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## **ISOE INFORMATION SHEET**

# **UPDATE OF THE ANNUAL OUTAGE DURATION AND DOSES IN EUROPEAN REACTORS (1993-2001)**

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This Information Sheet presents, on the basis of three year rolling averages for the time period 1993-2001, an analysis of the evolution and dispersion of outage doses, outage durations and outage doses per day in the reactors participating in ISOE through the European Technical centre (see Annex).

The data from the ISOE 1 database are available on a calendar year basis. Therefore, when an outage starts during one calendar year and ends during the next year, doses and duration for the outage from the first year have been added to those of the second year. In that case, the outage is assigned to the year of the beginning of the outage.

### **1. Evolution per reactor type**

Table 1 gives the three year rolling average of the outage dose, outage duration and outage dose per day, and the number of outages considered for the PWRs, BWRs and VVERs.

**Table 1. Three year rolling average of the outage dose, outage duration and outage dose per day in Europe**

	Years	PWR	BWR	VVER
Average outage dose (man.mSv)	1993-95	1609.65	1449.70	472.91
	1994-96	1457.30	1385.40	495.44
	1995-97	1355.54	1515.95	510.23
	1996-98	1200.68	1539.03	608.07
	1997-99	1078.17	1302.89	548.73
	1998-00	965.56	910.85	594.52
	1999-01	889.49	721.69	491.47
Average outage duration (No. of days)	1993-95	55.22	43.75	44.74
	1994-96	51.19	42.76	44.78
	1995-97	51.59	44.47	47.15
	1996-98	50.35	48.45	51.52
	1997-99	52.54	46.19	49.36
	1998-00	53.55	40.00	48.98
	1999-01	51.84	32.02	45.43
Average outage dose/day (man.mSv/day)	1993-95	29.15	33.13	10.57
	1994-96	28.47	32.40	11.07
	1995-97	26.27	34.09	10.82
	1996-98	23.85	31.77	11.80
	1997-99	20.52	28.21	11.12
	1998-00	18.03	22.77	12.14
	1999-01	17.16	22.54	10.82
<i>Total number of outages</i>	<i>1993-95</i>	<i>230</i>	<i>57</i>	<i>38</i>
	<i>1994-96</i>	<i>235</i>	<i>59</i>	<i>40</i>
	<i>1995-97</i>	<i>239</i>	<i>58</i>	<i>41</i>
	<i>1996-98</i>	<i>232</i>	<i>60</i>	<i>42</i>
	<i>1997-99</i>	<i>234</i>	<i>57</i>	<i>42</i>
	<i>1998-00</i>	<i>234</i>	<i>57</i>	<i>42</i>
	<i>1999-01</i>	<i>238</i>	<i>57</i>	<i>44</i>

As far as PWRs are concerned, the three year rolling average outage dose shows a regular decrease from the period 1993-1995 to the period 1999-2001 (reaching -45% at the end of the period). During the same period, the average outage duration has fluctuated around 52 days ( $\pm 5\%$ ). Therefore, the dose decrease cannot be explained by the evolution of the outage length. However, there has been a continuous decrease of the outage dose per day (-41% for the whole period). As the data represent an average over a large number of plants, several factors may have contributed to this reduction as e.g. work management may have allowed a reduction of the number of workers and of the workload in high dose areas; the work during outages may have been reduced by shifting work to the operational period, or larger improvements may have allowed a reduction in dose rates.

Regarding BWRs, there is no regular tendency for the collective dose during the whole period: after a decrease, an 11% increase can be noticed from 1994-1996 to 1996-1998, followed by a significant decrease (by 53%) in the last periods. A similar evolution may be observed for the outage duration suggesting an impact of the duration on the outage dose. However, this is not enough to explain the reduction of the collective dose during the last period. Therefore, it is not surprising to notice also a significant decrease of the dose per day during the period 1996-1998 / 1999-2001 (-29%).

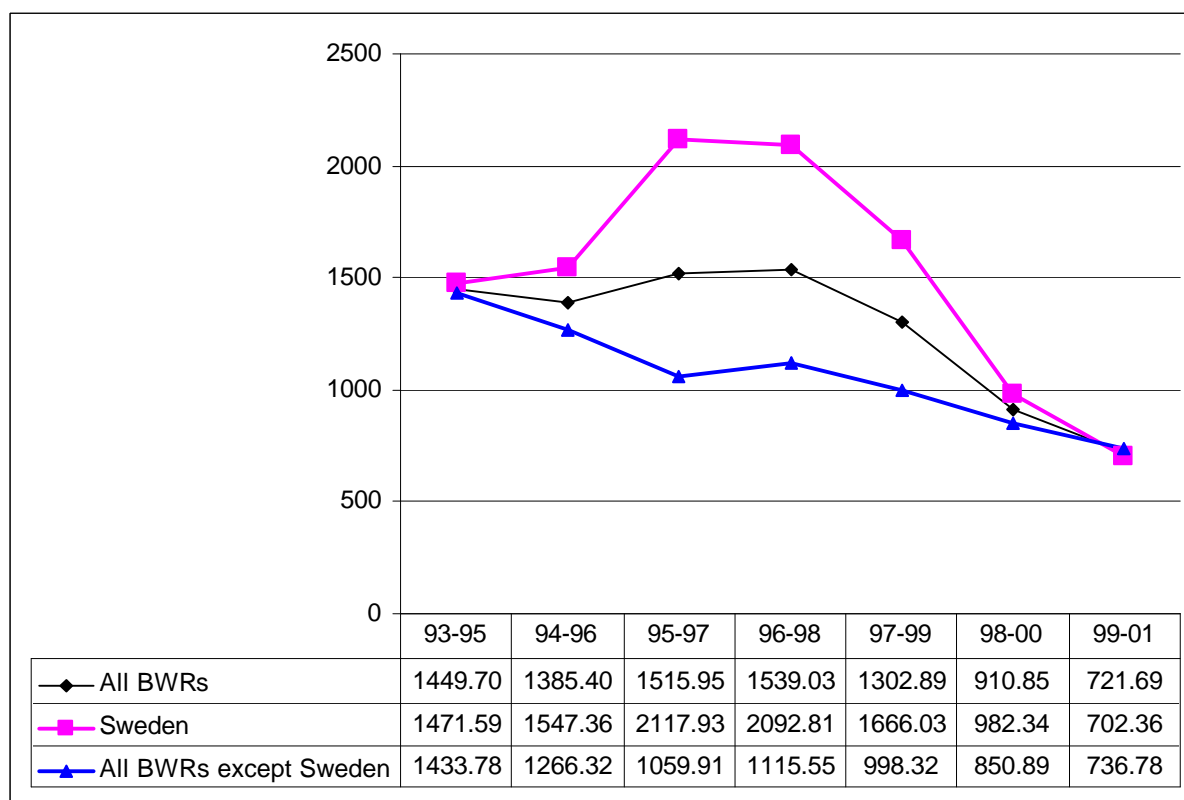
Finally, VVERs have shown a regular increase in the average outage dose up to 1996-1998 when it started to decrease to the same level of outage dose as for the period 1994-1996. During the whole period, the outage dose per day remains quite stable.

**2. Evolution per country**

An analysis has also been performed by country. All the detailed results are given in the Annex.

**2.1 Evolution of BWR outage dose per country**

The evolution of the BWR outage dose appeared to be influenced mainly by the extensive maintenance programme (modernisation) performed in the Swedish BWR reactors. In the following figure, an increase in the outage dose in Sweden up to 1996-1998 can clearly be noticed whereas the doses of other European operating BWRs decreased quite regularly. The modernisation programme has nearly reached its end and the Swedish BWR collective dose per outage is now back to the same level as that of other European BWRs. Up to the 1996-98 period the outage duration continuously increased in Sweden but since then, a decrease started (-66% from 96-98 to 99-01). The dose per day fluctuated around 37 man.mSv/day up to 1996-1998, it then showed a significant decrease, down to 18 man.mSv/day in 1999-2001 which is the lowest dose per day ever found in Europe. Therefore, one may expect a positive impact of the modernisation programme on the outage dose in the future.



**Figure 1. BWR Outage Dose Evolution**

## 2.2 Evolution of PWR outage dose per country

Most countries show a regular decrease in the outage dose during the period, except for the U.K. where the first outage doses were already very low (around 0.5 man.Sv). However, two groups of countries may be observed:

- Belgium, Spain, Sweden, Switzerland and the UK with outage doses around 0.3 to 0.6 man.Sv in the last period (1999-2001),
- France and Germany with outage doses around 0.9 to 1.0 man.Sv in the last period (1999-2001).

In the first group, Belgium has good results both in terms of duration and dose per day while Sweden and the UK have very good results mainly in terms of the dose per day.

## 2.3 Evolution of VVER outage dose per country

Except in the Czech Republic where there is regular decrease in the outage doses, the VVERs in the other countries show a tendency to increase their doses. There is a continuous increase in Hungary (from 430 man.mSv in 1993-1995 to 620 man.mSv in 1998-2000) and successively a period of increase and a period of decrease in Finland (an increase up to around 900 man.mSv and then a decrease to about 700 man.mSv).

## ANNEX

**Table A. Three years rolling average of: outage dose, outage duration and outage dose per day (man.mSv) for countries operating BWRs**

	Years	Finland	Germany	Netherlands	Spain	Sweden	Switzerland
Average outage dose (man.mSv)	1993-95	742.27	1567.22	648.48	3359.00	1471.59	1221.74
	1994-96	744.96	1165.44	630.70	2984.03	1547.36	1212.55
	1995-97	625.31	946.72	660.77	2326.59	2117.93	1066.08
	1996-98	790.70	998.34	674.06	2326.59	2092.81	1038.70
	1997-99	673.01	926.02	-	1950.18	1666.03	869.82
	1998-00	684.13	742.27	-	2053.50	982.34	706.02
	1999-01	542.82	588.69	-	1798.63	702.30	617.77
Average outage duration (No. of days)	1993-95	15.50	61.67	52.33	46.33	39.29	39.50
	1994-96	15.67	46.87	57.00	43.25	45.36	41.33
	1995-97	15.83	41.20	56.50	34.25	54.96	40.33
	1996-98	17.67	50.35	56.00	34.25	57.54	42.67
	1997-99	15.50	46.80	-	33.25	56.88	37.67
	1998-00	13.83	40.75	-	36.33	47.88	31.83
	1999-01	11.67	29.00	-	35.75	40.00	24.67
Average outage dose/day (man.mSv/day)	1993-95	47.89	25.41	12.39	72.50	37.45	30.93
	1994-96	47.55	24.87	11.06	68.99	34.11	29.34
	1995-97	39.49	22.98	11.69	67.93	38.54	26.43
	1996-98	44.76	19.83	12.04	67.93	36.37	24.34
	1997-99	43.42	19.79	-	58.65	29.29	23.09
	1998-00	49.45	18.22	-	56.52	20.51	22.18
	1999-01	46.53	20.30	-	50.31	17.56	25.04
<i>Total number of outages</i>	1993-95	6	15	3	3	24	6
	1994-96	6	15	3	4	25	6
	1995-97	6	15	2	4	25	6
	1996-98	6	17	1	4	26	6
	1997-99	6	15	0	4	26	6
	1998-00	6	16	0	3	26	6
	1999-01	6	16	0	4	25	6

**Table B. Three years rolling average of: outage dose, outage duration and outage dose per day (man.mSv) for countries operating PWRs**

	Years	Belgium	France	Germany	Netherlands	Spain	Sweden	Switzerland	UK
Average outage dose (man.mSv)	1993-95	1199.26	1703.22	1868.25	1064.70	1618.20	742.83	988.63	-
	1994-96	991.21	1570.22	1570.21	1049.77	1755.41	648.44	698.25	485.13
	1995-97	822.59	1457.28	1470.91	1443.76	1659.11	642.54	600.13	476.26
	1996-98	609.14	1368.19	1168.09	1370.20	1250.27	530.16	547.14	476.26
	1997-99	505.21	1222.28	1111.23	1145.36	936.75	486.52	588.57	551.08
	1998-00	489.62	1139.02	976.69	383.69	647.93	419.97	585.75	526.96
	1999-01	437.47	1045.63	918.67	329.43	619.59	342.14	540.22	526.96
Average outage duration (No. of days)	1993-95	54.63	59.18	41.66	42.33	50.29	62.33	54.50	-
	1994-96	51.20	56.39	35.64	41.00	54.44	40.56	37.63	55.00
	1995-97	43.63	58.78	32.59	79.00	58.12	38.89	37.13	52.00
	1996-98	38.63	59.67	28.03	73.00	49.33	31.56	34.43	52.00
	1997-99	32.71	64.23	26.95	67.33	46.75	30.78	41.29	57.50
	1998-00	28.33	68.07	29.37	21.33	37.75	42.33	41.00	57.00
	1999-01	27.50	66.45	27.19	16.67	33.63	44.00	40.67	57.00
Average outage dose/day (man.mSv/day)	1993-95	21.95	28.78	44.85	25.15	32.17	11.92	18.14	-
	1994-96	19.36	27.84	44.06	25.60	32.25	15.99	18.56	8.82
	1995-97	18.85	25.22	45.13	18.28	28.55	16.52	16.16	9.16
	1996-98	15.77	22.93	41.68	18.77	25.34	16.80	15.89	9.16
	1997-99	15.45	19.03	41.23	17.01	20.04	15.81	14.26	9.58
	1998-00	17.28	16.73	33.26	17.99	17.16	9.92	14.29	9.24
	1999-01	15.91	15.73	33.79	19.77	18.43	7.78	13.28	9.24
<i>Total number of outages</i>	1993-95	19	139	35	3	17	9	8	0
	1994-96	20	142	36	3	16	9	8	1
	1995-97	19	144	37	3	17	9	8	2
	1996-98	19	139	38	3	15	9	7	2
	1997-99	17	141	39	3	16	9	7	2
	1998-00	18	137	41	3	16	9	8	2
	1999-01	18	139	42	3	16	9	9	2

**Table C. Three years rolling average of: outage dose, outage duration and outage dose per day (man.mSv) for countries operating VVERs**

	Years	Czech Rep.	Finland	Hungary	Slovak Rep.
Average outage dose (man.mSv)	1993-95	355.87	816.94	433.08	439.73
	1994-96	328.47	895.57	488.46	451.78
	1995-97	338.19	700.74	509.74	594.54
	1996-98	314.26	906.49	582.45	778.27
	1997-99	299.48	698.45	540.05	731.82
	1998-00	262.12	891.59	623.66	749.25
	1999-01	263.61	732.15	569.30	516.92
Average outage duration (No. of days)	1993-95	47.36	29.17	41.83	55.78
	1994-96	46.91	34.67	38.42	55.09
	1995-97	50.42	26.33	37.00	66.00
	1996-98	48.58	30.50	39.67	76.83
	1997-99	45.25	22.67	40.00	76.17
	1998-00	40.83	27.50	41.83	75.00
	1999-01	40.58	24.67	39.83	63.29
Average outage dose/day (man.mSv/day)	1993-95	7.51	28.01	10.35	7.88
	1994-96	7.00	25.83	12.71	8.20
	1995-97	6.71	26.61	13.78	9.01
	1996-98	6.47	29.72	14.68	10.13
	1997-99	6.62	30.81	13.50	9.61
	1998-00	6.42	32.42	14.91	9.99
	1999-01	6.50	29.68	14.29	8.17
<i>Total number of outages</i>	1993-95	11	6	12	9
	1994-96	11	6	12	11
	1995-97	12	6	12	11
	1996-98	12	6	12	12
	1997-99	12	6	12	12
	1998-00	12	6	12	12
	1999-01	12	6	12	14