DOSE REDUCTION BY NEW SIPPING PROCESS IN GERMAN BWRS

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Abstract

The integrity of fuel bundles has an important influence on the contamination level of filtering materials, primary system surfaces emissions and waste of nuclear power plants. The integrity of fuel rods also has an influence on workers dose: On the one hand because of the higher activity level in the primary system, on the other hand because of additional working time on the refueling floor for the integrity testing program.

To make sure, that a new cycle is started without a leaking fuel bundle, it is necessary to use the most precise fuel leak detection (sipping) combined with a minimum of needed time in the radiation field during outages. Two cases that cause a need of testing fuel integrity have to be distinguished: Firstly short shutdowns only to exclude defect fuel elements out of the core and secondly regularly outages, where extra fuel handling operations in radiation fields are necessary to perform the testing.

In German Boiling Water reactors working time in radiation fields and collective doses have been optimised for leak detection recently. Experiences with different sipping equipments and the doses of different campaigns are shown in this paper and compared for 2 different boiling water reactors.

Sipping methods

The detection of leaking fuel elements is called sipping. The leak detection uses the characteristic release of small amounts of volatile fission products through the leak.
The following sipping methods are commonly used in light water reactors:

<u>Box-Sipping</u>: A fuel element is placed in a sipping box which is located in the spent fuel pond and is cooled by clean deionized water. Volatile fission products, released through a leak can be detected by water samples, taken out of the sipping box and analyzed in the laboratory. [1]

<u>Elevator-Sipping</u>: Lifting a fuel element means that the hydrostatic pressure of the surrounding water of the fuel element is reduced. In the case of a leak fuel rod the release of gaseous fission products leads to a new state of equilibrium between inside pressure (fission gas) and outside pressure (hydrostatic pressure). The gaseous fission products mainly consist of radioactive Xenon isotopes and Krypton isotopes which can be detected by either water samples or by online gas measurements. This method is the most sensitive technique for leak detection and can be performed very flexible incore, during offload of fuel elements and in the fuel pond. Fuel elements have to be grapped and moved.

<u>Hood sipping</u> (only feasible with fuel elements in fuel channels): By placing a hood on one or more fuel element heads and stopping the water circulation through the fuel channels by pressing gas into

the hood. The fuel elements under the hood start to warm up. The increasing temperature leads to a higher pressure of the fission gases inside the fuel elements. In the case of a leak fuel rod the fission gases and other volatile fission products are released and can be detected by water samples or online gas measurements. An advantage of this method is, that no fuel element has to be grapped or moved. For short shut downs for localisation and take off of defect elements this method is the best choice.

The hood sipping device for 16 fuel elements, referred to as hood sipping (new) in this paper was developed for 3 German BWRs by Höfer & Bechtel.

Aspects of radiation protection in connection to sipping

According to the basic rules of radiation protection one aspect is to keep the time needed for operation, here sipping, as short as possible. The over all sipping working time is significantly shortened by the online gas measurement instead of laboratory measurement of water samples. In the case of hood sipping the possibility to get 16 fuel elements sipped in one step is reducing the sipping duration.

According to the next basic rule of radiation protection to maximize the distance from radioactive sources, there is an advantage of the hood sipping versus elevator sipping. The equipment and thus the operating stuff for elevator sipping is placed on the refueling machine where the dose rate is higher than at the refueling floor where the equipment and operating stuff of the hood sipping device works.

Regarding the radioactive source, relevant for the exposure of the sipping stuff, the sipping devices themselves can be the main contributor for exposure. As described above, water out of the reactor or spent fuel pool is continuously sucked through the sipping device. This water contains radioactive substances like activated corrosion products and fission products, not only in the case of a leak fuel rod. These radioactive substances may accumulate in the sipping device and thus lead to radiation exposure of the operating stuff.

For both, hood sipping (new) and so called adapter sipping (telescope- or elevator sipping for VVER), attention to radiation protection aspects was directed from the beginning of the design process. This was also a result of the operating experience of the BWR operators.

The sipping devices are manufactured in a way that the accumulation of radioactive particles is mostly avoided. Surfaces that are contacted by radioactive media are polished. Hoses, tubes and wear parts are chosen of a kind that they can be replaced easily and cost effectively.

Several connections for flushing the systems water- and gas-path are provided. Lead shielding of the separators, which are the components with the highest contamination potential is installed and can be enforced during sipping, if necessary.

Sipping experiences in KKI 1 and KKK

To compare collective doses of sipping campaigns of different power plants it is useful to describe geometric factors of the cores first. The cores of the German boiling water reactors are different in geometry and in the number of fuel elements.

<u>KKI</u>
The core of Isar 1 power plant (KKI 1) consists of 592 fuel elements and 145 control rods.
With the sipping hood for 16 fuel elements 46 steps are necessary. The core geometry has 12 positions which can not be reached by the sipping hood for 16 fuel elements. To get these fuel elements sipped a special sipping hood for single fuel elements was designed and can be connected to the sipping device. Average sipping time per step is 25 minutes.

KKK

The core of Kruemmel power plant (KKK) consists of 840 fuel elements and 205 control rods.Using a sipping hood for 16 fuel elements at least 61 steps are necessary to perform a full incore sipping. Each step takes in average about 25 minutes.

The knowledge of the background level of activity is necessary to make the sipping process as sensitive as possible to detect defect fuel elements, by choosing the appropriate detectors and their shielding. The measuring time of water samples is also influenced by the background activity level. The concentration of corrosion products, on the other hand, influences the sipping doses.

The following table shows the specific background activity of reactor water for the two NPPs:

	specific activity [Bq/m³]		
Nuclide	KKK (96 - 03)	KKI 1 (05)	KKI 1 (04)
I-131	2,50E+07	5,4E+07	2,40E+06
I-132	5,40E+08	2,2E+07	1,50E+07
Cs-134	1,10E+07	< 3,4E+05	8,30E+05
Cs-137	7,00E+06	< 3,7E+05	1,00E+06
Np-239	1,20E+08	2,3E+06	1,70E+06
Cr-51	1,40E+08	< 3,4E+06	< 7,8E+05
Mn-54	5,00E+06	6,0E+06	1,50E+07
Co-58	7,20E+06	1,40E+07	1,70E+07
Co-60	1,60E+07	5,90E+06	1,00E+07
Fe-59	5,30E+06	< 6,6E+05	< 1,9E+05
Zn-65	3,60E+07	2,30E+06	5,20E+06
Sr-91	2,20E+08		

Tab. 1 specific activity of reactor water
KKK: 95-percentile value during cycle between nov. 1996 and nov. 2003
KKI 1: representative value for the sipping campaigns

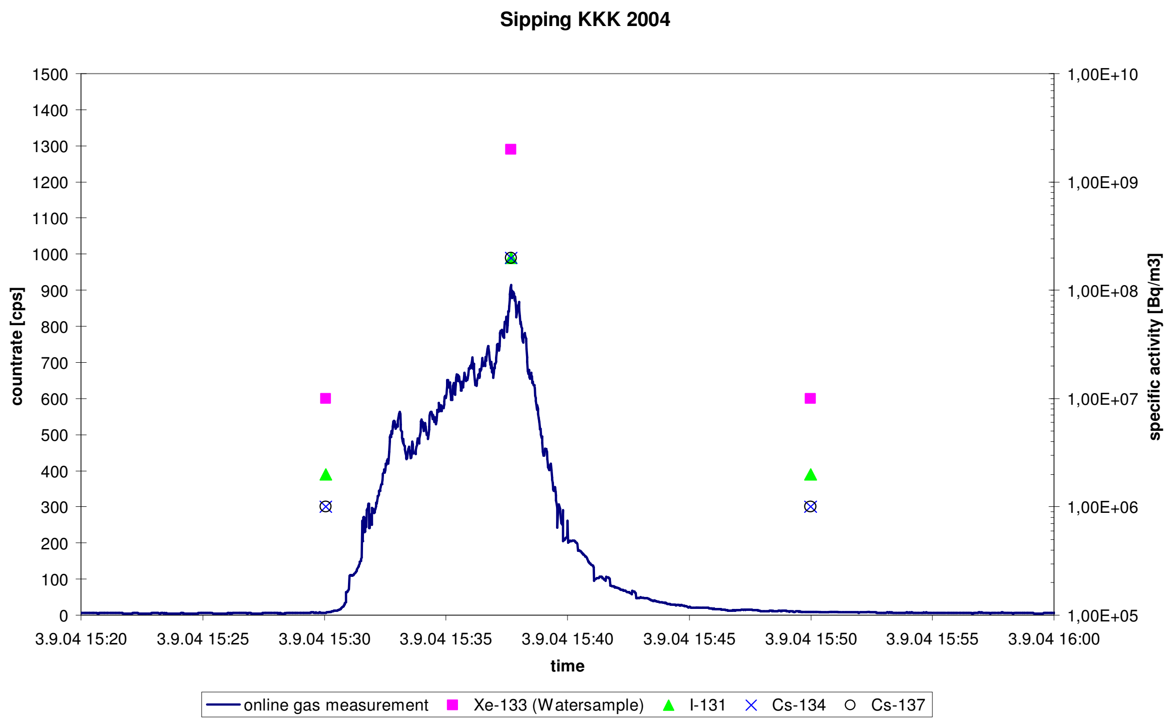

Fig. 1 Online gas measurement compared to specific activity in corresponding water samples, sipping hood for 16 fuel elements

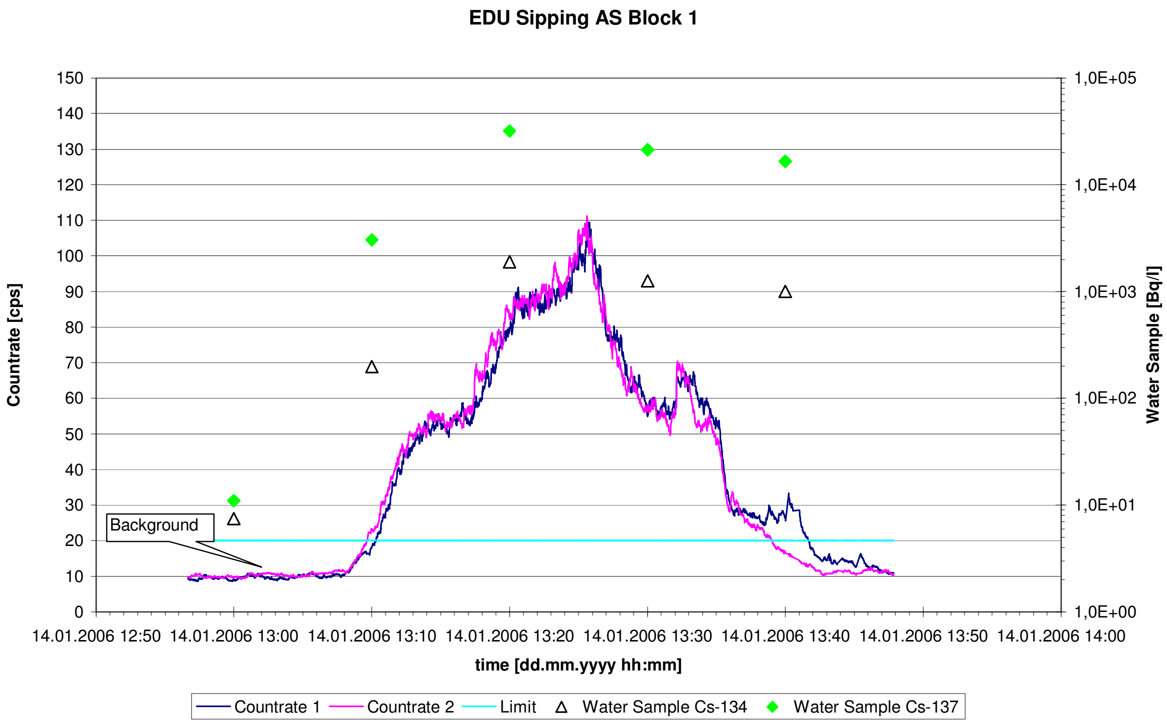

Fig. 2 Online gas measurement compared to specific activity in corresponding water sample, elevator sipping, 6 years old fuel element of VVER 440, Dukovany, CZ

The above figures 1 and 2 show, that the water samples can be replaced by the online gas measurement which saves time and thus dose.

The following tables show characteristic data of the sipping experiences of the two NPPs:

NPP	year of sipping	duration of sipping [h]	sipping method	collective dose [mSv]	remark
KKK	1995		elevator	6,42	first use
KKK	1996	36	hood (old)	3,50	hood from 1983
KKK	2000	40	elevator	3,51	40 h incore 584 elements, 24 h off load 99 elements,
KKK	2002	48	hood (old)	5,10	short shutdown
KKK	2004	56	hood (new)	4,12	first use
KKK	2005	211	elevator	[1]	complete off load
KKI 1	2000	42	elevator		
KKI 1	2001	159	elevator	4,505	complete off load
KKI 1	2003	31	hood (old)	2,294	
KKI 1	2004	28	hood (new)	2,187	
KKI 1	2005	41	hood (new)	1,792	real sipping hood 16 – time: 26:03:02

Tab. 2 doses for different sipping campaigns

[1] Sipping dose inseparable from over all offload dose

	doserate [µSv/h]	
place	**elevator sipping**	**hood sipping (new)**
working area of sipping stuff (begin of sipping)	20	3
working area of sipping stuff (end of sipping)	40	5
sipping device	300	5

Tab. 3 dose rates for different sipping methods (KKK, elevator 1998, hood (new) 2004)

Further possibilities for radiation protection by sipping devices

Having a leaking fuel rod, the sipping and even more the unloading of the defect fuel element does lead to a higher release of fission products into the reactor resp. spent fuel pool water. The release of fission products during the unloading of defect fuel is due to the same effect that is used by the elevator sipping. In the case of a defect with high fission gas release rate the gas may evaporate from the water into the air of the refueling floor and thus may lead to limitation of residence on the refueling floor.

Figure 3 shows the stack measurement for radioactive noble gases handling a defect fuel element without using the sipping device, which means the activity went over the air of the refueling floor.

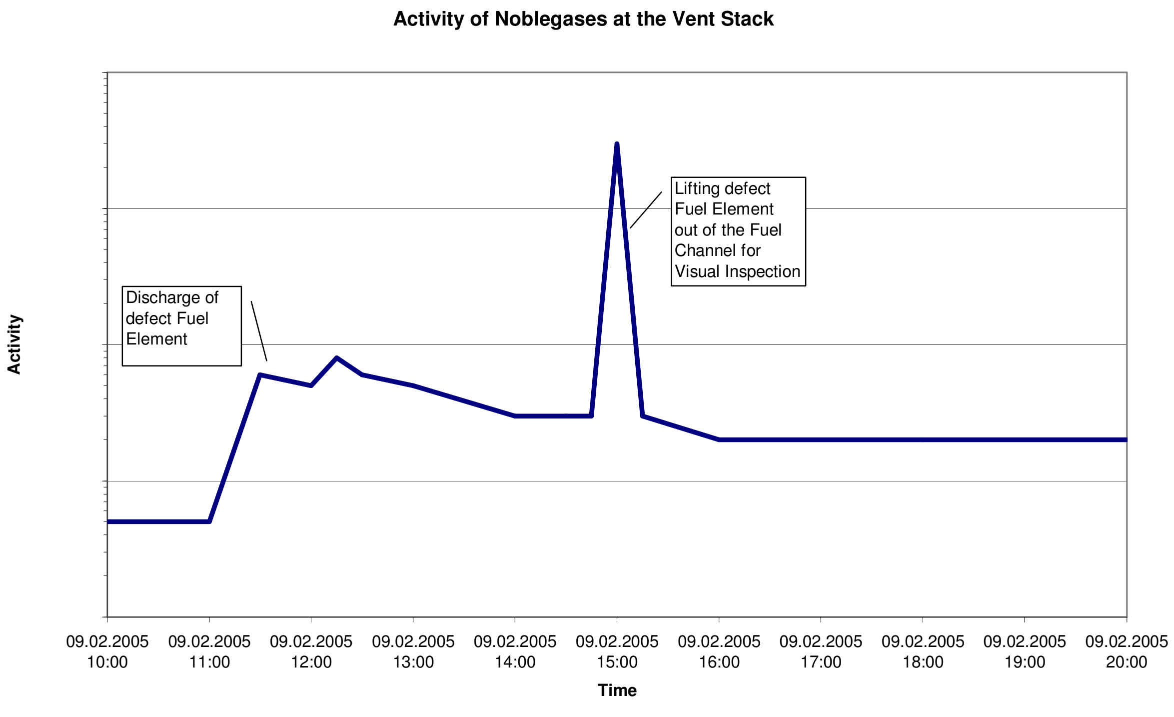

Fig. 3 Activity of noble gas release at the vent stack during handling of a defect fuel element in KKI 1

The BWR KKI 1 has decided to add a new fuel element gripper which is suitable for elevator sipping with the sipping device of the sipping hood for 16 fuel elements in 2005. This special gripper was equipped with an additional small hood above the catch of the gripper to suck off the released fission products, especially the fission gases. During the unloading of a defect fuel element water is sucked through the modified gripper and the small hood above the gripper and goes through the sipping device. Here it is deaerated and the gas is continuously monitored for radioactivity. When the gas release falls below a defined limit the defect fuel element can be transferred to the spent fuel pond

After passing the detectors the gas is passed through the exhaust gas system of the plant, so first there is no uncontrolled release into the air of the refueling floor. The second effect will be, because of the delayed release through the exhaust gas system the Xe-133 is almost decayed, the emission to the environment will be close to zero.

This system was tested in February 2006 with a defect fuel element in the spent fuel pool of KKI 1.

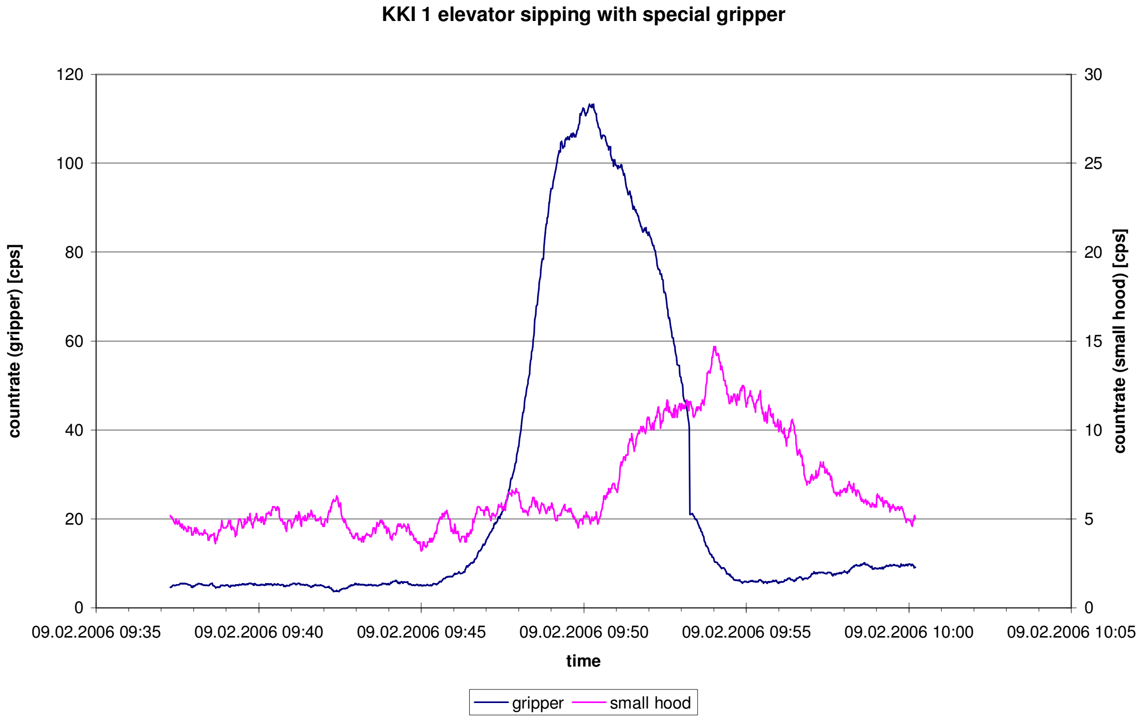

Fig. 4 Test of modified gripper with hood for use with hood sipping for 16 fuel elements (new) with old defect fuel element in the spent fuel pool

Conclusions

The increased sensitivity of new optimized sipping equipment guarantees that the next cycle is started with intact fuel elements. The use of latest sipping equipment can help to reduce doses in different ways. The most effective way is by shortening the outage time. As rule of thumb, KKI 1 calculates 30 mSv collective dose per day that can be saved. Saving time on the critical path also helps to run the NPP cost efficient. On the other hand the doses for sipping can be reduced by accounting for radiation protection aspects in the design of the sipping device and by using the sipping device to minimize uncontrolled fission product release.

References

[1] E. Schrüfer: Strahlung und Strahlungsmeßtechnik in Kernkraftwerken; Elitera Verlag, Berlin, 1974

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