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TASK RELATED DOSES IN SPANISH PRESSURIZED WATER REACTORS OVER THE PERIOD 1988-1992

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ABSTRACT

In order to evaluate in depth the collective dose trend and its correlation with the effectiveness of the practical application of the ALARA principle in Spanish nuclear facilities, and base the different policy lines to promote this criteria, the CSN has fulfilled an analysis of the task related doses data over the period 1988-1992. Previously, the CSN had required to the utilities the compilation of their refuelling outage collective dose from 1988 according with a predeterminate number of tasks, in order to have available a representative and retrospective set of data in an homogeneous way and coherent with the international data banks on occupational exposure in NPP, as the CEC and the NEA ones. The scope of this analysis was the following: first, the collective dose summaries for outage tasks and departments for PWR and for BWR, including the minimum, maximum and average dose (and statistics data) for 18 different refuelling outage tasks and 12 personal departments for each generation of each type of rector, the task and department related collective dose trends in each plant and in each generation, and second, the dose reduction techniques having been used during that period in each plant and the relative level of adoption. In this presentation the main results and conclusions of the first part of the study are reviewed for PWR.

INTRODUCTION

The trend in average occupational collective dose per reactor in Spanish Pressurized Water Reactors (PWR) seems to be stabilising and lightly decreasing during the studied period of time, 1988-1992, within the same range of the average levels in the OECD countries (figure 1).

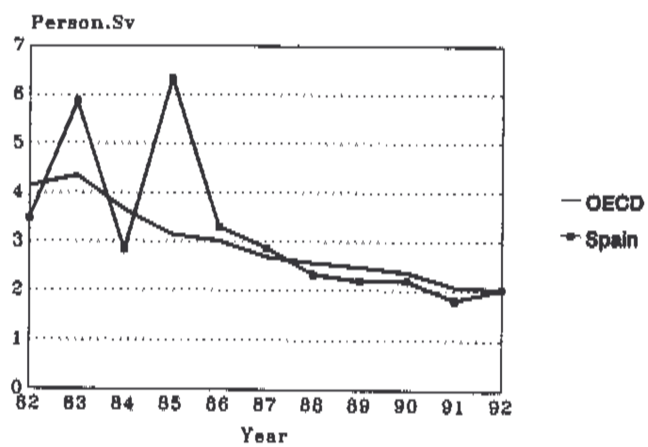

Figure 1. Average annual dose for Spanish and OECD PWR

A tendency towards stability because in 1985 the backfitting operations in J. Cabrera, the first generation reactor, finished and this led to very high peacks in 1983 and 1985. A tendency towards a moderate decrease, because on one hand the second generation reactors broke their fast rise of the early years of operation and, on the other hand, because in 1988 the starting up of the third generation reactors, Vandellós II and Trillo, took place, incorporating more ALARA design characteristics than the formers.

Observing the collective dose per unit of electricity produced evolution, the first generation reactor values remain higher than average both in Spain and in OECD countries, this last being 0.3 Person.mSv/Gwh in 1991*, while the second generation presents average values near the OECD ones and the third has always been under it.

TASK RELATED COLLECTIVE DOSE RESULTS

In order to know the radiological relative weight of each task in which the refuelling outage operations have been distributed, according with the CSN guide 1.5, the average, maximum and minimum for each task has been figured out in this study. In addition, statistics data, as standard deviation and the variation coefficient has also been calculated to have an estimation of the dispersion of the results. Establishing a selection criteria of 5% of the total dose, i.e. around 100 Person.mSv, we have focused this presentation in those tasks whose average contribution exceed this value (table 1).

Table 1. Task related dose results for all PWR generations

Task	Average Person.mSv	%	Maximum Person.mSv	Minimum Person.mSv	Standard Deviation	Variation Coefficient
Steam gen. primary side	588	28	1676	30	406	0.69
General works	274	13	755	44	188	0.68
Refuelling	210	10	497	32	121	0.58
System not listed	205	10	618	1	202	0.98
Valve work	157	8	322	21	81	0.51
Insulation	123	6	384	15	95	0.75
Reactor coolant pumps	104	5	535	2	107	1.03
Routine inspections	97	5	259	20	58	0.6

Depending on the special characteristics of each generation and reactor design, the size (only J. Cabrera is significantly smaller) and the aging effect in the source term, among other factors, the order of this list of relevant tasks is different in each generation (figure 2).

On the other hand, the dispersion of the values for each task within each generation reflects the variety of the scope of the different works included in each one, from one outage to another and from one reactor to another, depending on the inspection requirements, the incidents registered during the operation cycle, the ambient dose rates in working areas, systems and components involved and job procedures. In any case, the variation coefficient for a task can be a rough indication of its relative dose reduction potential (ref. 2).

*This data and the OECD values of figure 1 are taken from reference 1

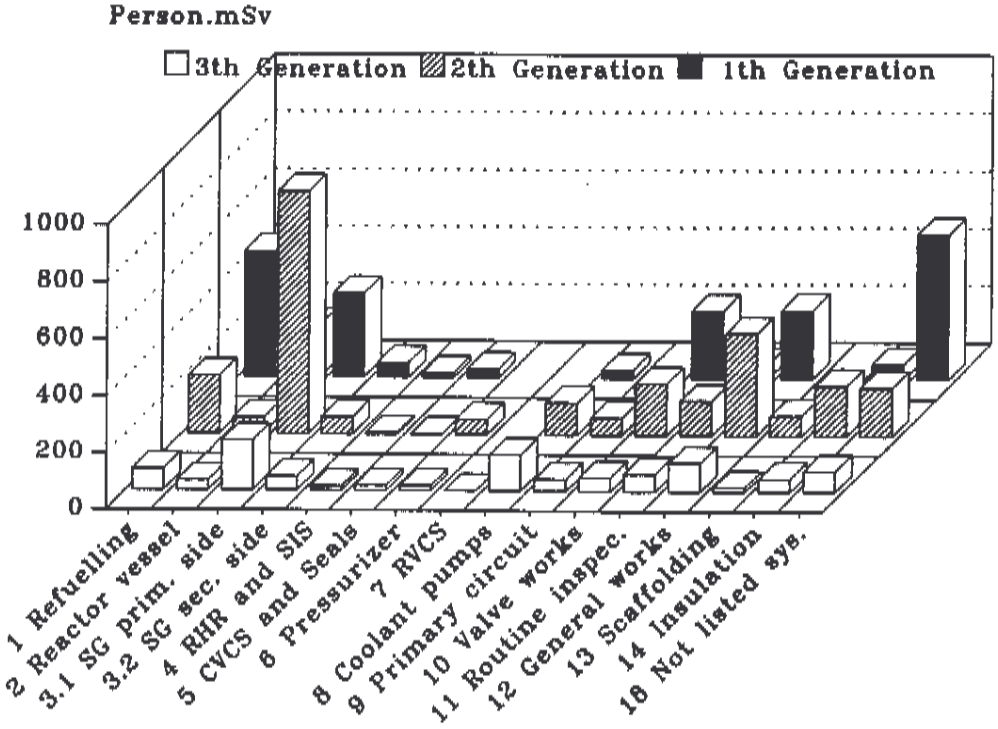

Figure 2. Average collective dose for each task and ech generation

Another factor to take into account is the added difficulties to reassign the collective dose to a new task code from a previous an inhomogeneous one. In addition, some plants do not have computer capability to provide automated the radiation work permit information, at least for part of the studied period, to elaborate the reassignment. We will proceed to comment in some detail each one of the selected tasks.

Steam Generator Primary Side

Steam generator (SG) primary side has been, and still is, the highest contributor to the refuelling outage collective dose in Spanish PWR, both for global and for the last two generation average1. The global average trend of this task presents a progressive slight decrease, except in 1990 in which an important rise took place, owing to the influence of the first and second generation. The second generation reactors represent far and away the major amount to the average collective dose of this task, while the first and third generation results fall rather lower than average. These very different values among generations lead to high standard deviation and variation coefficient.

The singular design of the first generation reactor, Westinghouse with a single coolant system loop and a SG Model 24 with tubes of Inconel 600 MA, the design and material of the second generation SG, Westinghouse Model D3 with tubes of Inconel-600 MA, and the improvements introduced in the third generation, one of which is KWU/Siemens with tubes of Incoloy 800 and the other an advanced Westinghouse Model F, are relevant aspects that explain greatly the mentioned difference and fluctuations of this task.

Table 2. Steam generator primary side results. Comparison among generations

	Average Person.mSv	%	Maximum Person.mSv	Minimum Person.mSv	Standard Deviation	Variation Coefficient
All generations	588	28	1676	30	406	0.69
First generation	295	14	621	100	180	0.60
Second generation	852	34	1676	441	318	0.37
Third generation	177	19	297	30	104	0.59

As we have mentioned above, the contribution of the first generation is significantly lower in this task than that of the second, for similar radiation levels in the SG channel head, maintaining the same relation between respective average collective dose values as the number of loops relation, 1:3. The average collective dose for the first generation would have been even lower if it had not registered an extremely high value in 1991, 621 Person.mSv, due principally to exceptional works (22 PIPs and drill of 8 explosives pluggs). José Cabrera has experienced relatively few problems in the SG tubes, principally thinning at the top of the tubesheet and stress corrosion cracking (SCC), with only 5% of the tubes plugged in 23 years, which have led to a lower scope of this task than in the next generation and consequently lower doses.

The second generation SGs have had substantial problems in their tubes, axially cracks located at support plates and the roll expansion and transition zones, and also some circumferential cracks, that have caused a large scope of inspections, plugging and sleeving works. So much so that utilities have decided to replace the steam generator of both plants in the near future (95-97). These problems joined to the corrective measures taken, as the shotpeening of tubes, has caused a good deal higher collective dose than the average. Nevertheless, the evolution of the collective dose in the second generation shows an inflection point in 1990. Awaiting deeper analysis, we can say in advance that two of the factors which have had a notable influence to break the trend and maintain the collective dose in moderate levels are: the change in the primary chemistry (pH from 6.9 to 7.4) and the systematic use of robots for plugging the tubes (SM-10 y ROSA-III).

The relative relevance of this task in the third generation is nearly exclusively due to Vandellós II. In effect, the SGs of Trillo have not experienced up to now any problem of cracking in their tubes, only one remains plugged due to a loose part. The collective dose registered in Vandellós II is in any case lower than that of the former generation, due principally to the new Westinghouse model of SG mentioned, which has presented only a extensive problem of fretting in the contact zone with the anti-vibration bars (AVB) and with the replacement of the bars for an optimized design in 1992, the need for plugging tubes and the dose associated will be reduced significantly.

Consequently, 1997, the year of the last SG replacement of the second generation PWR, will probably mark a historical date in which the works involving the SG primary side will stop being the critical task for Spanish PWR from the radiological point of view.

General Works

The average collective dose on general works shows a tendency to decrease from 1990, where it was registered a peack owing to a general rise presented in all generations. The higher contribution to this average comes from the second generation and the lower from the third, leading to a high variation coefficient for all generation and within the second and third one. The major contribution to this task is due to decontamination and cleaning works and shielding, and the results depend greatly of the radiological conditions and the scope of the job. These are the aspects where higher efforts should be done in order to reduce unnecesary dose: the source term and the systematic evaluation of the balance between dose saved and resulting dose.

Table 4. General works results. Comparison among generations

	Average Person.mSv	%	Maximum Person.mSv	Minimum Person.mSv	Standard Deviation	Variation Coefficient
All generations	274	13	755	44	188	0.68
First generation	241	11	348	60	63	0.26
Second generation	359	14	755	114	194	0.54
Third generation	103	11	237	44	56	0.55

The first generation average is located within the global range, but a clear increasing trend until 1991 was broken in 1992 where was registered a value under the average. As we have mentioned before, one factor to take into account in this analysis is the difficulties to reassign the collective dose to a new task code from a previous an inhomogeneous one. In this sense, we have found a particular case of the second generation reactors, while Ascó tends to amount all the auxiliary works within the general works task, Almaraz includes it in the system no listed task. So, the values of Almaraz are not very representative of this task. In the other case, Ascó shows a fairly good correlation trend with the evolution of the source term.

In relation with the third generation, the results recorded in Trillo, with an average value of 122 Person.mSv, are higher than those of Vandellós II, with 85 Person.mSv in average. In 1991 the highest value in Trillo, due to both an important increase in the scope of decontamination works, greatly related with the primary coolant pumps works, and a generalized increment in radiation levels, around a 50%, took place.

Refuelling

Stability is the tendency shown by the results of this task, with a progressive decrease from 1989 and remaining around 200 Person.mSv after that date. This value is nearly the same as the second generation average, since the starting up of the third one in 1988 balanced the contribution of J. Cabrera. In effect, the first generation collective doses are significantly higher than those of the rest, with cyclic behaviour in even years, while the third generation plants present much lower values.

These extremes differences are reflected in a moderate high variation coefficient for all generations in comparison with those of each generation. Refuelling includes reactor disassembly and assembly, fuel shuffle and cavity decontamination. A very short variability in its scope and the amounted experience in workers involved in these repetitive works can explain the stability and a small variation coefficient in each generation. Only difference in source terms, tools (i.e. remote reactor vessel head multistud tensioner and spinner out) or the ocurrence of any incident (i.e. stud grips) can cause some fluctuation among the collective values in this task.

The fact that refuelling means higher collective dose for J. Cabrera than for the rest is very significant and characteristic for this reactor and its peculiar design. Effectively, its average value is over the average, both in absolute and in relative terms, and it is the second major contributor to its collective dose, twice the values of the third. Though, last years the influence of a new tool, a triple tensioner, seems to notice in its results, but some gripping problems mask them.

The evolution of this task is very stable for the second generation, with a very low variation coefficient, in which a clear correlation can be established with the diminishing source term from 1991; although, remaining over twice the third generation values.

Table 5. Refuelling results. Comparison among all generations

	Average Person.mSv	%	Maximum Person.mSv	Minimum Person.mSv	Standard Deviation	Variation Coefficient
All generations	210	10	497	32	121	0.58
First generation	441	21	497	359	47	0.11
Second generation	205	8	276	154	37	0.18
Third generation	76	8	115	32	26	0.34

Third generation results show a significant different behaviour between both reactors that make it up. In effect, the average collective dose in Trillo is nearly half the one in Vandellós II, despite the important increase that took place in Trillo in 1991, up to 90 Person.mSv, due to 20 stud grips that had to be finally pulled out manually. This different conduct can be related with the use in Trillo of a remote reactor vessel head multistud tensioner from the beggining, and another similar for straction from 1991. This plant estimates in 50% the dose saved with the use of this tool.

As the impact of this kind of tools has been reflected clearly in the third generation, the accomplishment of an ALARA quantitative analysis to figure out its advantage for the second generation reactors and Vandellós II would be recommendable. Plenty of examples have been made for this particular item and the majority with a positive conclusion (ref. 3).

System not listed

As we have mentioned before, the presence of this task among the higher relative weight in collective dose (10%) is due more to the difficulties in supervising the collective dose associated to the rest of the task or reassigning them to a new task code than to the radiological relevance in any particular system not listed. In this sense, the results of this task can give an rough idea of the validity of the rest of data.

Tabla 6. System not listed. Comparison among generations

	Average Person.mSv	%	Maximum Person.mSv	Minimum Person.mSv	Standard Deviation	Variation Coefficient
All generations	205	10	618	1	202	0.98
First generation	507	24	618	424	70	0.14
Second generation	169	7	461	1	189	1.12
Tercera generación	76	8	162	27	52	0.68

These results show a clear difference among generations, the more modern the generation is the lower collective dose, concuring with more computer capability to provide automated overseeing and assignment of the collective dose according with a predetermine code. In the case of the first generation reactor, J. Cabrera, the lack of an electronic operational dosimetric system during the studied period has greatly risen its difficulties.

Anyway, a general tendency to deminish seems to indicate an improvement with the homogeneity introduced with the publication of the CSN guide 1.5, and can be even further reduced taking advantage of the lesson learned in this analysis.

Valve works

The average collective dose of this task remains stable, around 160 Person.mSv, during the studied period, with a light drop from 1991, despite the cyclic behaviour of the first generation reactor, which contributes in first range, owing principally to the steadiness of the second and third results. Consequently, this is the task with lower variation coefficient for all generations. This is a peculiar conduct taking into account the variety of the scope of this task, according to the number of valves involved and the extent of the work (inspection, maintainance, repair or modification), and the diversity of radiological conditions according to their location.

Table 7. Valve works. Comparison among generations

	Average Person.mSv	%	Maximum Person.mSv	Minimum Person.mSv	Standard Deviation	Variation Coefficient
All generations	157	8	322	21	81	0.51
First generation	239	11	322	139	74	0.31
Second generation	183	7	251	98	45	0.25
Third generation	50	5	74	21	18	0.37

The fact that the first generation reactor presents the highest average collective dose is very significant taking into account that the design is less complex, with a single coolant loop. Less ALARA regards, concerning biological shielding, accessibility and easiness for maintenance, among others, could explain these results.

The evolution of the valve works collective dose in the second generation reflects the same correlation with the source term as we have seen for other tasks before, but remaining in any case three times as high as that of the third values. More inspection requirements, less ALARA design characteristics and the effect of aging on source term can be related with this fact.

Insulation

The behaviour of the insulation average collective dose for all the generations is cyclic, showing a profile with picks in even years, owing essentially to the second generation contribution. In 1991, the third generation suffered an important increase, but it was counteracted by the drop of the results of the first one. The disparity among the respective values of each generation leads to a high variation coefficient for the array and for the second and third one.

Insulation removal and replacement greatly depends of the scope of other works, specially in-service inspection, complexity and design of the plant and the type of insulation, principally if it comprises quick connect tabs.

These considerations can make intelligible the fact that J. Cabrera, with a single loop, registers the lower collective doses, while the second generation presents the highest. On the other hand, problems related with coordination and the distribution of responsability have been detected as the cause of rework and an excessive extent of the task that explain, at least partially, some of the higher values recorded.

Tabla 8. Insulation removal and replacement results. Comparison among generations

	Average Person.mSv	%	Maximum Person.mSv	Minimum Person.mSv	Standard Deviation	Variation Coefficient
All generations	123	6	384	15	95	0.75
First generation	52	2	80	38	15	0.29
Second generation	176	7	384	76	92	0.52
Third generation	48	5	119	15	33	0.68

Reactor coolant pumps

Coolant pump works present an increasing trend until 1992, date in which a remarkable fall is registered. The main contribution comes from the third generation, especially in 1990 and 1991, and from the second one, while the first generation has not registered relevant collective dose during the studied period. Important fluctuations among both different plants and different outages have led to a very high variation coefficient for the array of PWR and for each generation.

These fluctuations reflect principally the great dependence of this task of the scope of the work, where inspection, maintenance and repair of the pump internals involves the main radiological risk. Such is the case of the profile shown by the second generation, where, despite the specific shielding and decontamination performanced, the pump internals inspections have been responsible of the important peaks registered in 1989, Ascó II and Almaraz II, and in 1990, Almaraz I.

Problems found in reactor coolant pumps of Trillo in 1989 have become in this plant the main contributor to the PWR average collective dose for this task and this task represents the first range for the global collective dose during the refuelling outages. In 1991, where a maximum value of 535 Person.mSv was registered, the internals of the three coolant pumps were removed, inspected, repaired or modified and, parallel, the source term of the plant increased significantly.

Table 9. Reactor coolant pump results. Comparison among generations

	Average Person.mSv	%	Maximum Person.mSv	Minimum Person.mSv	Standard Deviation	Variation Coefficient
All generations	104	5	535	2	107	1.03
First generation	31	2	104	2	39	1.27
Second generation	114	5	302	32	76	0.67
Third generation	129	14	535	27	162	1.26

Routine inspections

The profile of the collective dose evolution for this task presents a slight increase until 1990, diminishing in 1991, and rising again in 1992. The major contribution comes from the second generation, although the first one also contributed to the increment of 1992 in a relevant way, but remaining before that in lower values than the average and meaning this task less than selection level (5%) of the total collective dose for this generation.

The results of this task are very dependent of the scope of the testing program (that includes in-service inspection not listed in other tasks and snnuber, hanger and anchor bolt inspections) and the location of the components to inspect, which determines the radiological conditions associated to the work. The first factor is defined by safety codes (ASME codes and IE bulletins) and only a relief on high collective dose inspections by the regulatoy body or ASME can modify it. In relation with the second factor, the plant design has a strong influence but can be modified by shielding the local hot spots, testing in a low dose rate area and delating the high dose rate components inspections as much as possible.

Table 10. Routine inspections results. Comparison among generations

	Average Person.mSv	%	Maximum Person.mSv	Minimum Person.mSv	Standard Deviation	Variation Coefficient
All generations	97	5	259	20	58	0.60
First generation	51	2	85	35	18	0.35
Second generation	123	5	259	20	59	0.48
Third generation	64	7	102	22	30	0.68

Both, first and third generation show a cyclic behaviour with alternant peaks that counteract among them. Any way, relevant fluctuations have been registered for the PWR average leading to high variation coefficient for the global array and the generation coefficient of each one. The close relation with insulation makes their respective evolution profiles very analogous.

CONCLUSIONS

Although tentatively, on one hand because this is the first approach of this kind in Spain, and because a parallel analysis on dose reduction thecnics evolution, now under way, has to be finished, the following conclusions can be said:

The trend in average occupational collective dose per reactor in Spanish Pressurized Water Reactors (PWR) seems to be stabilising and lightly decreasing during the studied period of time, 1988-1992, within the same range of the average level in the OECD countries. In these global terms, each respective ALARA regards in design have been determinant in the results of each generation.

The evolution of the collective dose in the second generation shows an inflection point in 1990 for many tasks. Awaiting deeper analysis, we can say in advance that some of the factors which have had a notable influence to break the trend and maintain the collective dose in moderate levels are: the change in both plants of the primary chemistry (from pH 6.9 to 7.4); a 100% fuel inspection, a fuel no damage policy and a global plan for hot spot shielding in Ascó.

Steam generator (SG) primary side has been, and still is, the highest contributor to the refuelling outage collective dose in Spanish PWR, both for global and for the last two generation average. Nevertheless, 1997, the year of the last SG replacement of the second generation PWR, will probably mark a historical date in which the works involving the SG primary side will stop being the critical task for Spanish PWR from the radiological point of view.

As the impact of remote reactor vessel head multistud tensioner has been reflected clearly in the third generation, the accomplishment of an ALARA quantitative analysis to figure out its advantage for the second generation reactors and Vandellós II would be recommendable.

Several tasks, as valve works, insulation and general works, have shown to be very sensitive to problems related with a lack of coordination and an ambiguous distribution of responsability, causing rework and an excessive extent of the task that explain, at least partially, some of the higher values recorded. Efforts to avoid these problems would be among the priorities to reduce the collective dose of these tasks.

Finally, in spite of other analysis results, we can affirm that a progressive development of ALARA culture is having a positive impact in Spanish PWR and we have to develope even further.

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