OECD Nuclear Energy Agency
International Atomic Energy Agency

ISOE

European Technical Centre

**General Distribution**
**April 2010**

# ISOE INFORMATION SHEET

## PWR OUTAGE COLLECTIVE DOSE: ANALYSIS PER SISTER UNIT GROUP FOR THE 2002-2007 PERIOD

**ISOE European Technical Centre - Information Sheet No. 52 (2010)**

---

***The purpose of this information sheet is to explore the potential impact of nuclear power plant design on the outage collective dose and its evolution during the 2002-2007 period.***

***The various designs are classified in the ISOE database according to the name of the designer*, the numbers of loops and the generation of the reactor. Plants of similar design are grouped into "sister unit groups".***

***The first part of this information sheet focuses on the comparison of the designers within the same generation and the second part compares the generations within each designer.***

***Note:***

- ***Detailed data related to the name of the reactors in each sister unit group, the construction start dates, the number of outages, the average outage collective dose and the standard deviation by year by sister unit group are provided in Appendixes 1, 2 and 3.***
- ***The average outage collective dose for a sister unit group for a given year is calculated by averaging all the outage collective dose data available for this year for the units belonging to the group.***

---

* The generic term "designer" is to be understood as NSSS designer (i.e. Nuclear Steam System Supplier)

Table of content

*Notes:*

*- The design is, of course, not the only factor influencing the outage collective dose. Other factors such as the outage duration, the regulatory control requirements, the radiation protection practices, etc also impact the level of outage dose. The figures presented in this information sheet are thus to be considered as indications of the general trends of outage collective dose of each design category. More detailed analysis would be necessary to better explain the differences.*

*- The number of reactors belonging to each sister unit group varies significantly from one group to another: from 1 up to 20 reactors. For these reasons, the comparisons between groups have to be made carefully. Notably, when the group is large, the calculated average outage collective dose might hide some extreme values (low or high). Please refer to the Appendixes tables for more detailed information.*

## 1. Comparison of the designers within the same generation

### 1.1. PWR 2 loop reactors

The following PWR 2 loop sister unit groups are considered:

- W21, W22: Westinghouse, 2 loops, first and second generation.
- M21, M22: Mitsubishi, 2 loops, first and second generation.
- C21, C22: Combustion Engineering, 2 loops, first and second generation.
- B21: Babcock & Wilcox, 2 loops, first generation
- S21: Siemens, 2 loops, first generation

*First generations*

The five sister unit groups belonging to the first generation of 2 loops PWR can be separated into three groups according to their outage dose results:

- **S21 and W21**: around **0.5 man.Sv and below**,
- **M21**: between **0.5 and 1 man.Sv**,
- **B21 and C21**: **above 1 man.Sv**.

To be noted:

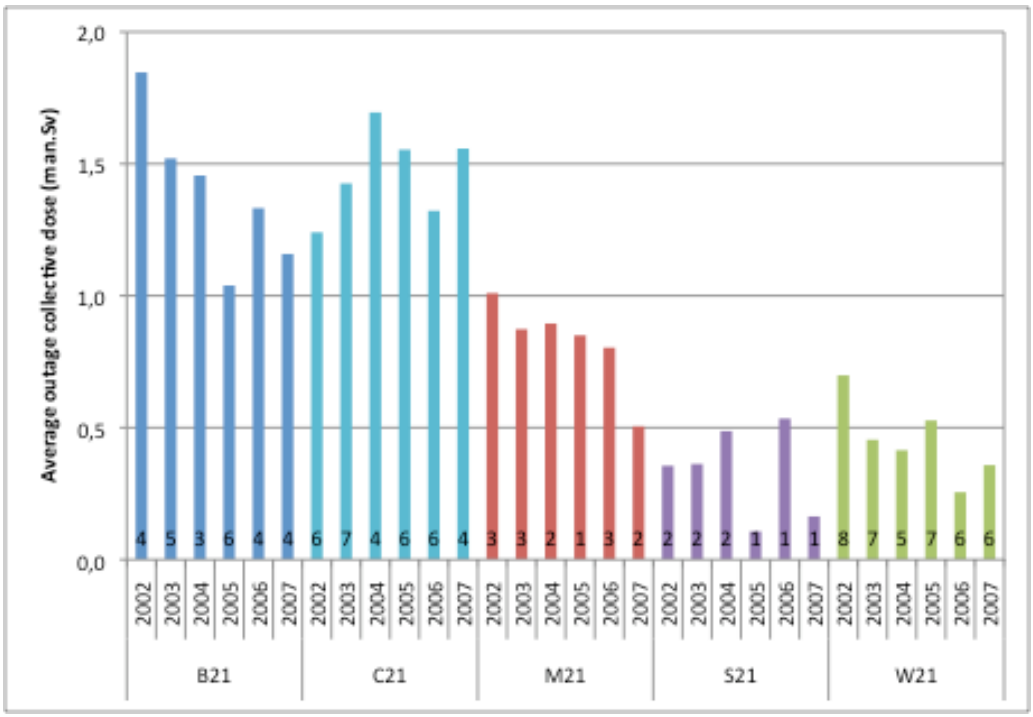
- B21, M21 and W21 are those showing a decreasing trend of the average outage collective dose between 2002 and 2007: around 37% for B21, and around 50% for M21 and W21.

*Second generations*

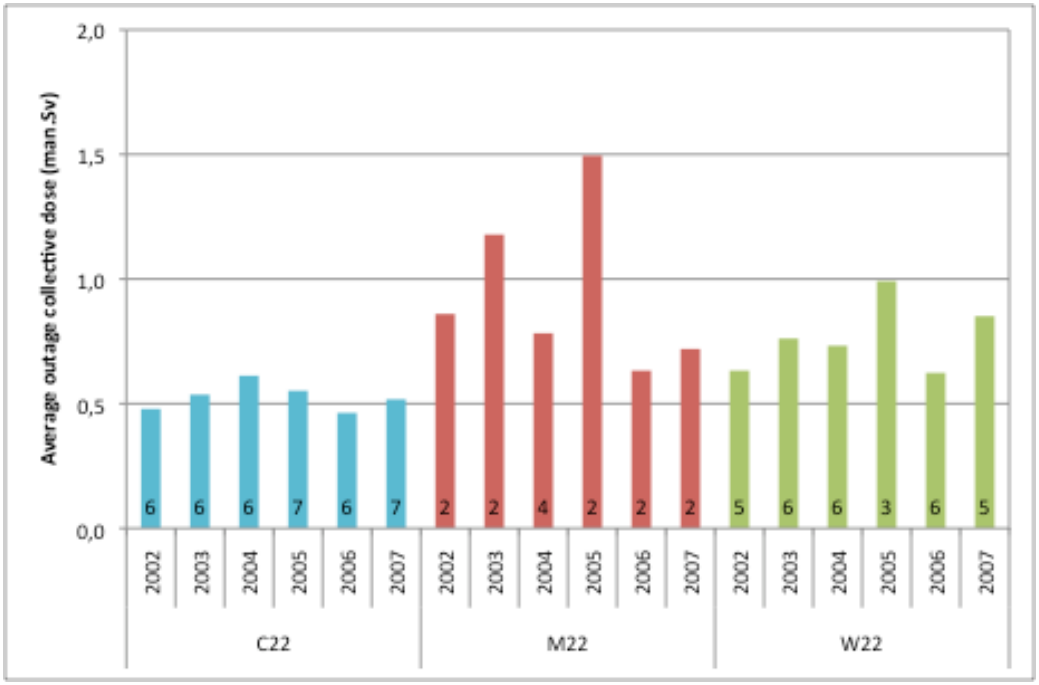
Three sister unit groups are considered in the second generation of 2 loops PWR reactors. The profile of average outage dose per year shows two main groups:

- **M22** and **W22**: **0.8 man.Sv** on average,
- **C22** : around **0.5 man.Sv**

It can be noted that for M22, some results were greater than 1 man.Sv, and up to 1.5 man.Sv (in 2005). One explanation may come from the fact that M22 reactors are situated in Japan, a country characterized by the long duration of outages due to a national inspection system which requires comprehensive inspections between operating cycles.




*First generations*




*Second generations*

**Figure 1. Average outage collective dose for PWR 2 Loops reactors – first and second generations**

Note: The number in each histogram indicates the number of outages for a sister unit group, for a given year.

### 1.2. PWR 3 loop reactors

The following PWR 3 loop sister unit groups are considered:

- F31, F32: Framatome, three loops, first and second generation.
- W31, W32: Westinghouse, three loops, first and second generation.
- M31, M32: Mitsubishi, three loops, first and second generation.
- S32: Siemens, three loops, second generation.

*First generations*

The outage collective dose of the sister unit groups of the 3-loop first generation - **F31, M31 and W31** – is, most of the time, around **0.9 man.Sv** on an average.

To be noted:

- The outage collective dose of the F31 sister unit group has notably decreased between 2002 and 2004 (almost 40 % decrease) and is stable since that time.
- The average outage collective dose for the W31 group is fluctuating during the considered period, the lowest value being 0.6 man.Sv in 2005 (average of 7 outages) and the highest, 1.43 man.Sv in 2003 (average of 8 outages).
- A very good result for M31 in 2007, with an outage at 0.41 man.Sv.

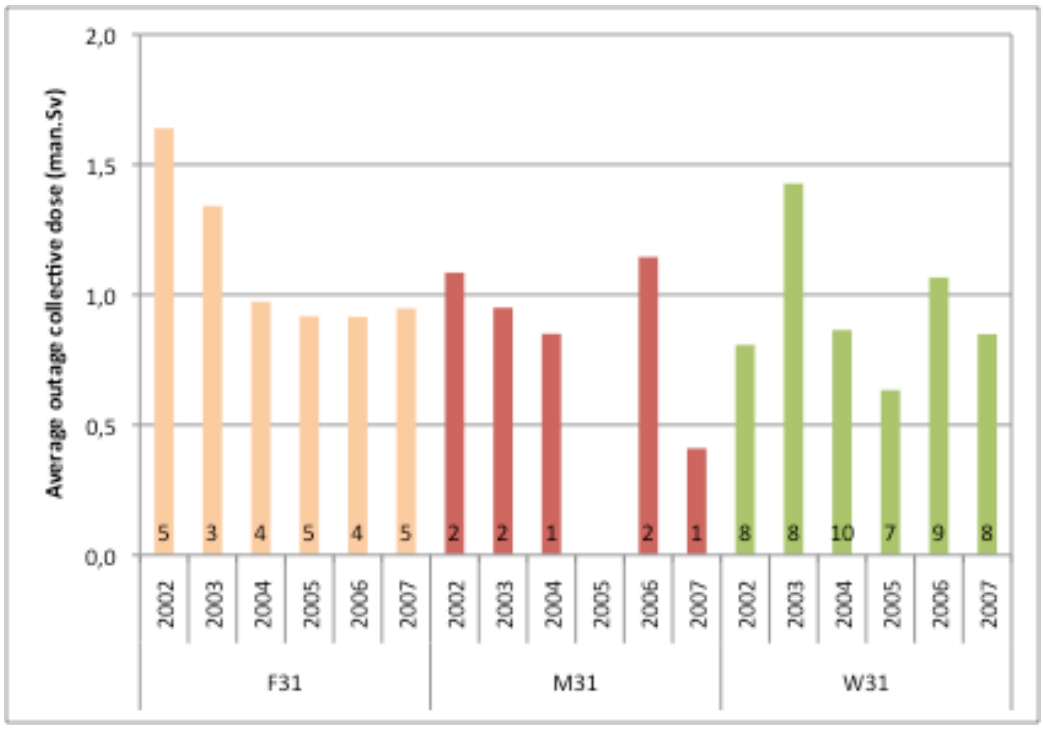
*Second generations*

The 3-loop second generation reactors can be divided into 3 groups according to the level of outage collective dose:

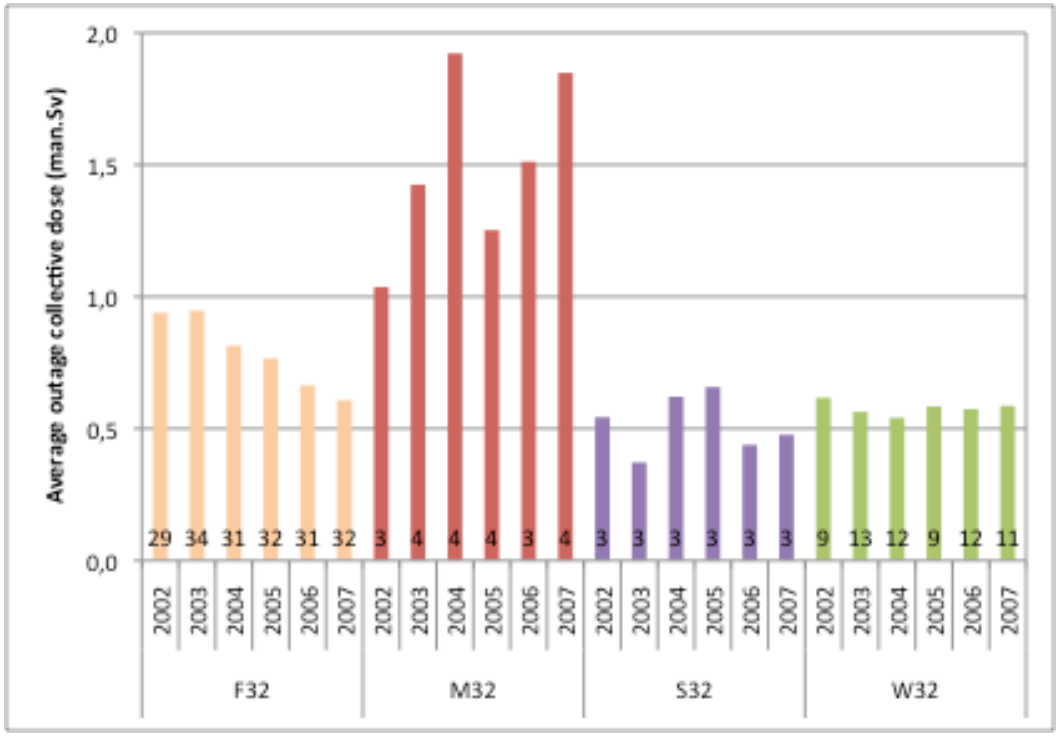
- **M32** sister unit group presents the highest outage collective doses: above **1 man.Sv (up to 1.9 man.Sv** for the highest value)
- **F32** from **0.9 to 0.6 man.Sv**
- **S32 and W32** sister unit groups are in the **same order of magnitude**, **i.e. around 0.5 man.Sv.**

To be noted:

- A **regular decrease** of the outage collective dose during the considered period for **F32** sister unit group (A **40% decrease** between 2002 and 2007, reaching the average value of W32 outage collective dose of 0.6 man.Sv).
- **A regular 3-year increase** of the average outage collective dose of **M32**, which could correspond to a three-year maintenance and inspection plan.




*First generations*




*Second generations*

**Figure 2. Average outage collective dose for PWR 3 Loops reactors – first and second generations**

### 1.3. PWR 4 loop reactors

In the analysis, the following PWR 4 loop sister unit groups are considered:

- F42, F43: Framatome, four loops, second and third generation.
- M41, M42: Mitsubishi, four loops, first and second generation.
- S41, S42, S43: Siemens, four loops, first, second and third generation (Konvoi).
- W41, W42: Westinghouse, four loops, first and second generation.

Note: The scale of the figure of each generation is not the same. It has been adapted due to the large discrepancies of the maximum outage collective dose values between the generations.

*First generations*

The three groups belonging to the first generation of 4-loop PWR reactors present important differences in terms of outage collective dose:

- **S41** sister unit group is quite specific: outage collective doses are most of the time higher than **3 man.Sv**, **up to 4.4 man.Sv in 2003**,
- **W41** sister unit group shows quite **regular values** for the considered period, with outage collective dose around **1.4 man.Sv**,
- The outage collective dose of **M41**, which includes only one reactor, is around **1.2 man.Sv**, except for 2004, where it reached a value of **3.5 man.Sv.**

*Second generations*

The outage collective dose of the second generation of 4-loop PWR reactors is quite different according to the designer:

- **M42** presents the highest values, fluctuating between **1 and 1.5 man.Sv**,
- The results of **W42** are varying between **0.7 and 1.2 man.Sv**,
- **F42** has a set of values around **0.7 man.Sv,**
- **S42,** the **pre-Konvoi design reactors in Germany**, is the sister unit group with the lowest outage collective dose of the second generation, usually **below 0.5 man.Sv** (except in 2006).

To be noted:

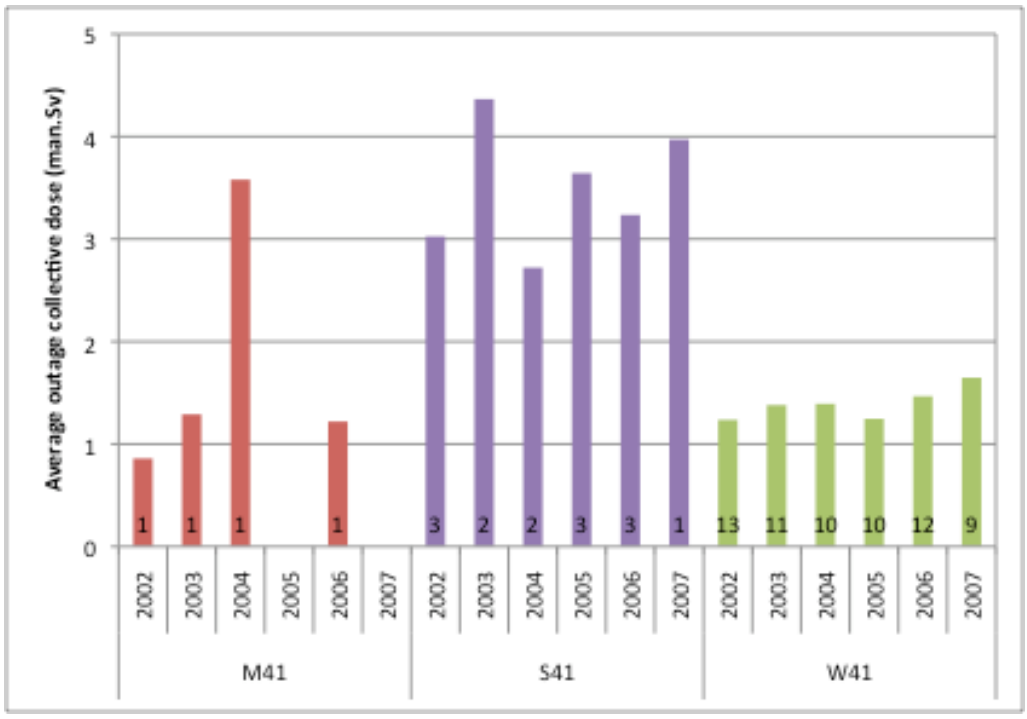
- For all design groups, and more specially for M42 and S42, the outage collective dose is fluctuating each year between a high and a low value, apparently reflecting cycles in the workload of maintenance and inspection.
- While taking into account these fluctuations, the outage collective dose of W42 sister-unit group seems to be increasing since 2002.

*Third generations*

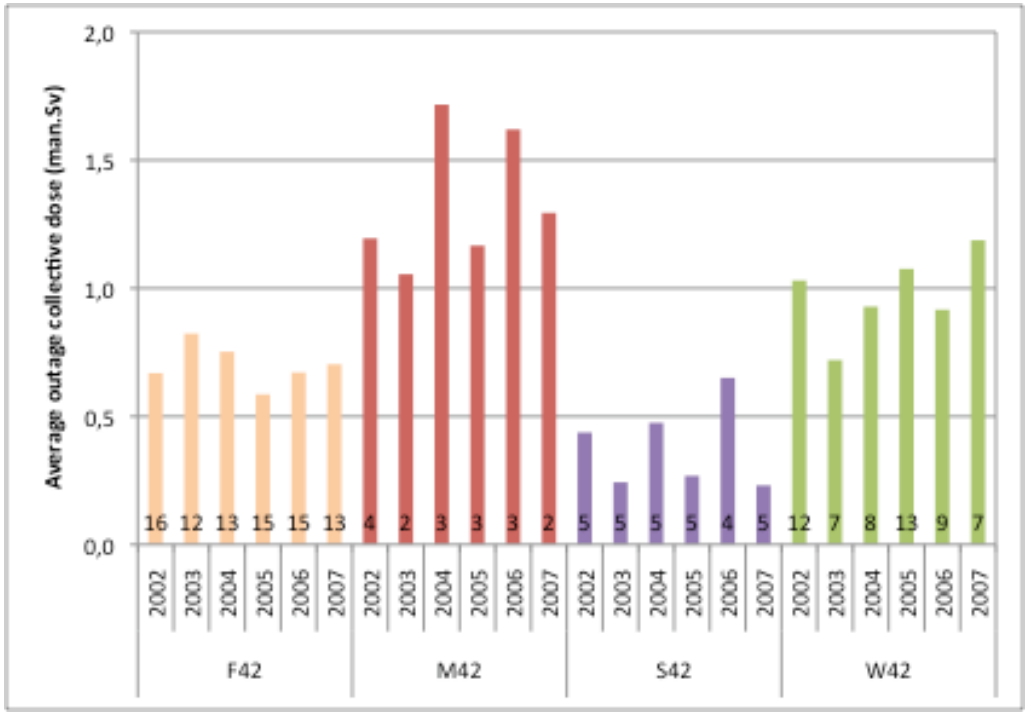
This generation shows the lowest outage collective dose of all the generations of 4-loop PWR reactors:

- **F43,** shows an outage collective dose **fluctuating between 0.15 and 0.5 man.Sv**,
- **S43**, corresponding to the **Konvoi design reactors in Germany**, includes NPPs with outage collective doses **below 0.2 man.Sv, fluctuating between 0.07 and 0.15 man.Sv.**

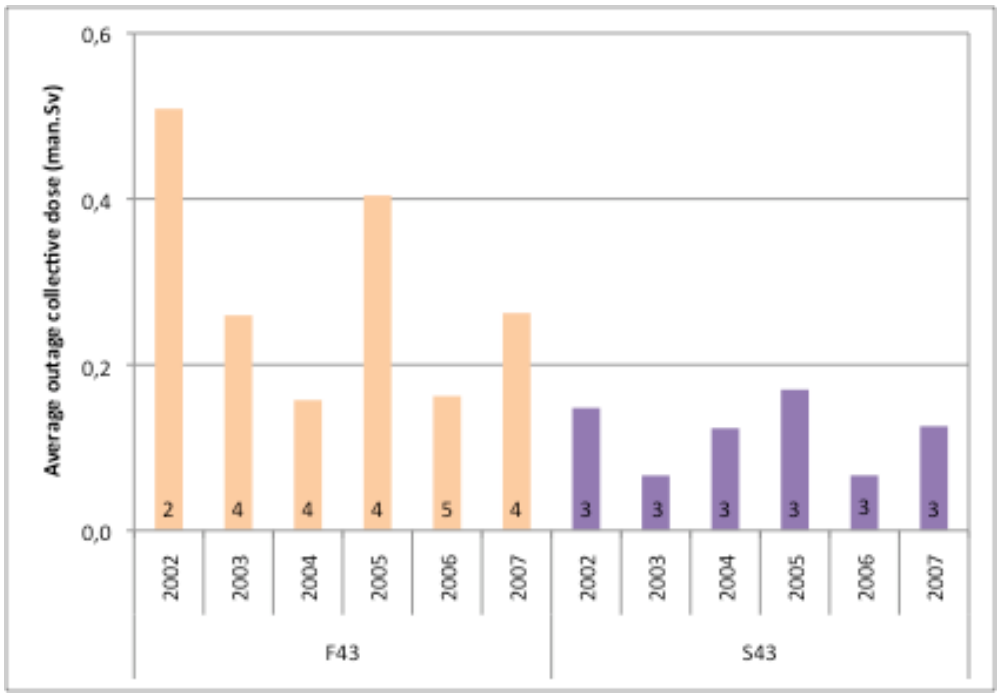
All reactors present regular fluctuation of outage dose, again certainly due to cycles of maintenance and inspection workload. It can be noticed that the lowest outage collective dose of F43 reactors (i.e. 0.16 man.Sv) are similar to the highest one of S43.




First generation




Second generation




Third generation

**Figure 3. PWR 4 Loop reactors, average outage collective dose**

## 2. Comparison of the generations within each designer

Note: The scale of the figure for each designer is not the same. It has been adapted due to the large discrepancies of the outage collective dose maximum value between the designers.

For an equal number of loops and a same designer, in some cases, a clear decrease of the average outage collective dose can be noticed in the last generation(s) of reactor compared to the first ones. For example:

- **Combustion engineering reactors**:
  - A decrease of the average outage collective dose between the 2 generations of the 2-loop reactors can be observed: from around 1.5 man.Sv for C21 to around 0.5 man.Sv for C22.

- **Framatome reactors**:
  - Three loops (F31 and F32): during the considered period, F32 has always show lower outage collective doses than F31 for a given year. A large reduction of outage doses in both generations is also noted: the last results of F31 (0.95 man.Sv in 2007) are the same for F32 reactors in 2002. The results of this latter design are, in 2007 close to 0.6 man.Sv.

  - Four loops (F42 and F43): While fluctuating each year (between 0.16 and 0.4 man.Sv), F43 reactors always present a much lower outage collective dose than F42 (between 0.59 and 0.8 man.Sv).

- **Siemens reactors**:
  - The improvement of the outage collective dose results of the 4-loop reactors generations is "spectacular". The very first generation S41 presents very high outage collective dose (usually greater than 3 man.Sv, and one time greater than 4 man.Sv), while the average outage collective dose of second generation (S42 – pre-Konvoi) are fluctuating between 0.2 man.Sv and 0.7 man.Sv. The last generation (S43 – Konvoi) also shows fluctuating results between 0.07 man.Sv and 0.17 man.Sv.

- **Westinghouse reactors**:
  - Three loops reactors (W31 and W32): the average outage collective dose of the 1st generation is fluctuating between 0.63 man.Sv and 1.43 man.Sv, while that of the second generation is relatively stable on the considered period, around 0.6 man.Sv.

  - 4 loop reactors (W41 and W42): the average outage collective dose of W41 is fluctuating between 1.24 man.Sv and 1.65 man.Sv, with a global increasing trend over the considered period. Lower values are observed for the W42 reactors: between 0.72 man.Sv and 1.19 man.Sv.

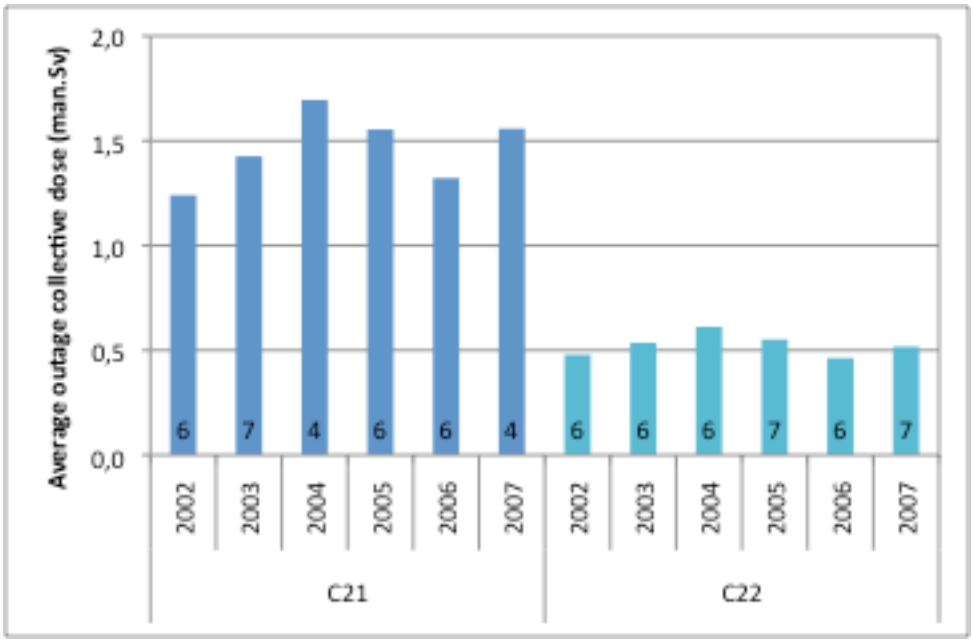
In some cases, for an equal number of loops, the change of generation does not clearly the average outage collective dose which shows in some cases, higher outage collective dose for the second generation than for the first one. For example:

- **Mishubishi reactors:**
  - 2 loop reactors (M21 and M22): The average outage collective dose of M22 group is quite close to that of M21. The higher values of M22 (1.18 and 1.5 man.Sv) have not been reached by M21 reactors (which in most of the cases present average outage collective doses around 0.8 man.Sv, and even 0.5 man.Sv in 2007).

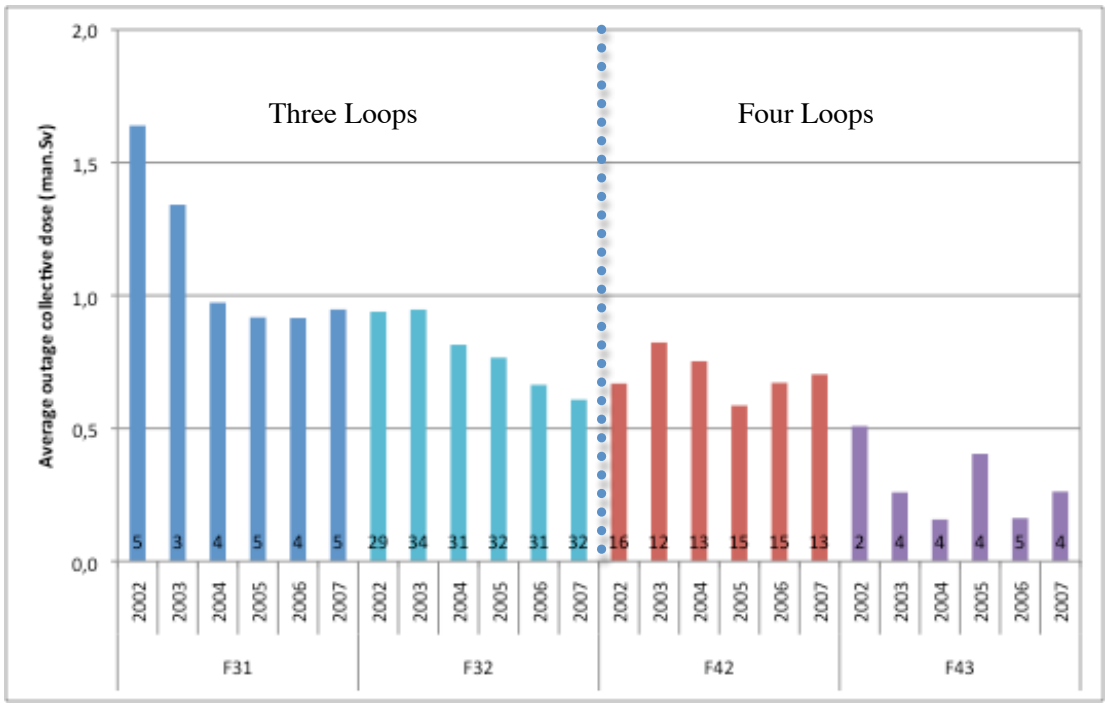
  - 3 loop reactors (M31 and M32): M32 reactors present higher outage collective doses than the M31 group. The latter is situated between 0.8 and 1 man.Sv, with one particularly low value of 0.41 man.Sv (in 2007 – only one outage this year). M32 reactors show outage collective dose fluctuating between 1 and 1.9 man.Sv

  - 4 loop reactors (M41 and M42): the outage collective dose of the first generation group M41, which contains only 1 reactor, is around 1.2 man.Sv (except one year with 3.58 man.Sv). The second generation shows fluctuations between 1 and 1.7 man.Sv

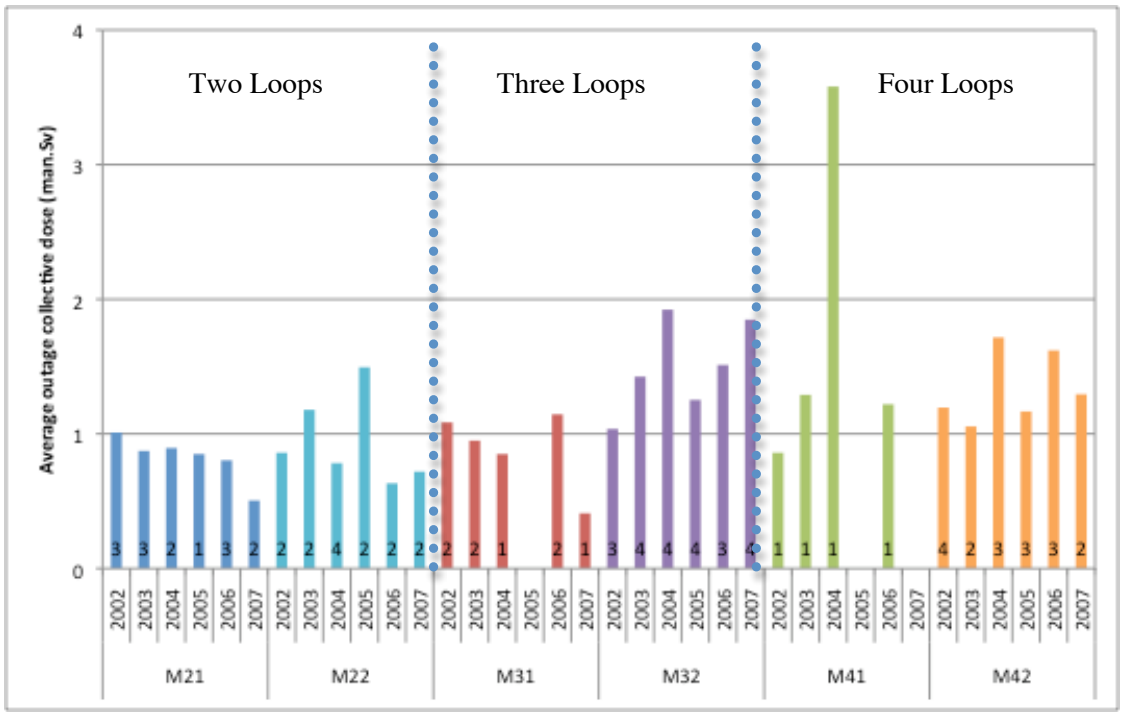
- **Westinghouse reactors**:
  - 2 loop reactors (W21 and W22): The first generation W21, with outage collective dose around 0.4 man.Sv on the considered period (with a lower value of 0.26 man.Sv) are nearly 50 % below the second generation W22 for which the outage collective dose is around 0.7 man.Sv (reaching 0.99 man.Sv in 2005).




Combustion Engineering

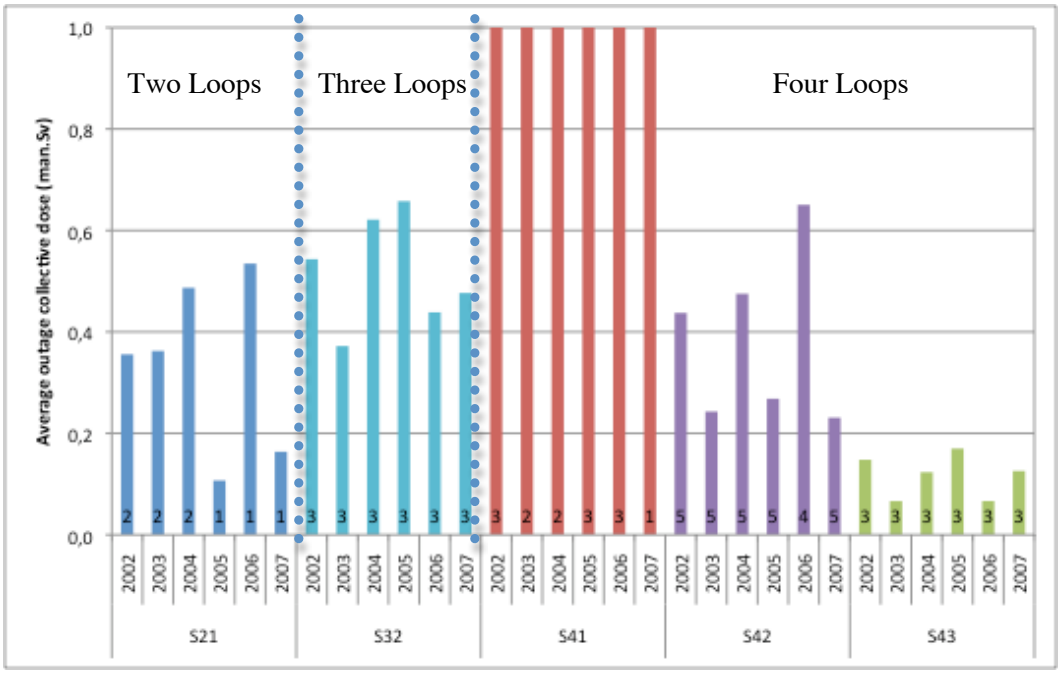



Framatome

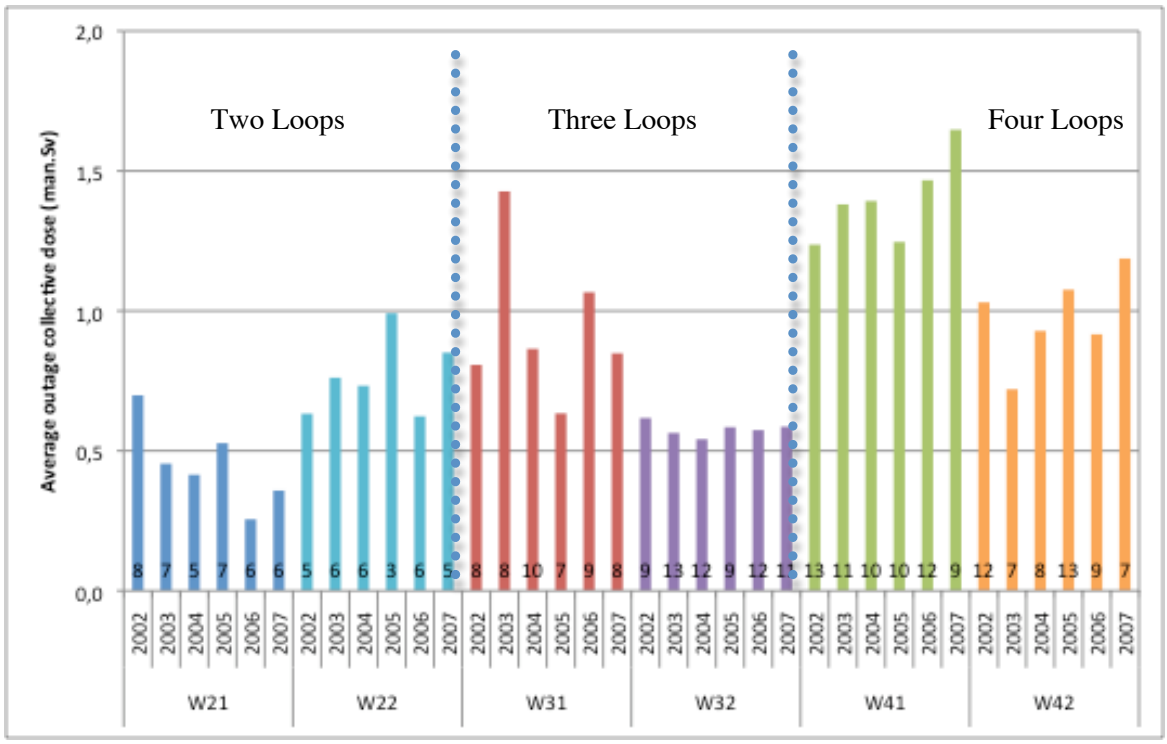



Mitsubishi

S41 outage dose (man.Sv): 3 - 4.4 - 2.7 - 3.6 - 3.2 - 4




Siemens (For S41, the data for each year are indicated above the chart: x/x)




Westinghouse

**Figure 4. PWR reactors, average outage collective dose by sister unit groups by designer**

## APPENDIX 1. TWO LOOP REACTORS

### Table 1. PWR 2 loops, reactors in each sister unit group by country

| **PWR 2 loops reactors** | | | |
|---|---|---|---|
| **Sister unit group** | **Country** | **Reactors (Construction started date)** | |
| B21<br>*Babcock & Wilcox, 2 loops, first generation* | USA | Arkansas 1 (1968)<br>Crystal River 3 (1968)<br>Davis Besse 1 (1970) | Oconee 1, 2, 3 (1967)<br>TMI 1 (1968) |
| C21<br>*Combustion Engineering, 2 loops, first generation* | USA | Arkansas 2 (1968)<br>Calvert Cliffs 1, 2 (1969)<br>Millstone 2 (1970) | Saint Lucie 1, 2 (1970, 77)<br>Waterford 3 (1974)<br>San Onofre 2, 3 (1974) |
| C22<br>*Combustion Engineering, 2 loops, second generation* | Korea | Ulchin 3, 4 (1993) | Yonggwang 3, 4, 5, 6 (1989, 90, 97) |
| | USA | Paloverde 1, 2, 3 (1976) | |
| M21<br>*Mitsubishi, 2 loops, first generation* | Japan | Genkai 1 (1971)<br>Ikata 1 (1973) | Mihama 2 (1968) |
| M22<br>*Mitsubishi, 2 loops, second generation* | Japan | Genkai 2 (1977)<br>Ikata 2 (1978) | Tomari 1, 2 (1985, 86) |
| S21<br>*Siemens, 2 loops, first generation* | Germany | Obrigheim 1 (1965) | Shutdown in 2005 |
| | Netherlands | Borssele 1 (1969) | |
| W21<br>*Westinghouse, 2 loops, first generation* | Belgium | Doel 1, 2 (1969-71) | |
| | Japan | Mihama 1 (1967) | |
| | Switzerland | Beznau 1, 2 (1965-1968) | |
| | USA | Ginna 1 (1966) | Point Beach 1, 2 (1967-68) |
| W22<br>*Westinghouse, 2 loops, second generation* | Brazil | Angra 1 (1971) | |
| | Korea | Kori 1, 2 (1972-77) | |
| | Slovenia | Krsko 1 (1975) | |
| | USA | Kewaunee 1 (1968) | Prairie Island 1, 2 (1968-69) |

**Table 2. PWR 2 loops, average outage collective dose and standard deviation by sister unit group and year**

| Sister unit group *(No. of reactors)* | Type of data | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| B21 *(7)* | av. outage coll.dose | 1.85 | 1.52 | 1.46 | 1.04 | 1.33 | 1.16 |
| | σ (standard deviation) | 1.32 | 0.47 | 0.40 | 0.79 | 0.40 | 0.46 |
| | No. of outages | 4 | 5 | 3 | 6 | 4 | 4 |
| C21 *(9)* | av. outage coll.dose | 1.24 | 1.43 | 1.70 | 1.55 | 1.32 | 1.56 |
| | σ (standard deviation) | 0.49 | 0.61 | 0.54 | 0.48 | 0.22 | 0.56 |
| | No. of outages | 6 | 7 | 4 | 6 | 6 | 4 |
| C22 *(9)* | av. outage coll.dose | 0.48 | 0.54 | 0.61 | 0.55 | 0.46 | 0.52 |
| | σ (standard deviation) | 0.13 | 0.40 | 0.27 | 0.18 | 0.14 | 0.17 |
| | No. of outages | 6 | 6 | 6 | 7 | 6 | 7 |
| M21 *(3)* | av. outage coll.dose | 1.01 | 0.87 | 0.90 | 0.85 | 0.80 | 0.51 |
| | σ (standard deviation) | 0.49 | 0.10 | 0.49 | 0 | 0.10 | 0.11 |
| | No. of outages | 3 | 3 | 2 | 1 | 3 | 2 |
| M22 *(4)* | av. outage coll.dose | 0.86 | 1.18 | 0.78 | 1.50 | 0.63 | 0.72 |
| | σ (standard deviation) | 0.34 | 0.44 | 0.23 | 0.79 | 0.05 | 0.09 |
| | No. of outages | 2 | 2 | 4 | 2 | 2 | 2 |
| S21 *(2)* | av. outage coll.dose | 0.36 | 0.36 | 0.49 | 0.11 | 0.53 | 0.16 |
| | σ (standard deviation) | 0.11 | 0.17 | 0.22 | 0 | 0 | 0 |
| | No. of outages | 2 | 2 | 2 | 1 | 1 | 1 |
| W21 *(8)* | av. outage coll.dose | 0.70 | 0.45 | 0.41 | 0.53 | 0.26 | 0.36 |
| | σ (standard deviation) | 0.70 | 0.32 | 0.27 | 0.31 | 0.11 | 0.26 |
| | No. of outages | 8 | 7 | 5 | 7 | 6 | 6 |
| W22 *(7)* | av. outage coll.dose | 0.63 | 0.76 | 0.73 | 0.99 | 0.62 | 0.85 |
| | σ (standard deviation) | 0.21 | 0.35 | 0.25 | 0.21 | 0.16 | 0.21 |
| | No. of outages | 5 | 6 | 6 | 3 | 6 | 5 |

## APPENDIX 2. THREE LOOP REACTORS

### Table 3. PWR 3 loops, reactors in each sister unit group by country

| **PWR 3 loop reactors** | | | |
|---|---|---|---|
| **Sister unit group** | **Country** | **Reactors (Construction started date)** | |
| F31<br>*Framatome, 3 loops, first generation* | France | Bugey 2, 3, 4, 5 (1972-73-74) | Fessenheim 1, 2 (1971-72) |
| F32<br>*Framatome, 3 loops, second generation* | China | Daya Bay 1, 2 (1987-88) | |
| | France | Blayais 1, 2, 3, 4 (1977-78)<br>Chinon B1, B2, B3, B4 (1977--80-81)<br>Cruas 1, 2, 3, 4 (1978, 79)<br>Dampierre 1, 2, 3, 4 (1975) | Gravelines 1, 2, 3, 4, 5, 6 (1975- 76- 79)<br>Saint-Laurent B1, B2 (1976)<br>Tricastin 1, 2, 3, 4 (1974- 75) |
| | Korea | Ulchin 1, 2 (1983) | |
| | South-Africa | Koeberg 1, 2 (1976) | |
| M31<br>*Mitsubishi, 3 loops, first generation* | Japan | Mihama 3 (1972) | Takahama 2 (1971) |
| M32<br>*Mitsubishi, 3 loops, second generation* | Japan | Ikata 3 (1986)<br>Sendai 1, 2 (1979-81) | Takahama 3, 4 (1980-81) |
| S32<br>*Siemens, 3 loops, second generation* | Germany | Neckar 1 (1972) | |
| | Spain | Trillo 1 (1979) | |
| | Switzerland | Gosgen 1 (1973) | |
| W31<br>*Westinghouse, 3 loops, first generation* | Japan | Takahama 1 (1970) | |
| | Sweden | Ringhals 2 (1970) | |
| | USA | Beaver Valley 1, 2 (1970,74)<br>Farley 1, 2 (1972)<br>North Anna 1, 2 (1971) | Robinson 2 (1967)<br>Surry 1, 2 (1968)<br>Turkey Point 3, 4 (1967) |
| W32<br>*Westinghouse, 3 loops, second generation* | Belgium | Doel 4 (1978) | Tihange 3 (1978) |
| | Korea | Kori 3, 4 (1979, 1980) | Yonggwang 1, 2 (1981) |
| | Spain | Almaraz 1, 2 (1973)<br>Asco 1, 2 (1974-75) | Vandellos 2 (1980) |
| | Sweden | Ringhals 3, 4 (1972-73) | |
| | USA | Harris 1 (1978) | Summer 1 (1973) |

**Table 4. PWR 3 loops, average outage collective dose and standard deviation by sister unit group and year**

| Sister unit group *(No. of reactors)* | Type of data | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| F31 *(6)* | av. outage coll.dose | 1.64 | 1.34 | 0.97 | 0.92 | 0.92 | 0.95 |
| | σ (standard deviation) | 0.99 | 0.61 | 0.25 | 0.39 | 0.53 | 0.48 |
| | No. of outages | 5 | 3 | 4 | 5 | 4 | 5 |
| F32 *(34)* | av. outage coll.dose | 0.94 | 0.95 | 0.81 | 0.77 | 0.66 | 0.61 |
| | σ (standard deviation) | 0.74 | 0.54 | 0.59 | 0.53 | 0.52 | 0.37 |
| | No. of outages | 29 | 34 | 31 | 32 | 31 | 32 |
| M31 *(2)* | av. outage coll.dose | 1.09 | 0.95 | 0.85 | - | 1.15 | 0.41 |
| | σ (standard deviation) | 0.25 | 0.24 | 0 | - | 0.07 | 0 |
| | No. of outages | 2 | 2 | 1 | - | 2 | 1 |
| M32 *(5)* | av. outage coll.dose | 1.04 | 1.43 | 1.92 | 1.25 | 1.51 | 1.85 |
| | σ (standard deviation) | 0.25 | 0.27 | 0.14 | 0.14 | 0.54 | 0.35 |
| | No. of outages | 3 | 4 | 4 | 4 | 3 | 4 |
| S32 *(3)* | av. outage coll.dose | 0.54 | 0.37 | 0.62 | 0.66 | 0.44 | 0.48 |
| | σ (standard deviation) | 0.20 | 0.10 | 0.30 | 0.38 | 0.03 | 0.17 |
| | No. of outages | 3 | 3 | 3 | 3 | 3 | 3 |
| W31 *(13)* | av. outage coll.dose | 0.81 | 1.43 | 0.86 | 0.63 | 1.07 | 0.85 |
| | σ (standard deviation) | 0.29 | 0.65 | 0.31 | 0.14 | 0.50 | 0.39 |
| | No. of outages | 8 | 8 | 10 | 7 | 9 | 8 |
| W32 *(15)* | av. outage coll.dose | 0.62 | 0.56 | 0.54 | 0.58 | 0.57 | 0.59 |
| | σ (standard deviation) | 0.25 | 0.18 | 0.23 | 0.27 | 0.24 | 0.21 |
| | No. of outages | 9 | 13 | 12 | 9 | 12 | 11 |

## APPENDIX 3. FOUR LOOP REACTORS

### Table 5. PWR 4 loops reactors in each sister unit group by country

| **PWR 4 loop reactors** | | | |
|---|---|---|---|
| **Sister unit group** | **Country** | **Reactor (Construction started date)** | |
| F42<br>*Framatome,4 loops, second generation* | France | Belleville 1, 2 (1980) | Nogent 1, 2 (1981-82) |
| | | Cattenom 1, 2, 3, 4 (1979-80-82-83) | Paluel 1, 2, 3, 4 (1977-78-79-80) |
| | | Flamanville 1, 2 (1979-80) | Penly 1, 2 (1982-84) |
| | | Golfech 1, 2 (1982-84) | Saint-Alban 1, 2 (1979) |
| F43<br>*Framatome, 4 loops, third generation* | France | Chooz B1, B2 (1984-85) | Civaux 1, 2 (1988-91) |
| M41<br>*Mitsubishi, 4 loops, first generation* | Japan | Tsuruga 2 (1982) | |
| M42<br>*Mitsubishi, 4 loops, second generation* | Japan | Genkai 3, 4 (1988-92) | Ohi 3, 4 (1987-88) |
| S41<br>*Siemens, 4 loops, first generation* | Germany | Biblis A, B (1970-72) | |
| | | Unterweser 1 (1972) | |
| S42<br>*Siemens, 4 loops, second generation* | Brazil | Angra 2 (1976) | |
| | Germany | Brokdorf 1 (1976) | Grohnde 1 (1976) |
| | | Grafenrheinfeld 1 (1975) | Philippsburg 2 (1977) |
| S43<br>*Siemens, 4 loops, third generation (Konvoi)* | Germany | Emsland 1 (1982)<br>Isar 2 (1982) | Neckar 2 (1982) |
| W41<br>*Westinghouse, 4 loops, first generation* | Japan | Ohi 1, 2 (1972) | |
| | USA | Catawba 1, 2 (1975) | McGuire 1, 2 (1973) |
| | | Cook 1, 2 (1969) | Salem 1, 2 (1968) |
| | | Diablo Canyon 1, 2 (1968-70) | Sequoyah 1, 2 (1970) |
| | | Indian Point 2, 3 (1966-69) | Watts Bar 1 (1973) |
| W42<br>*Westinghouse, 4 loops, second generation* | UK | Sizewell B1 (1988) | |
| | USA | Braidwood 1, 2 (1975) | Millstone 3 (1974) |
| | | Byron 1, 2 (1975) | Seabrook 1 (1976) |
| | | Callaway 1 (1976) | South Texas 1, 2 (1975) |
| | | Comanche Peak 1, 2 (1974) | Vogtle 1, 2 (1976) |
| | | Wolf Creek 1 (1977) | |

**Table 6. PWR 4 loops, average outage collective dose and standard deviation by sister unit group and year**

| Sister unit group *(No. of reactors)* | Type of data | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| F42 *(20)* | av. outage coll.dose | 0.67 | 0.82 | 0.75 | 0.59 | 0.67 | 0.70 |
| | σ (standard deviation) | 0.46 | 0.55 | 0.33 | 0.44 | 0.46 | 0.46 |
| | No. of outages | 16 | 12 | 13 | 15 | 15 | 13 |
| F43 *(4)* | av. outage coll.dose | 0.51 | 0.26 | 0.16 | 0.40 | 0.16 | 0.26 |
| | σ (standard deviation) | 0.04 | 0.04 | 0.05 | 0.09 | 0.08 | 0.16 |
| | No. of outages | 2 | 4 | 4 | 4 | 5* | 4 |
| M41 *(1)* | av. outage coll.dose | 0.86 | 1.29 | 3.58 | - | 1.22 | - |
| | No. of outages | 1 | 1 | 1 | - | 1 | - |
| M42 *(4)* | av. outage coll.dose | 1.20 | 1.06 | 1.72 | 1.17 | 1.62 | 1.29 |
| | σ (standard deviation) | 0.39 | 0.24 | 0.97 | 0.17 | 0.80 | 0.18 |
| | No. of outages | 4 | 2 | 3 | 3 | 3 | 2 |
| S41 *(3)* | av. outage coll.dose | 3.03 | 4.37 | 2.72 | 3.64 | 3.24 | 3.97 |
| | σ (standard deviation) | 3.42 | 0.38 | 0.14 | 1.71 | 2.21 | 0 |
| | No. of outages | 3 | 2 | 2 | 3 | 3 | 1 |
| S42 *(5)* | av. outage coll.dose | 0.44 | 0.24 | 0.48 | 0.27 | 0.65 | 0.23 |
| | σ (standard deviation) | 0.45 | 0.08 | 0.42 | 0.14 | 0.57 | 0.06 |
| | No. of outages | 5 | 5 | 5 | 5 | 4 | 5 |
| S43 *(3)* | av. outage coll.dose | 0.15 | 0.07 | 0.12 | 0.17 | 0.07 | 0.13 |
| | σ (standard deviation) | 0.08 | 0.01 | 0.04 | 0.07 | 0.00 | 0.03 |
| | No. of outages | 3 | 3 | 3 | 3 | 3 | 3 |
| W41 *(17)* | av. outage coll.dose | 1.24 | 1.38 | 1.39 | 1.25 | 1.47 | 1.65 |
| | σ (standard deviation) | 0.48 | 0.62 | 0.33 | 0.45 | 0.74 | 0.80 |
| | No. of outages | 13 | 11 | 10 | 10 | 12 | 9 |
| W42 *(15)* | av. outage coll.dose | 1.03 | 0.72 | 0.93 | 1.08 | 0.92 | 1.19 |
| | σ (standard deviation) | 0.63 | 0.26 | 0.18 | 0.50 | 0.30 | 0.41 |
| | No. of outages | 12 | 7 | 8 | 13 | 9 | 7 |

* 2 outages were performed in 2006 in Chooz B1