Safety Significance of Component Ageing, Exemplary for MOV, Based on French and German Operating Experience

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Abstract: An outline is given of how IPSN and GRS assess the effects of physical ageing on the safety of French and German Nuclear Power Plants (NPPs) on the basis of the available knowledge and how investigations are carried out. The presentation is focused exemplarily on a preliminary study illustrating approaches for the evaluation of the ageing behaviour of active components, the motor-operated valves (MOV). The results so far seems to demonstrate that the developed methodological approaches are suitable to obtain qualitative evidence with regard to the ageing behaviour of technical facilities such as MOV. The evaluation of the operating experience with French 900 MWe plants seems to reveal, for MOV of one system, a trend similar to some international findings about ageing-related events with increasing operating time; this trend will have to be confirmed. For the German NPPs so far, there appears to be no significant increase of ageing-related events concerning MOV as the plants get older. Future work on ageing scheduled at IPSN and GRS includes further co-operation on this issue, too ; a deep analysis is necessary to explain the reasons of such apparent differences before any conclusion.

1. INTRODUCTION

Different ageing processes occur in all technical facilities and also in systems, structures and components (SSCs) of nuclear power plants (NPPs). Their occurrences must be controlled and their effects mitigated.

NPPs consist of a variety of SSCs which are designed for different life times, ranging from a short life time for some qualified equipments which are replaced at rather short intervals of less than 5 years, to a life expectancy of 40 years or more, mainly for structures and large components, to. NPP ageing can result, if not correctly managed, in the operating safety level falling below the reference safety level set at the design and construction stages of the plant and accepted by the regulator prior to plant operation. To control and maintain ageing degradation of SSCs in NPPs within acceptable limits, comprehensive engineering, operations and maintenance actions are taken. These are, in particular :

- the consideration of current knowledge on ageing in the design, manufacturing and inspection of SSCs,
- the inspection and monitoring of SSCs and monitoring of operating conditions with respect to detecting any deterioration important to safety,

- the regular replacement of parts known to be susceptible to ageing degradation by preventive maintenance,
- an upgrading or replacement of components in case weaknesses important to safety are found,
- the optimisation of SSCs and of operating conditions
- the continuous evaluation of operating experience, implementing findings from the feedback of experience.

The IPSN activities related to ageing issues [1-3] mainly concern :

1. analysis, on the basis of available data concerning events, of operating experience and feedback :
   - extensive approach about active components reliability and passive structure in-service behaviour,
   - inspection and maintenance programmes,

   The objective is to identify :
   - materials, zones or components sensitive to ageing damage mechanisms
   - degradation or failure root causes related to material specifications or component environmental conditions or/and operating stressors.
2. research and development specifically intended to assess utility's actions and incite the utility to lead :
   - ageing understanding research,
   - control development,
   - technical expertise of samples of real components taken up from reactors.

The investigations cover for example :

- metallic, polymer and concrete materials ageing phenomena and degradation kinetics
- influence of environmental and operating conditions,
- safety margins evaluation from ageing simulation accelerated tests,
- ageing impact on accidental phase behaviour,
- non-destructive ultrasonic and eddy current examination devices and methods performances.

The GRS activities in the ageing field are summarised in **Fig. 1.**

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Fig. 1 GRS activities in the field of ageing

For almost 25 years, GRS has been systematically evaluating the operating experience of German NPPs. In this connection the ageing behaviour of SSCs has been considered at an early stage, too [4-6]. Since the mid-nineties, GRS is using the data base to analyse more systematically the ageing behaviour of SSCs, e. g. [7-10]. The analyses concerned all relevant groups of SSCs, i. e. passive and active engineered components, I&C components as well as structural components. This included above all the evaluation of operating experience in German and foreign plants as well as the investigation of relevant damage mechanisms and areas susceptible to ageing. Current activities concern the evaluation of ageing management with regard to the physical ageing of SSCs, technological obsolescence as well as the maintaining of knowledge.

In the following, an outline is given on how IPSN and GRS assess the effects of physical ageing on the safety of French and German NPPs on the basis of the available knowledge and how investigations are carried out. The presentation is focused exemplary on the evaluation of the ageing behaviour of motor-operated valves (MOV). The following paragraphs contain a description of the general understanding of MOV ageing, a characterisation of the French and German NPP fleet with regard to ageing-relevant aspects, a presentation of the methodical approaches developed by IPSN and GRS to evaluate the operating experience with MOV, a discussion of the corresponding preliminary results obtained as well as possible conclusions with regard to the safety significance of MOV ageing and future work.

2. GENERAL UNDERSTANDING OF MOV AGEING

MOV are extensively used in all fluid systems of power plants. In NPPs, MOV perform an essential function in safety systems, e.g. emergency core cooling and residual heat removal systems of NPPs under accident conditions. They have to response to opening or closing operations with a high degree of reliability so as to initiate core cooling or to isolate the primary circuit and containment. Gate, butterfly, and globe valves are used to fulfil these functions.

Kommentar [sde1]:

When discussing operating experience with a specific component like valves, it is important to define the component boundary for the investigation. The following equipment is considered as part of MOV :

- valve body and its internals,
- actuator and transmission gear / linkage,
- limit and torque switch devices,
- power supply directly associated with the valve,
- actuation and control logic devices directly associated with the valve.

The ageing behaviour of a MOV is dependent, among other things, on its design, its service conditions and the maintenance including in-service inspections performed. Examples of service conditions, so-called stressors, which have been identified and investigated to date include according to [11] environmental and loading conditions such as number and frequency of operations (cyclic loading), temperatures (internal and external, cycling), pressure (internal, cycling), radiation, flow rates, phase change, system chemistry (corrosion), internal mechanical loading (due to friction and/or fluid-dynamic loading), electrical loading (on motors, wiring), external loading from connected piping, solid matter in the fluid (erosion), normal valve positions (torque spring set), lubrication break-down and vibration.

Via a variety of ageing mechanisms, these stressors can produce degradation that can finally result in MOV failure. Typical examples from the international operating experience are :

- wear and / or corrosion of different parts such as gates, guides, valve stems, bearings,
- erosion of valve bodies,
- deterioration of bonnet seals,
- hardening of lubricants and greases,
- insulation break down.

3. EVALUATION OF FRENCH AND GERMAN OPERATING EXPERIENCE

In the following, the French and German operating experience concerning MOV ageing is described and discussed in detail. When discussing the methodological approaches developed and the results obtained one should also keep in mind the different situations in France and in Germany with regard to the plant fleet, i. e. the different number of NPPs in operation and the corresponding generations, as described below.

3.1 French experience

Pressurised water reactors - Westinghouse licensed PWRs - operated in France are quite standardised on the 34 plants of CP0 and CPY series - 900 MWe (14 to 24 years old), and the 20 plants of the series P4 and P'4 - 1300 MWe (8 to 17 years old); most of those French nuclear power plants were commissioned in the 80's-90's ten years period (average age: 15 years). The French design N4 - 1450 MWe plants have been commissioned in the latest 90's.

The similarity of the design and the homogeneity of the ages favour operating experience feedback in a first approach, beyond maintenance considerations, for a study on ageing trends of active components such as MOV of 900 MWe units. Engineering design, construction and installation choices have been taken into account in order to prevent the equipment from ageing. This applies, indeed, to valves and their own requirements, their specific environmental and operating conditions.

3.1.1 IPSN methodology

The IPSN study identifies the ways in which ageing potentially affects the 900 MWe plants MOV of five systems selected as representative of different operating and environmental conditions in a plant.

The approach is outlined in **Fig. 2**.

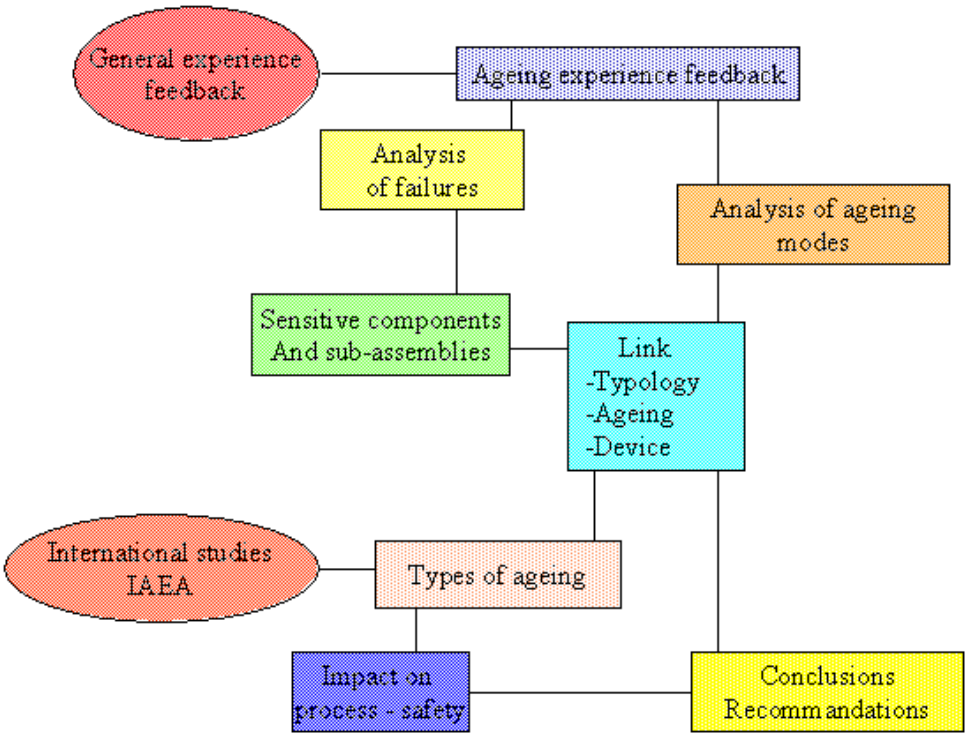

Fig. 2 Study methodology

The first step was to analyse general experience feedback on MOV to determine, system-by-system, which events could be attributed to ageing of these valves.

On the basis of this experience feedback (known as ageing experience feedback), a highly simplified analysis is made of the failure modes and of their criticality, using the databases “Events” of the utility (events : everything happening in the plant, except maintenance observations) and “Sapide” of IPSN (important incidents concerning directly safety).

From the analysis of the failures, technological components and associated sub-assemblies are identified as being likely to age.

In addition, ageing experience feedback indicates the ageing modes most frequently encountered with these types of equipment.

The indications in the “Events” database are very often succinct, so the knowledge of the potential ageing modes of the equipment may help to understand more precisely the origin of the event.

Moreover, this approach may be helpful to upgrade the systems.

The different types of ageing indicated by the IAEA on the basis of bibliographical study of publications and symposium reports give a very general view of ageing mechanisms.

The link between the results of the analysis of the French experience feedback and the types identified by the IAEA makes it possible to suggest further categories and supplement the information in the “Events” database for better understanding of the phenomena.
The criticality of the event may be associated to the damage or failure mode.

3.1.1.1Breakdown into technological units

Valves and their motors were divided into 11 components according to the cause of the event; a 12th item was added (“indeterminate”) to include events without sufficient information on component associated but with ageing mode deduced from similar events.

For sake of the efficiency of the study, the choice doesn’t focus on the elementary components which are the most sensible to ageing, but consider them as parts of the so-called “maintenance units”, similar to those used for the control and maintenance actions (adjustment, machining, part replacement etc.) carried out on equipment.

The servomotor item includes the gear-motor and the universal joints, if there are any. The clutch is included in the mechanical transmission. The electrical power supply includes the entire power system from the cell to the motor junction boxes but excludes the turn, push light switches in the control room.
The breakdown used for the study, shown in **Fig. 3**, lies somewhere between the IAEA proposal (not usable to analyse the French experience feedback, since the information available to the IPSN is not accurate enough) and a preliminary GRS analysis [12].

3.1.1.2 Damage or failure mode

The damage or failure modes are mainly identified through their consequences which are internal leaks, external leaks, sticking shut, sticking open. Spurious opening or closing never occurred in this study.
Since the study is aimed at giving overall trends on the ageing of MOV, the mechanical stiffness observed during surveillance or qualification tests in the instances of sticking shut or open, are included. Indeed, even if a device moves when challenged, sticking may be indicative of damage due to ageing of one or all the components.

3.1.1.3 Detection circumstances

It is worth knowing the detection circumstances (during operation - control and monitoring - and/or in outage modes - inspections), since it can be used to assess the dynamics of the ageing modes (operating conditions, number of opening/closing cycles etc.).

Detection may be done during surveillance tests, by alarm, during facility operation actions (field inspections, chemical measurements etc.), or related to maintenance operations (human error, inspections).

Further investigation of the links between detection circumstances and facility operation procedures would make it possible to gain a deeper knowledge of the consequences of opening/closing cycles (or the lack of them) and operating conditions on ageing phenomena, particularly fatigue and wear.

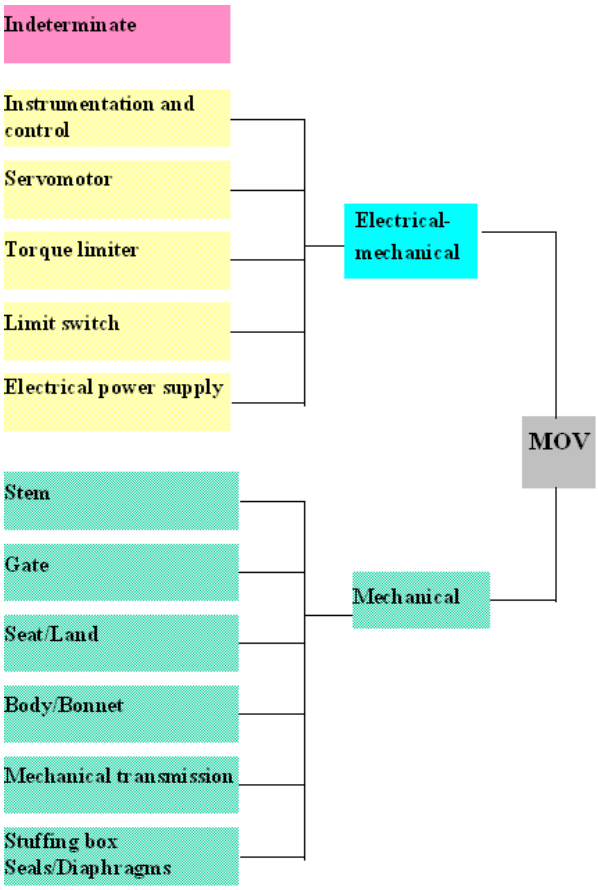

Fig. 3 MOV technological sub-assemblies

3.1.1.4 Ageing mode

The description of damage proposed by the IAEA covers all types of damage encountered in motor-operated valves. From this, a preliminary list of the ageing modes affecting the equipment being studied here can be drawn :

(W) wear, flow erosion, mechanical sticking associated with the ageing of lubricants,

(S) fatigue, fatigue-corrosion, mis-adjustments,

(C) inner surface, crevice or pitting, or stress corrosion cracking,

(EC) erosion by cavitation,

(RD) damage to elastomer seals,

(D) design.

3.1.1.5 Selection and processing of data

As indicated in the methodology adopted, MOV of five systems in the units of French 900 MWe plants have been selected: Safety Injection System, Containment Spray System, Component Cooling System, Chemical and Volumetric Control System and Residual Heat Removal System.

These five systems provides a total of 125 motor-operated valves of various types made by five different manufacturers. The analysis was carried out using the “Events” database available at IPSN, regularly updated and supplemented by EDF. The inaccuracy of some items makes detailed analysis difficult, however it seems to reveal a general trend which has to be confirmed ; this is described in the followings.

3.1.2 Results obtained

A statistical analysis of the results makes it possible to note an increase in the overall failure rate for all MOV in the systems being studied, due to ageing phenomena.

3.1.2.1 Analysis of data obtained on the motor-operated valves of the five systems

The number of failures/cases of damage is ten times lower for the Chemical and Volumetric Control System (RCV) than for the Residual Heat Removal System (RRA) (**Fig. 4**). Furthermore, in the case of the Component Cooling System (RRI) which operates continuously, the figure is half that for the Safety Injection System (RIS) and Containment Spray System (EAS). These two observations confirm that the failure/damage rate depends on operating conditions.

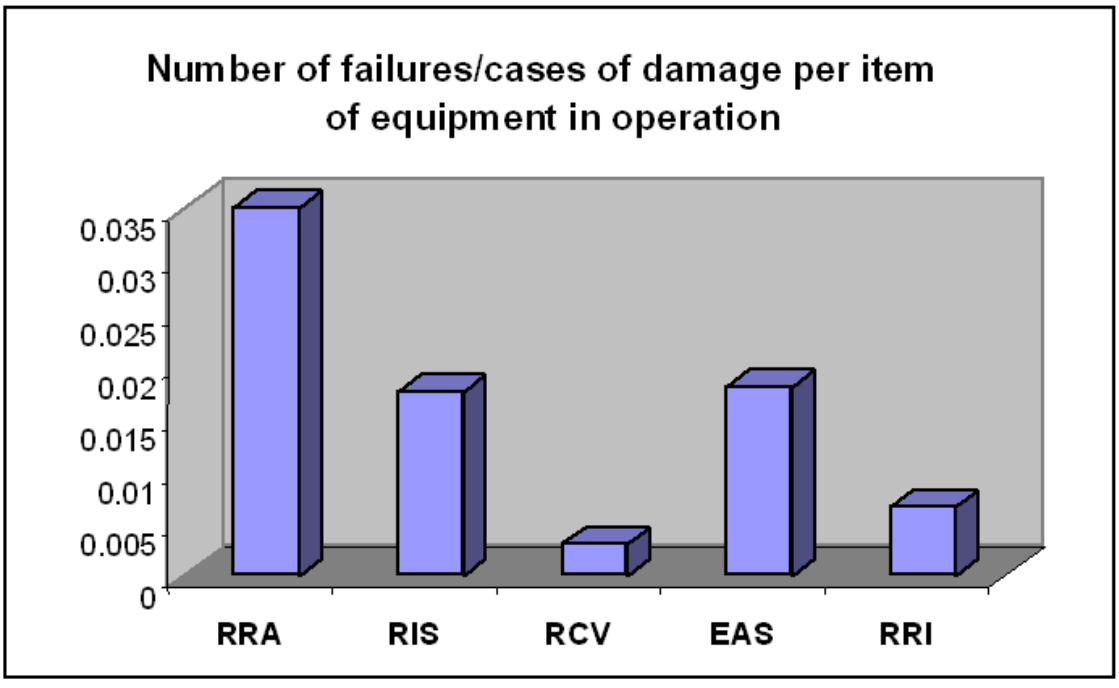

Fig. 4 Number of failures/cases of damage per item of equipment in operation

3.1.2.2 The applicability of the method : the example of the Component Cooling Water System

In the following is presented the results of the method applied to the Component Cooling Water System (French RRI). More precisely, is assessed the change over time of the number of failure/damage events occurred on MOV of this system. This example is interesting for it has also been studied in American PWR.

The age of the MOV (**Fig. 5**) was defined as follows:

- all valves have the same age as the unit in which they are installed,
- the valve “birthday” is the date of Industrial Commissioning of the unit,
- the age of the unit is rounded up or down to the nearest whole number,
- allowance is made for generic modifications or valve replacement (when information exists).

The bar chart plots the failure/damage number per year per unit versus the age of CCW system MOV.

The main features of this chart may be related to operational aspects :

Two periods during which the number of cases of valve failure or damage increases, between 1 and 9 years (first operating years) and between 10 and 14 years (after the first ten-yearly inspection and restoration of valves) ; the fact that the failure/damage number does not return to its initial value after the ten-yearly inspection could confirm that valves could not be restored to full working “as good as new” ; no matter how high the standard of maintenance.

A third period during which the number drops, from 15 years onwards, could be related to the impact of changes in the basic maintenance programmes, particularly through the implementation of preventive maintenance ; however, this interpretation must be weighted against the number of units that have currently reached this age.

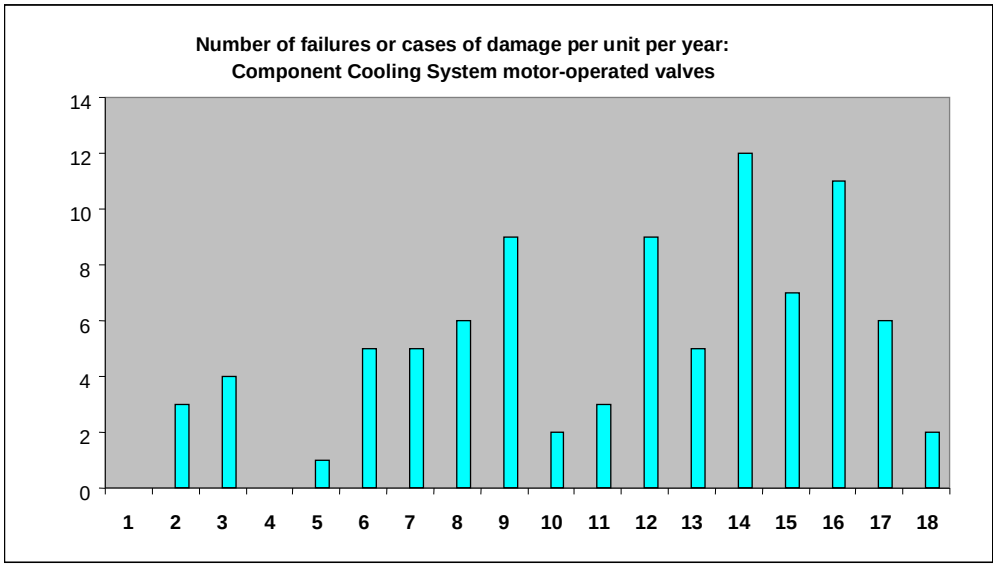

Fig. 5 Number of CCSystem MOV failures/cases of damage per unit per year versus age in operation

The comparison with the study of the ageing of Component Cooling Water System equipment, including pneumatic valves, carried out by the NRC in the USA (NUREG/CR-5693, BNL-NUREG-52283 by Brookhaven National Laboratory, report published in june 1992), and based on events listed in the Nuclear Plant Reliability Data System and the Licensee Event Report, corroborates the first results presented above for French NPPs.

The change in the number of failures recorded by NUREG shows that the valves in the Component Cooling Water System of nuclear power plants in the USA are tending to age.

Similar observations can be made by comparing ageing modes, despite slight differences : ilt should be noted that events associated with valve body corrosion were not included in the NUREG analysis (investigations about this mode : further as part of the studies on plant life extension).

The comparison of ageing of the different affected components indicates a similar sharing.

The available data concerning the basic maintenance programmes implemented by the licensees (excluding surveillance tests) are :

- in France : a visual inspection at the end of each fuel cycle, an adjustment of the valve-servomotor assembly every 3 fuel cycles and thorough servicing of the assembly every 5 fuel cycles ; a complete inspection is realised each 10 years.

- in the United States, approximatively (each licensee implements its own maintenance programme) : adjustment of the valve-servomotor assembly every 12 to 36 months, thorough servicing of the assembly every 10 years, checking of valve signatures using the MOVATS process every 18 months, replacement of servomotors every 5 years, replacement of seals and stuffing boxes every 3 years.

Their comparison would indicate that, despite the slight differences, the number of events tends to increase on both sides and that equipment ageing cannot be completely prevented, even with highly optimised maintenance programmes.

3.1.2.3 Detailed and specific results for each system

The next results show for each of the five systems which kind of ageing phenomena occur **(Fig. 6 Tab.1**) and also highlighted the MOV technological sub-assemblies that are most seriously affected by these modes and which could be subjected to close scrutiny during ten-yearly inspection (**Fig. 6 Tab. 2**).

Fig. 6 - Tab. 1 Percentages of degradation modes

Systems MOV Ageing modes	RIS	EAS	RRI	RRA	RCV
Wear	47 %	60	37	11	56
Fatigue	2	6	19	20	12
Corrosion	27	5	15	64	27
Design	-	6	4	-	-
Indeterminate	24	23	25	5	5

Fig. 6 - Tab. 2 Predominant ageing phenomena

Systems MOV Sensitive parts	RIS	EAS	RRI	RRA	RCV
Electric power supply			**wear**		fatigue
Instrumentation and control					
Limit switch	wear				
Servomotor	**wear**	**wear**	fatigue		fatigue
Torque limiter	wear		fatigue		
Stem					
Mechanical transmission			**wear**	wear	
Gate	corrosion		corrosion	**corrosion**	corrosion
Seat / Land			corrosion	**corrosion**	
Seals Diaphragm Stuffing box			**wear**		**wear**
Body Bonnet				fatigue	
Indeterminate					

Some comments on each system:

- RCV - Chemical and Volume Control System : the wear ageing mode is predominant, mainly affecting valve stuffing boxes.
- RRA – Residual Heat Removal System : the predominant ageing mode is corrosion; the valve gates are most affected.
- RRI - Component Cooling System : the wear ageing mode is predominant, mainly affecting electrical power supplies, mechanical transmission systems and seals, to an equal extent.
- EAS - Containment Spray System : wear is the predominant ageing mode for the valves; surveillance testing of the valves in the system (at least every two months) is the main cause; this mode mainly affects servomotors.
- RIS - Safety Injection System : the predominant ageing mode is wear; this result should be weighed against almost one quarter of the events attributed to ageing that are undetermined.

3.2 German experience

13 NPPs with pressurised water reactors (PWR) and 6 plants with boiling water reactors (BWR) are currently in operation in Germany. For the plants with PWRs the operating times rank from 13 to 33 years, for the plants with BWRs from 17 to 25 years. Because of the turn-key approach chosen by the utilities for the design and construction, there is a considerable consistency in the overall engineering concepts applied even though continuous evolution took place in the design of the different generations of reactors. This resulted in numerous differences in technical solutions and details. Corresponding to their design features, the

PWRs in operation may be grouped in 4 design generations and the BWRs in two construction lines.

A German 1300 MW plant with PWR, for example, contains approximately 17 000 valves. More than 30 manufacturers are involved in their supply. By far the largest proportion of valves (about 96 %) perform purely isolating functions while only 4 % are used for control tasks. About 700 valves perform a safety- related function [11].

3.2.1 GRS methodology

The general approach to evaluate the operating experience with regard to the ageing behaviour of active components in German NPPs is illustrated in **Fig. 7**. It is mainly based on the evaluation of the safety-related events reported to the authorities. In addition, further information available at GRS such as results from maintenance and root cause analyses have been evaluated, too. Moreover, plant-specific maintenance documents are evaluated discontinuously for defined time periods.

In Germany, safety-related events have to be reported to the state authorities. On behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), these events are centrally collected and generically evaluated by GRS. From the start of the first commercial NPP in Germany up to the end of 1999, about 4800 safety-related events were reported to the authorities. Due to the threshold of the reporting criteria, the events reported to the authorities focus on relevant findings. Minor problems, e. g. identified by scheduled maintenance well before the failure of a valve, are usually not contained in that data file.

When discussing the results obtained, one should keep in mind that the data file may not be homogeneous over time. Due to the technical development of the plants and the insights gained from both the events and the application of the reporting criteria, the reporting criteria have been modified three times in the past. Thus, there are some alterations in the points of interests when reporting events.

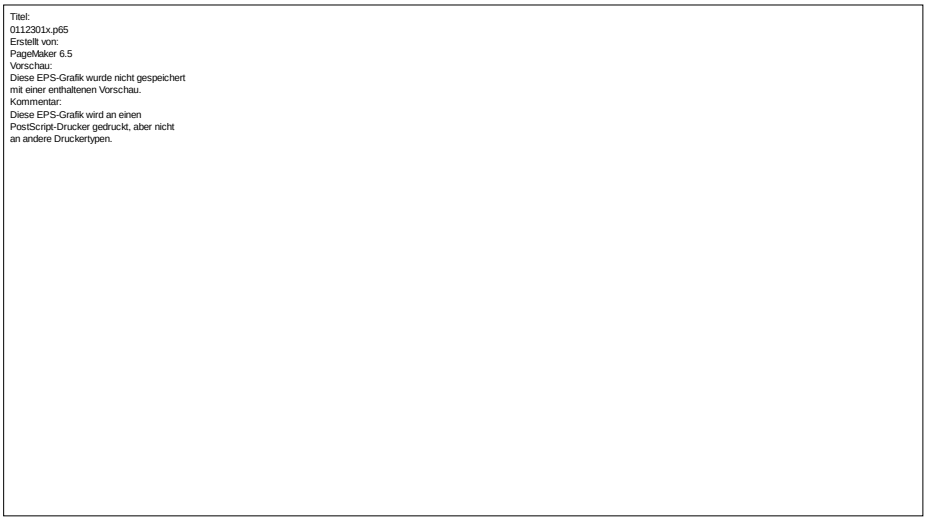

Fig. 7 Survey of the method of evaluating operating experience in connection with the ageing behaviour of active components in German NPPs

About 20 % of the events reported to the authorities are related to valve problems [12]. In a second step, the ageing relevance of each reportable event was judged from an engineering point of view. In this context, damage due to ageing has principally been understood as damage that has occurred in the design, manufacture, commissioning and operation of the components according to the requirements specified and which is caused by collective loads that were not foreseen at the time when the components were planned.

It has to be pointed out that the licensees are making efforts to provide immediate and sustained solutions to any damage that may occur. If the damage is identified as a single failure, repairs or replacement will follow in most cases without an in-depth analysis of the cause. This is why it is not always easy to decide on the basis of the information available whether the event has been caused by ageing or perhaps e. g. by design deficiencies, manufacturing faults or wrong installation.

In order to achieve a fast survey of the existing data under different aspects as well as the best-possible data management, a specific databases was created in a third step. Here, the relevant criteria for queries are :

- plant generation, plant, system, sub-unit affected,
- date of the event, operating time,
- detection mode,
- ageing mode (mechanism),
- measures taken.

On this basis, component-specific evaluations have been performed, in particular with the objective to :

- evaluate the influence of operating time on ageing behaviour,
- identify relevant ageing mechanisms and areas susceptible to ageing,
- evaluate the efficiency of measures taken to identify, monitor and control or avoid ageing degradation.

3.2.2 Results obtained

Within a time span of 25 years, about 300 ageing-related events have been reported from active components in German NPPs. About half of them are related to valves, and yet again half of these to MOV. Approximately 75 % of the ageing-related events concerning MOV occurred at isolating valves and about one quarter was reported from control valves. Other ageing-related events concerned pumps, compressors and emergency diesel engines (**Fig. 8**).

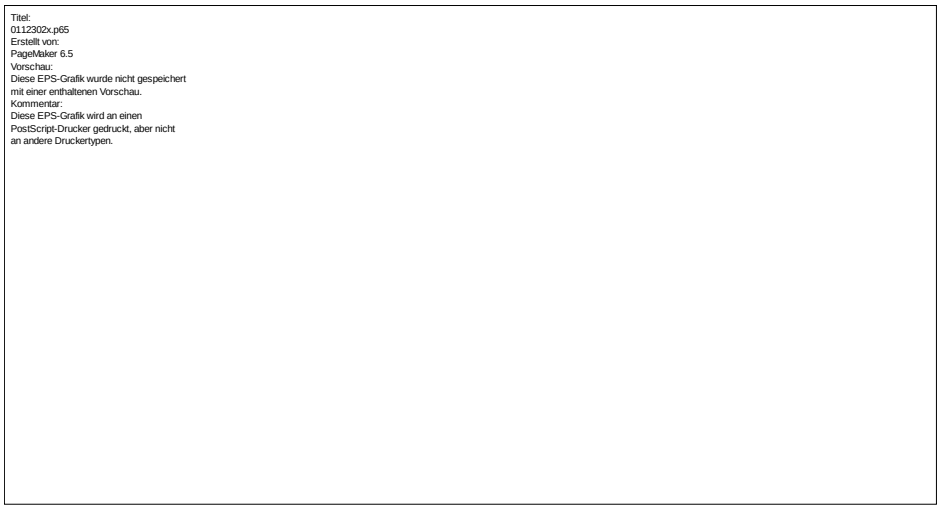

Fig. 8 Ageing-related events concerning active components in German NPPs (1974 - 1999) - shares of the different components affected

The overall number of ageing-related events affecting MOV in German NPPs is small. In **Fig. 9**, the number of events per plant operating years is broken down to the different plant generations concerned. No significant differences between the four PWR plant generations are recognisable. The plants of the BWR construction line 69 come off comparatively worse. On the other hand, the number of events per plant operating years for the plants of the BWR construction line 72 is significantly lower.

Fig. 9 Ageing-related events concerning MOV in German NPPs (as at December 1999) – allocation to plant generations affected

In **Fig 10**, the events due to ageing MOV in German NPPs are allocated to the calendar year of the event. It can be derived from this figure that despite an increase in the number of plants in operation, the number of incidents per year in German NPPs has almost remained constant, with the exception of the year 1990, in which 11 events were reported.

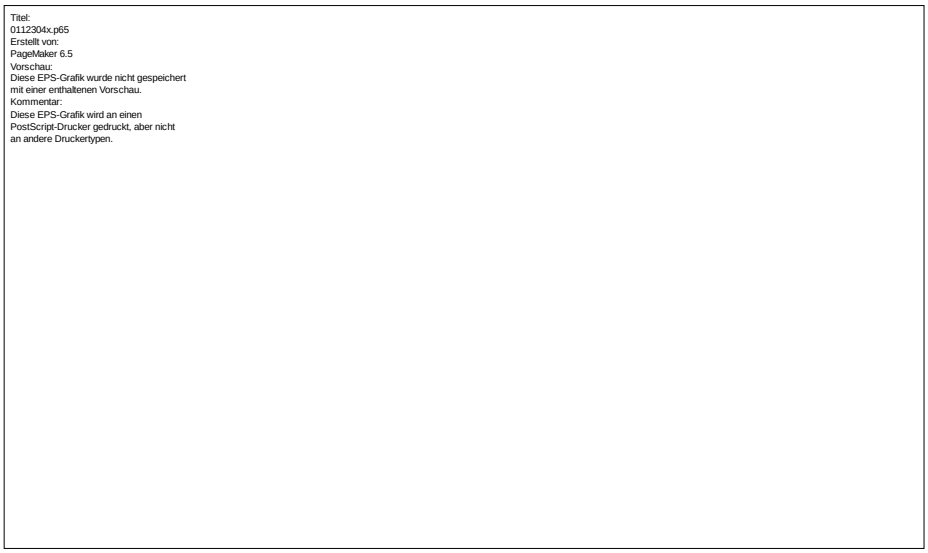

Fig. 10 Ageing-related events concerning MOV in German NPPs as at December 1999 - allocation to calendar year

In **Fig. 11**, the events due to ageing concerning MOV in German NPPs are allocated to the operating time of the plants at the date when the event occurred. Here, the year of the first criticality / grid synchronisation of the plants was defined as the starting point. A lot of the events occurred during the first years of operation. So far, no increase of the number of events with increasing operating times is recognisable.

Fig. 11 Ageing-related events concerning MOV in German NPPs (as at December 1999) - allocation to operating time of the plant at detection

A lot of different systems were affected, such as the chemical and volume control system, the residual heat removal system, and the feed water system. So far, no accumulation at any system is perceptible. Concerning the component sub-units affected, there is also no clear picture. However, most events concerned stems (approx. 16 %), valve seats and seals (approx. 15 % each) as well as bearings and controllers (approx. 8 % each).

About 3/4 of the events were detected within the framework of scheduled tests and in-service inspections (**Fig. 12**). About ¼ of the events were identified due to failure in case of actuation.

Fig. 12 Ageing-related events concerning MOV in German NPPs (as at December 1999) - shares of the different detection and ageing modes

Concerning the ageing mode it can be derived from the evaluation that the lion's share of about 41 % was caused due to changes of the material properties, in particular due to fatigue. About 28 % were caused by wear, followed by erosion due to cavitation (11 %), formation of deposits (10 %), corrosion (7 %) and others (3 %) (**Fig. 12**).

The shares of the different actions taken in German NPPs are illustrated in **Fig 13**. In many cases, more than one measure was taken, i. e. the total of the different shares is greater than 100 %. In most cases (approx. 56 %) the component sub-units affected have been repaired or replaced one by one. In approx. 38 % of the cases, component sub-units with improved design have been used. Moreover, other technical solutions have been developed and applied (approx. 15 %) and the requirements for in-service inspections have been enforced, e. g. with regard to the scope of the inspections and the inspection interval.

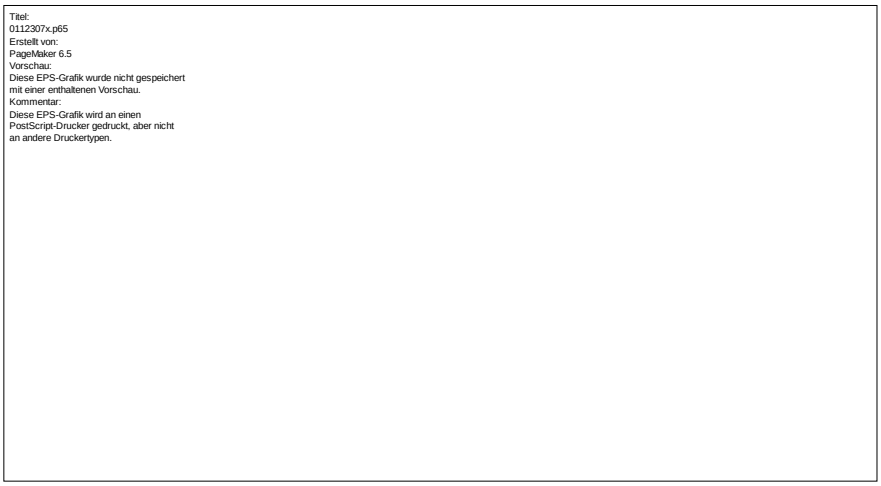

Fig. 13 Ageing-related events concerning MOV in German NPPs (as at December 1999) - shares of the different measures taken

4. CONCLUSIONS

At IPSN as well as at GRS, investigations have been performed to evaluate the influence of ageing on the safe operation of NPPs. For this reason, different methodical approaches have been developed.

The preliminary analysis of IPSN applied to events on the 125 MOV of five different safety systems during the average 15 operation years of 34 plants with 900 MWe PWR, based on a mixed methodology considering available events and incidents databases and technological ageing approach. The main operating experience feedback seems to reveal a trend to ageing with operating time for the MOV of each of the five systems, with different ageing modes, according to design type and in-service environmental and operating conditions. This trend would be consistent with US observations. The MOV damage or failure modes observed may impact system integrity, operability or functional capacity, thus cooling and containment safety functions. The prevention of MOV damage and failure modes is directly linked to surveillance and maintenance. A more accurate analysis of the combined MOV ageing mode

and technological sub-assembly or maintenance unit concerned could be a good investigation area to progress in ageing knowledge and adequate design (spare-parts included) and maintenance for still better safety level.

The analysis carried out by GRS is mainly based on the generic evaluation of events reported from all German NPPs. As to be seen from the results so far, (a) the total number of ageing-related events concerning MOV is low, (b) they were detected in time so that their safety significance was limited, (c) there appears to be no significant increase of ageing-related events as the plants get older, and (d) suitable measures to detect and control ageing-related changes were taken where necessary. For the component sub-units that were found to be susceptible to ageing, replacement measures were performed, and/or the causes were eliminated by using improved sub-units or other technical solutions, and/or in-service inspections were enforced. On the whole, the results demonstrate that the maintenance concept applied for MOV in German NPPs works satisfactory. However, possible changes in the maintenance practices may lead to a different picture. Moreover, operating experience has shown that new insights concerning the assessment of the ageing behaviour of SSCs may come to light in the course of time. It is therefore seen as a necessity that the investigations performed are continued in order to obtain indications of any safety-significant ageing-related changes at an early stage.

The approaches to evaluate the operating experience with regard to the ageing behaviour of MOV in French and German NPPs by IPSN and GRS seem to be comparable, but it looks necessary to deepen this comparison and so to validate the methodology.

The results obtained demonstrate that the developed methodological approaches are suitable to obtain qualitative evidence with regard to the ageing behaviour of technical facilities such as MOV. The evaluation of the operating experience with French 900 MWe plants seems to reveal a quite similar trend to existing international analysis of ageing-related events concerning the Component Cooling System MOV with increasing operating time. For the German NPPs so far, there appears to be no significant increase of the number of ageing-related events concerning MOV as the plants get older.

Reasons for the differences revealed may be due either to differences in the approach methodologies applied in the preliminary studies or in the design and in preventive maintenance practices (for instance sub-assemblies and frequencies considered) for the corresponding NPP fleets.

Consequently, future work on ageing scheduled at IPSN and GRS includes further co-operation on this issue, too. This co-operation will cover, in particular, an in-depth discussion and validation of the methods applied to evaluate the operating experience with regard to the ageing behaviour of MOV as well as of relevant boundary conditions, such as design, operating conditions and maintenance practices ; this implementation must be associated to a more accurate safety significant - risk analysis and also include international operating experience.

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