> <li>- ventilators</li> <li>- compressors</li> <li>- emergency power units (diesels)</li> <li>- ...</li> </ul>	<ul style="list-style-type: none"> <li>- actuators (electrical, magnetic)</li> <li>- transducers</li> <li>- connectors</li> <li>- cable penetrations</li> <li>- cables</li> <li>- emergency power system</li> <li>- reactor protection system (analog and digital)</li> <li>- ...</li> </ul>	<ul style="list-style-type: none"> <li>- reactor building</li> <li>- reactor auxiliary building</li> <li>- switch house</li> <li>- building of emergency diesels</li> <li>- auxiliary service water building</li> <li>- emergency feed building</li> <li>- ...</li> </ul>

Fig. 1: Safety relevant SSC of mechanical, electrical and I&C, building sectors are part of AM

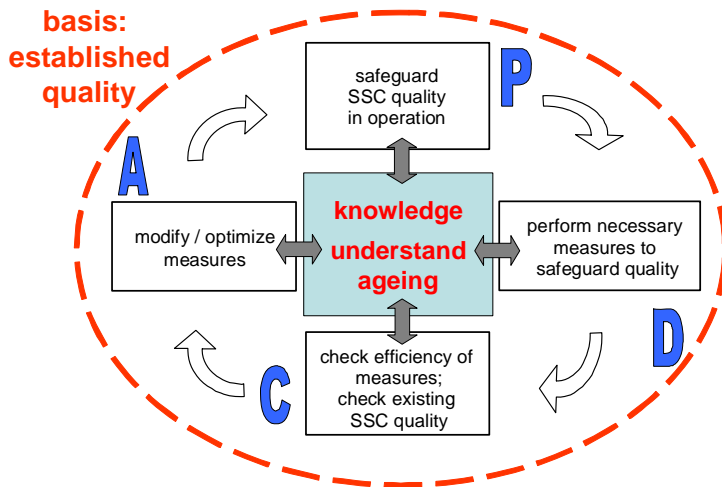


Fig. 2: AM in a Plan-Do-Check-Act scheme provides continuous optimization

mechanical SSC	electrical SSC and SSC of I&C	building SSC
<ul style="list-style-type: none"> <li>- monitoring (loose parts, vibration, leak detection)</li> <li>- check function</li> <li>- services (like oil services)</li> <li>- <b>inspection</b> incl. periodic <b>testing</b> like non destructive tests visual tests pressure tests function tests ...</li> <li>- <b>preventive maintenance</b></li> <li>- repair</li> <li>- analysis of events</li> <li>- failure analysis</li> </ul>	<ul style="list-style-type: none"> <li>- check function</li> <li>- failure /malfunction det.</li> <li>- services</li> <li>- <b>inspection</b> incl. periodic testing like <b>function tests</b> visual tests ...</li> <li>- preventive maintenance</li> <li>- repair</li> <li>- trending</li> <li>- analysis of events</li> <li>- <b>failure analysis</b></li> <li>- report of repair</li> <li>- <b>failure statistics</b></li> <li>- ...</li> </ul>	<ul style="list-style-type: none"> <li>- check function</li> <li>- services</li> <li>- <b>inspection</b> incl. periodic testing (mostly visual tests)</li> <li>- ...</li> <li>- preventive maintenance (e.g. preventive renewal of surface coatings)</li> <li>- repair</li> <li>- failure analysis</li> <li>- ...</li> </ul>

Fig. 3: Measures to safeguard the required quality of SSC in operation

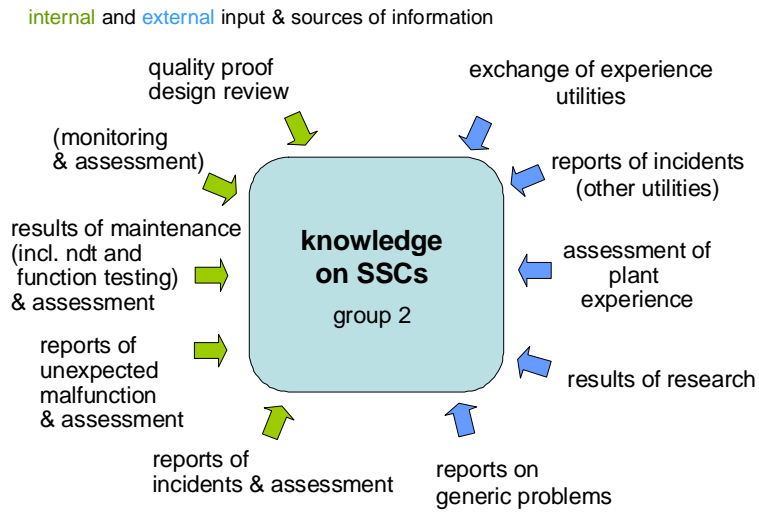


Fig. 4: Sources of information regarding knowledge on SSC

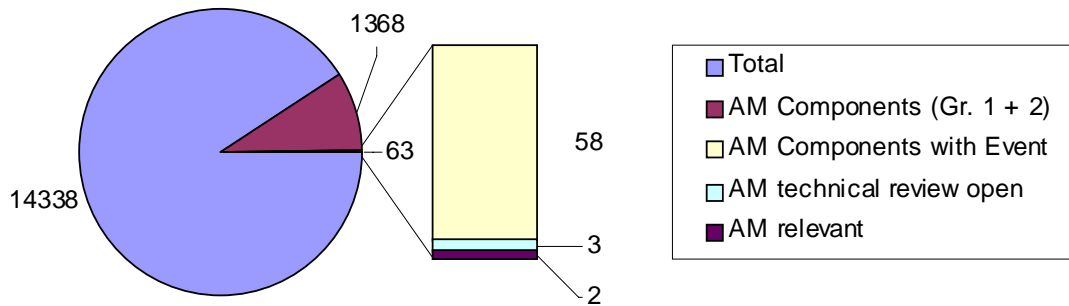


Fig. 5: Planned activities and not planned events in 2010 (Neckarwestheim unit 1 – mechanical SSC)

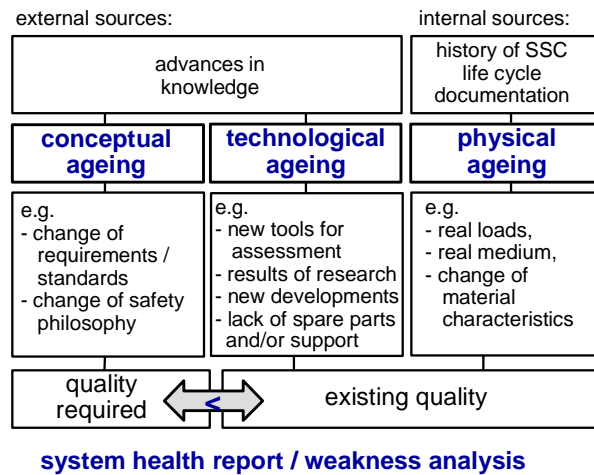


Fig. 6: Evaluation and assessment of external and internal information to perform SSC safety status analysis

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

After a certain period of operation (introduction of AM procedure) a review of the existing quality has to be done. For group M1 SSC of Neckarwestheim this was done in depth, see example in [4]. The results are summarized in six documents / six chapters of one document covering:

- actual construction (configuration)
- relevant loads
- stress analysis
- fatigue analysis
- fracture mechanics analysis
- surveillance and in-service inspection

Regarding all other safety relevant SSC (mechanical, electrical, I&C, building) the actual state of the documentation (incl. quality documents) was reviewed during implementation of AM.

These documents and the reaction of the licensing authorities have been stored into the *AM knowledge database*, see below.

### **SURVEILLANCE AND INSPECTION MEASURES IN OPERATION**

As shown in **Fig. 3**, there are a lot of different measures installed to guarantee / maintain the required quality in operation; major measures are

- monitoring
- function checks
- non destructive testing
- inspections
- maintenance.

These measures are performed on a planned basis. The sum of all the surveillance measures applied provides control of relevant known damage mechanisms as well as redundant check 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, ref. to **Fig. 4** (mech. SSC of group M2).

In Neckarwestheim unit 1 for example in 2010 there were 14.338 planned activities and not planned “events” regarding mechanical SSC. 1.368 of them have been related to safety relevant SSC, 58 of these 1.368 were identified to be not planned “events”. After assessment which is done by an ageing management team every 3 month only 2 events were left with ageing phenomena as reason, **Fig. 5**.

This result is a first verification that the sum of measures to safeguard ageing phenomena is effective. On the other hand the numbers show that a computer data base is necessary to manage all this information (*AM knowledge database*).

## ASSESSMENT OF SSC QUALITY STATUS

Within AM process the quality of safety relevant SSC has to be assessed, regularly, ref. to Fig. 2 and Fig. 6. Thus it is verified that

- physical ageing phenomena are under control and
- advances in technology and
- advances in safety philosophy as well as in standards

are considered. Summarized it is demonstrated that the quality at every stage of operation meets / exceeds the requirements and - if necessary - it can be reacted in time. It is obvious that the *AM knowledge database* provides comprehensive data for this assessment.

## AGEING MANAGEMENT KNOWLEDGE DATABASE

As introduced in the previous chapters the *AM knowledge database* contains comprehensive information on

- characteristic data
- history of quality documents
- life cycle documentation
- results of assessments

for every SSC. The AM knowledge database provides input and output of internal and external information, Fig. 7.

“Characteristic data” identify the individual SSC (name, position, material, drawings, design load, nominal loads in operation etc.) and provide information about possible damage mechanisms and the measures to control them.

“History of quality documents” provides information and reports on SSC quality incl. official correspondence, ref. to chapter “existing quality” and example in Fig. 8.

“Life cycle documentation” includes the results of surveillance and inspection measures incl. the assessment of “events”, see chapter above and example in Fig. 9. The evaluation and assessment of information of external sources (other plants, manufacturer, authorities etc.) is part of the life cycle documentation, too.

Finally, the “results of (regular) assessments” are stored in the AM knowledge database, ref. to chapter above. As a lot of SSC has to be managed only a summary of remarkable results is given on paper in the annual status reports.

## CONCLUSIONS

The Neckarwestheim NPP of EnBW have implemented a comprehensive ageing management. Basis of this procedure is a SSC quality according to the requirements. This quality status has to be guaranteed (group 1) or maintained (group 2) in operation.

The aging management knowledge data base is a comprehensive tool providing fast access to all aging management related documents and assisting the process of aging management in the organization. It can be used to prove and demonstrate the safety culture of the plant operating organization and to obtain economic benefit by reducing or even avoiding unplanned outages and thus operate a plant with optimum availability.

A further advantage of using the data base is that the procedure can easily be extended to components that are not safety-related but that are important for the availability of the plant. This extension is the next step towards plant life management and long term operation (LTO).

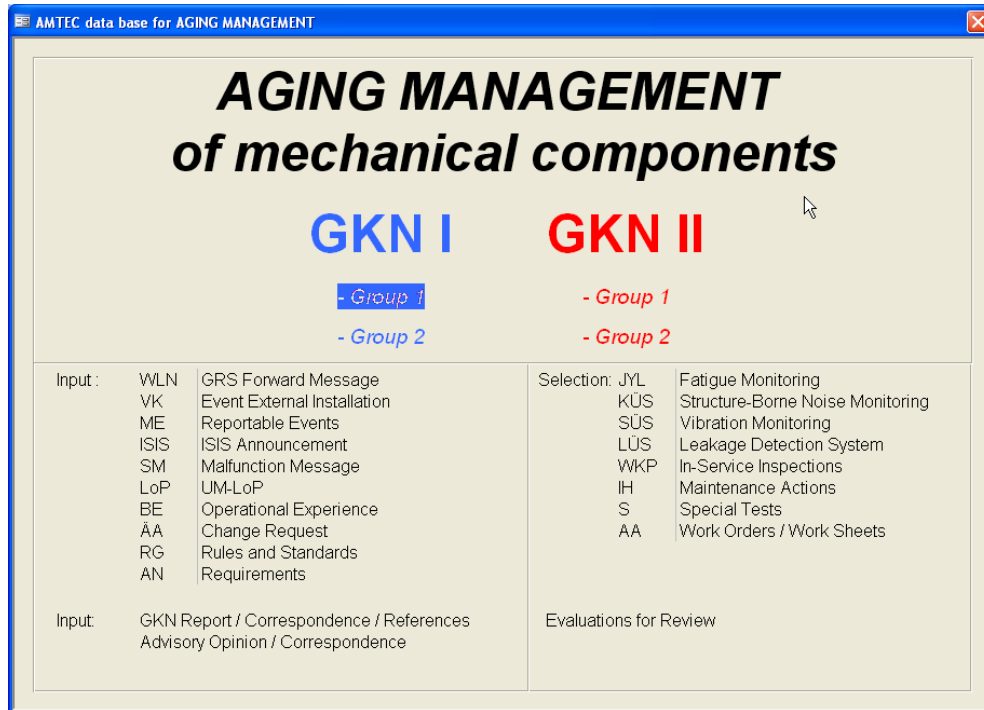


Fig. 7: AM knowledge data base provides comprehensive information on every safety relevant SSC

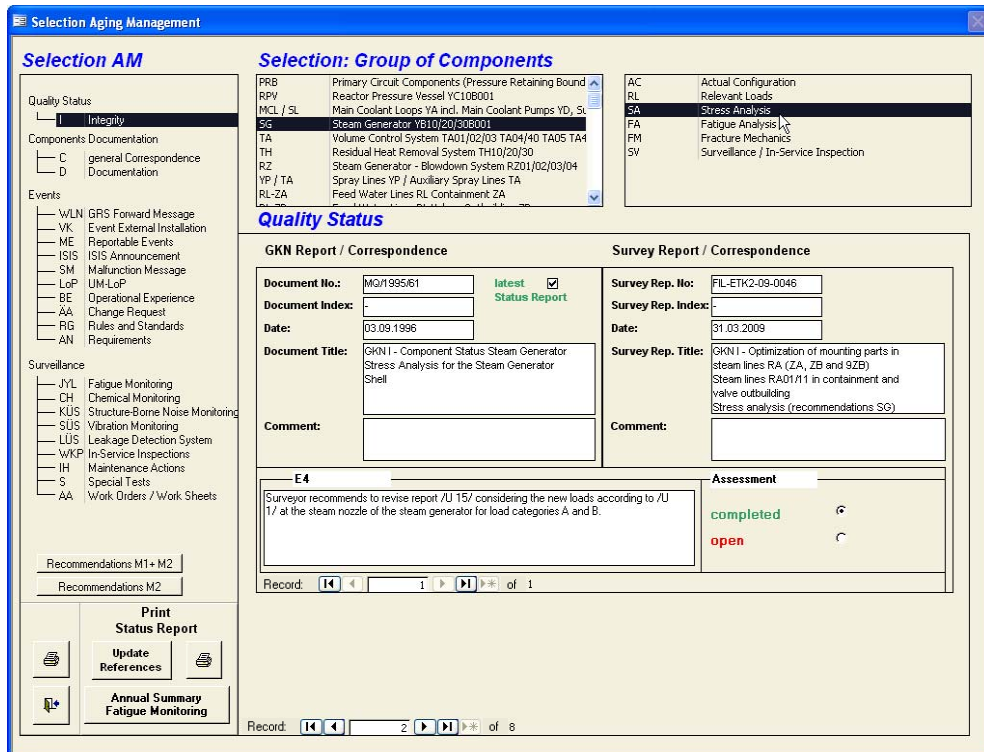


Fig. 8: Detailed data about SSC quality documentation

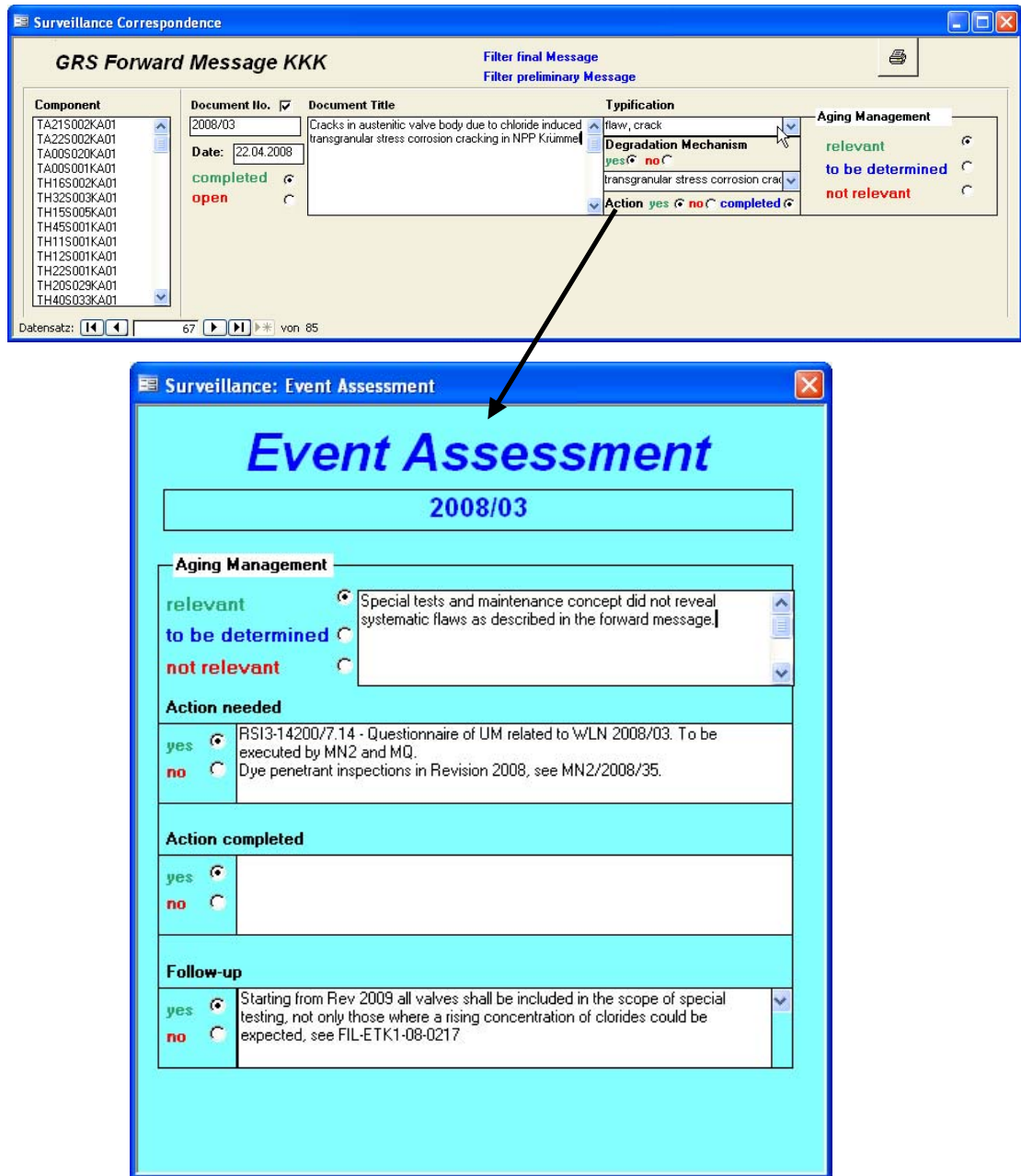


Fig. 9: Assessment of not planned “events”

REFERENCES

- [1] German Nuclear Standard KTA 3201.4 “Components of the Reactor Coolant Pressure Boundary of Light Water Reactors; Part 4: Inservice Inspections and Operational Monitoring”, November 2010.
- [2] German Nuclear Standard KTA 1403 “Ageing Management in Nuclear Power Plants”, November 2010.
- [3] IAEA Standard NS G 2.12 “Ageing Management in Nuclear Power Plants”, International Atomic Energy Agency, Vienna 2009
- [4] Bartonicek, J., Zaiss, W. and Schoeckle, F., “Ageing Management of the Steam Generator Internals”, Transactions of the SMiRT 20, Helsinki, Finland