Russian VVER– 1000 Reactors of V-187, V-338 and V-320 types: Collective Occupational Exposure Trends and Main Source-Term Reduction Efforts during the Planned Maintenance Works

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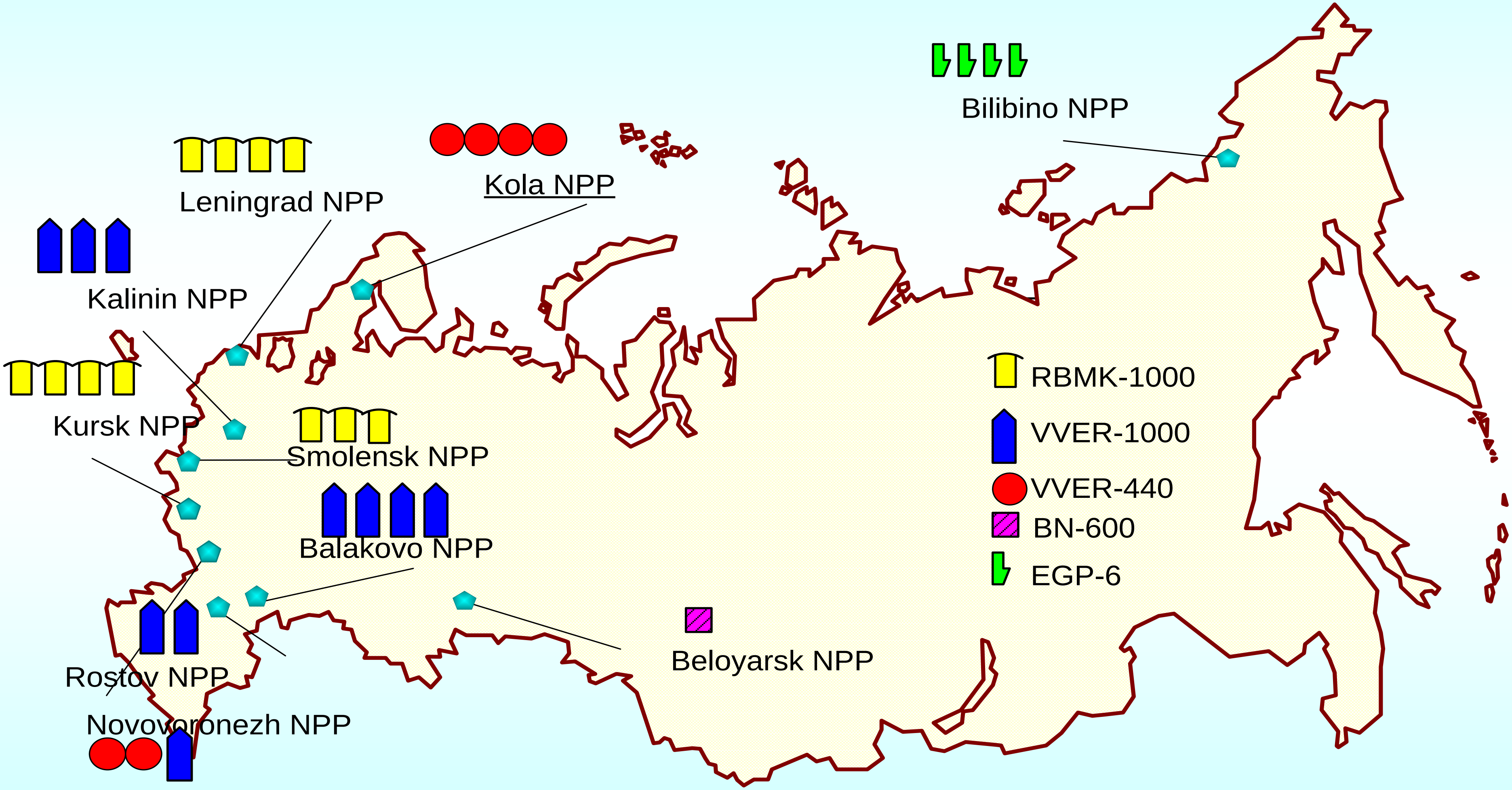
Russian operating reactors



At present time, there are 32 operating reactors at 10 Plants. According to reactor type and output, these reactors are divided by:

- **10 units VVER-1000 of 1000 MWe reactors;**
- **6 units VVER-440 of 440 MWe reactors;**
- **11 units RBMK-1000 of 1000 MWe reactors;**
- **1 unit BN-600 fast breeder reactor of 600 MWe (Beloyarsk);**
- **4 units EGP (custom-build water –graphite channel type reactor) with output 12 MWe each (Bilibino).**

Moreover, 4 reactors (2 units at Novovoronezh NPP and 2 units at Beloyarsk NPP) are at different stages of decommissioning.

In the year 2011, Russian operating reactors total output was 24242 MWe which provided near 16% from the total electricity production in the country.

Contribution of nuclear energy production is the most high in the industrialized North-West region where it is 37% approximately

Russian VVER (PWR) – 1000 operating reactors

Model, number of reactors	Name of reactor	First power (in chronological order)
V– 187, 1 reactor (prototype)	Novovoronezh 5	1980
V-338 , 2 reactors	Kalinin 1	1984
	Kalinin 2	1986
V-320, – 7 reactors	Balakovo 1	1985
	Balakovo 2	1987
	Balakovo 3	1988
	Balakovo 4	1993
	Rostov 1	2001
	Kalinin 3	2004
	Rostov 2	December 2010

VVER (PWR)-1000 total output is 10000 MWe or 41,3% from the total output of all Russian NPPs

It should be useful to compare three-year rolling average occupational exposure indicators for the periods 2000-2002 (*, **) and 2009-2011 to determine the exposure trends at VVER-1000/V-187, V-338 and V-320 models.

(*) – In 2000, the new national Radiation Protection Act was approved. In accordance with this Act, the main occupational dose limit was determined as 100 mSv per five successive years instead of 50 mSv/year used before.

(**) – For reactors which were put into operation after 2000, the first three year period of their operation was taken.

Sister group V-187: Novovoronezh 5

Three-year rolling average ANNUAL collective dose per unit

	2000 – 2002	2009 - 2011
Novovoronezh 5	1193 man·mSv /unit	930 man·mSv /unit

In the period 2009-2011, three-year rolling average annual collective dose decreased at 22% compared to 2000-2002

Three-year rolling average PLANNED OUTAGE collective dose per unit and three-year rolling average duration per unit

	2000 – 2002	2009- 2011
Novovoronezh 5	906 man·mSv /unit 64 days /unit	842 man·mSv /unit 142 days /unit

In the period 2009-2011, three-year rolling average outage collective dose decreased at 7% compared to 2000-2002 against the outage duration 122% increase

Sister group V-338: Kalinin 1 and Kalinin 2

Three-year rolling average ANNUAL collective dose per unit

	2000 – 2002	2009 - 2011
Kalinin 1 Kalinin 2	1223 man·mSv /unit	705 man·mSv /unit

In the period 2009-2011, three-year rolling average annual collective dose decreased at 42% compared to 2000-2002

Three-year rolling average PLANNED OUTAGE collective dose per unit and three-year rolling average duration per unit

	2000 – 2002	2009- 2011
Kalinin 1 Kalinin 2	1005 man·mSv /unit 62 days /unit	600 man·mSv /unit 48 days /unit

In the period 2009-2011, three-year rolling average outage collective dose decreased at 40% compared to 2000-2002 against the outage duration 23% decrease

Sister group V-320: Balakovo 1, Balakovo 2, Balakovo 3, Balakovo 4

Three-year rolling average ANNUAL collective dose per unit

	2000 – 2002	2009 - 2011
Balakovo 1 Balakovo 2 Balakovo 3 Balakovo 4	673 man·mSv /unit	526 man·mSv /unit

In the period 2009-2011, three-year rolling average annual collective dose decreased at 22% compared to 2000-2002

Three-year rolling average PLANNED OUTAGE collective dose per unit and three-year rolling average duration per unit

	2000 – 2002	2009- 2011
Balakovo 1 Balakovo 2 Balakovo 3 Balakovo 4	593 man·mSv /unit 76 days /unit	422 man·mSv /unit 38 days /unit*

In the period 2009-2011, three-year rolling average outage collective dose decreased at 29% compared to 2000-2002 against the outage duration 50%* decrease (* it should be noted that there were no outages at Unit 1 (2009), Unit 2 (2010) and Unit 3 (2011)

Sister group V-320: Rostov 1

Three-year rolling average ANNUAL collective dose per unit

	2002 – 2004	2009 - 2011
Rostov 1	185 man·mSv /unit	122 man·mSv /unit

In the period 2009-2011, three-year rolling average annual collective dose decreased at 34% compared to 2002-2004

Three-year rolling average PLANNED OUTAGE collective dose per unit and three-year rolling average duration per unit

	2002 – 2004	2009- 2011
Rostov 1	174 man·mSv /unit 48 days /unit	97 man·mSv /unit 37 days /unit

In the period 2009-2011, three-year rolling average outage collective dose decreased at 44% compared to 2000-2002 against the outage duration 23% decrease

Sister group V-320: Kalinin 3

Three-year rolling average ANNUAL collective dose per unit

	2005 – 2007	2009 - 2011
Kalinin 3	198 man·mSv /unit	256 man·mSv /unit

In the period 2009-2011, three-year rolling average annual collective dose increased at 29% compared to 2005-2007

Three-year rolling average PLANNED OUTAGE collective dose per unit and three-year rolling average duration per unit

	2005 – 2007	2009- 2011
Kalinin 3	183 man·mSv /unit 62 days /unit	235 man·mSv /unit 51 days /unit

In the period 2009-2011, three-year rolling average outage collective dose increased at 40% compared to 2005-2007 against the outage duration 18% decrease

As may be seen from slides # 6-10, the most considerable annual and outage collective doses decrease in 2009-2011 compared to 2000-2002 was observed at Kalinin 1 and Kalinin 2 reactors.

Sister group V-338: Kalinin 1 and Kalinin 2

Three-year rolling average ANNUAL collective dose per unit

	2000 – 2002	2009 - 2011
Kalinin 1 Kalinin 2	1223 man·mSv /unit	705 man·mSv /unit

In the period 2009-2011, three-year rolling average annual collective dose decreased at 42% compared to 2000-2002

Three-year rolling average PLANNED OUTAGE collective dose per unit and three-year rolling average duration per unit

	2000 – 2002	2009- 2011
Kalinin 1 Kalinin 2	1005 man·mSv /unit 62 days /unit	600 man·mSv /unit 48 days /unit

In the period 2009-2011, three-year rolling average outage collective dose decreased at 40% compared to 2000-2002 against the outage duration 23% decrease

Main reasons of significant occupational exposure at Kalinin 1 and 2 in 2000-2002:

- **Principal activities were aimed at keeping the individual doses at the level less than the main individual dose limit;**
- **Administrative pressure for decreasing of collective dose values was not quite sufficient;**
- **Adequate control of jobs and sub-jobs collective doses during the maintenance and repairing works could not be performed because of the old types or deficiency of electronic personal dosimeters;**
- **Many workers were extra exposed on the way to the working areas ("transit" doses);**
- **Plant staff did not have enough specialized tooling and instrumentation for working in high dose rate areas**

Main factors influenced on decrease of occupational exposure indicators at Kalinin 1 and 2 in the period 2007-2009:

- **Strengthening of the administrative pressure of Concern Rosenergoatom (Russian operating utility) aimed at collective doses optimization at all Russian NPPs and Kalinin plant too;**
- **Overall support of occupational exposure decrease policy by all senior managers of Kalinin NPP;**
- **Development of Kalinin NPP ALARA programme. Personnel education and training in ALARA principles;**
- **Practical implementation of the international experience as well as the recommendations of "Work Management in the Nuclear Power Industry", in particular;**
- **Development of the annual dose budget documentation and the planned outage reports;**
- **Application of modern personnel dosimetry equipment and software for occupational exposure control**

Three-year rolling average collective dose per system or job for Kalinin 1 and 2 during the periods of 2000-2002 and 2009-2011

System or Job	2000 - 2002, man·mSv /unit	2009 - 2011, man·mSv /unit
Refuelling	**26**	**25**
Reactor vessel	**255**	**248**
Reactor coolant pumps	**52**	**31**
Residual heat removal system	**20**	**18**
Chemical and volume control system	**19**	**22**
Steam generators: total of primary and secondary sides	**175**	**58**
Reactor water clean-up system	**10**	**8**
Pressuriser	**22**	**10**
Primary circuit	**12**	**8**
Scaffolding	**13**	**15**
Heat insulation	**90**	**38**

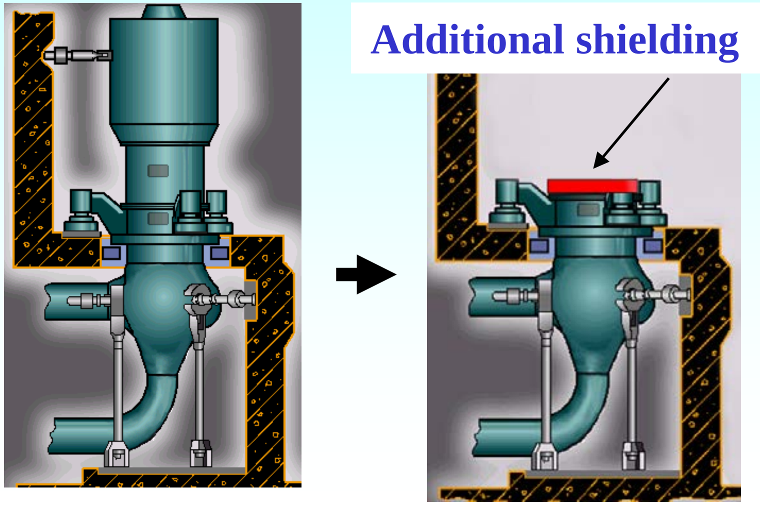
Optimization of occupational exposure during maintenance works at reactor coolant pumps

1. Decrease of gamma dose rate from sealing water pipes (presence of high radioactive point sources in the pipes gave dose rate around 10-100 mSv/h).

Methods to decrease: pipes flushing, installation of lead shielding, cutting the pipe section with high radioactive point sources.

Result: collective dose decreased at 5-7 man·mSv/unit per every outage; decrease of workers "transit" doses

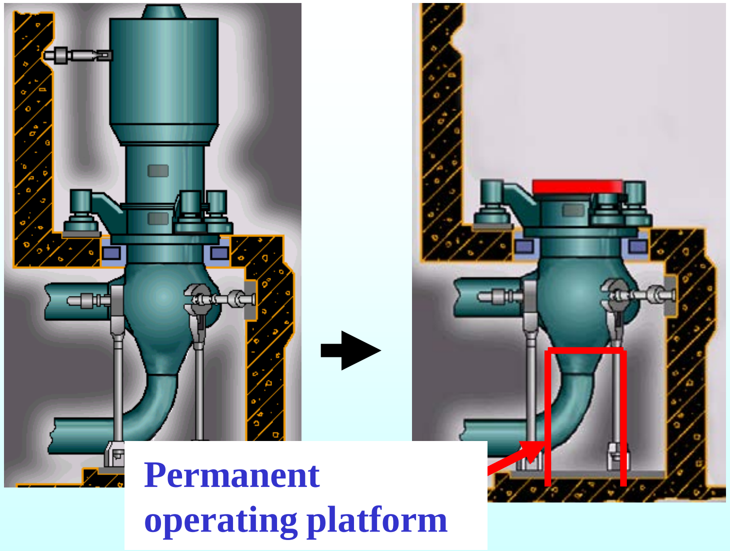
Optimization of occupational exposure during maintenance works at reactor coolant pumps (continuation)



2. The working area of the opened (i.e. without electromotor) pump elbow was characterized by the dose rate near 2,5 mSv/h.

A hollow steel disc loaded with the lead shot was used as the additional shielding to decrease the dose rate.

Result: decrease of dose rate to 50 µSv/h; decrease of workers "transit" doses.

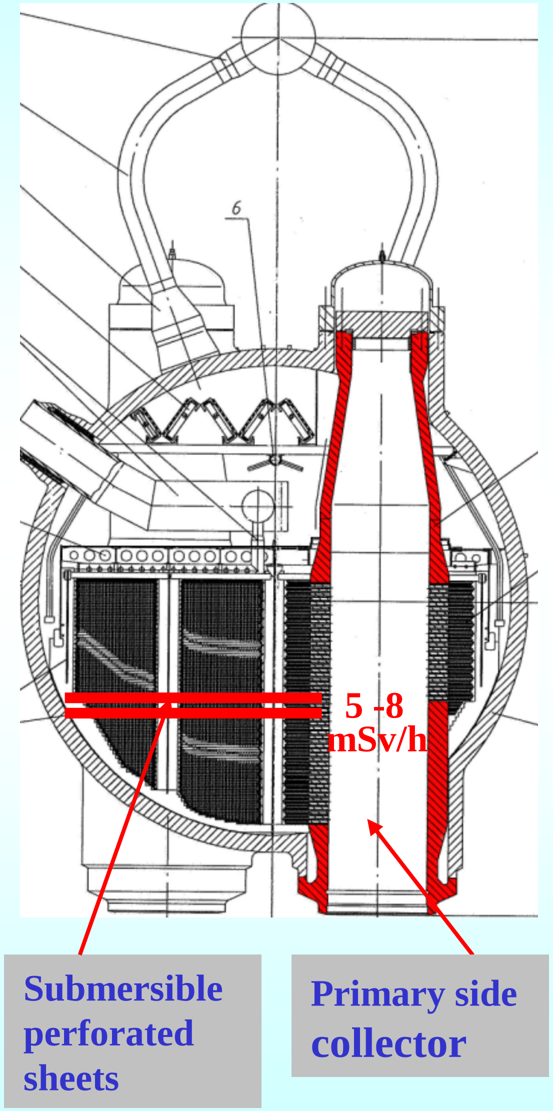


3. The temporary scaffoldings were initially used during every inspection and repair in the area of pump elbow. Installing and dismantling of the scaffoldings resulted in additional doses.

According to the data of special investigation, the permanent operating platform was designed and constructed.

Result: collective dose decreased at 6-8 man·mSv/unit per every outage

Optimization of occupational exposure during maintenance works at steam generators



1. Improvement of decontamination of the primary side collectors.

2. The special manipulator was used for the plugging of defective steam generator tubing at the primary side collectors.

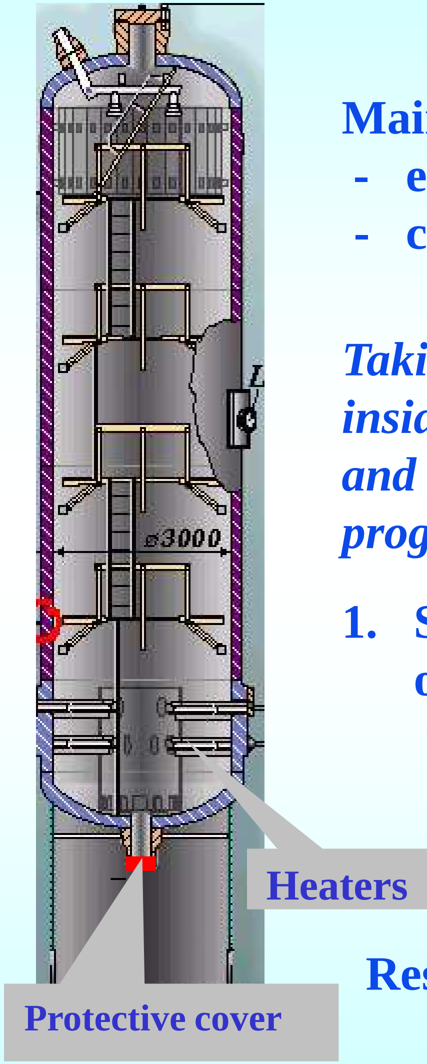
3. Optimization of bioshield in the area of submersible perforated sheets.

Lessons learned: a. Special investigation showed that the most effective occupational radiation protection was based on the procedure of changing the maximum water level for different maintenance works.

b. Installation of portable shieldings in the area of submersible perforated sheets did not provide considerable effect of dose rate decrease.

Result: collective dose decreased at 60-70 man·mSv/unit per every outage

Optimization of occupational exposure during maintenance works at pressuriser



Main jobs at the period of planned outages include the following:

- **examination and control of metal inside the pressuriser;**
- **control and replacement of pressuriser heaters.**

Taking into account the high potential danger of internal exposure, all jobs inside the pressuriser are treated as specially radiation dangerous works and should be performed accordance with the detailed ALARA programme.

1. **Special protective cover was installed at the pipe for reduction of occupational exposure during maintenance and repair of heaters;**
2. **Decontamination of the local equipment from the outside of pressuriser has been performed to decrease gamma background during heaters replacement.**

Result: collective dose decreased at 7-10 man·mSv/unit per every outage

Optimization of occupational exposure during maintenance works with thermal insulation

An example of steam generator quick detachable thermal insulation cassettes

Main dose optimization arrangement was connected with the wide use of quick detachable thermal insulation cassettes made of stainless steel cover filled with different types of insulating materials.

Thermal insulation installing /dismantling doses were significantly decreased as the result of rapid fastening equipment application. Moreover, the risk of personnel internal exposure was removed.

Result: collective dose decreased at
20-30 man·mSv/unit per every outage;
staff safety culture was improved

CONCLUSIONS

1. Ten Russian reactors VVER-1000 of the 2^{nd} design generation according to Russian classification (3^{rd} Soviet-design generation of VVER according to ISOE classification) have quite different occupational exposure indicators. For example, in the period 2009-2011, the value of three-year rolling average annual collective dose vary from 122 man·mSv/unit at Rostov 1 (V-320 type) to 930 man·mSv/unit at Novovoronezh 5 (V-187 type).

2. Distinctions in occupational exposure indicators are connected with a set of reasons. The most important reasons are:

- **practical design characteristics of V-187 (1 unit), V-338 (2 units) and V-320 (7 units) reactor types ;**
- **different time of reactors operation;**
- **management features of planning, preparation and implementation of radiation dangerous works at different plants.**

CONCLUSIONS (continuation)

3. Model V-338 at Kalinin 1 and 2 compared to the V-187 at Novovoronezh 5 (which was the prototype of all next VVER-1000 reactors) had considerable modernization:

- **total number of control rod drives decreased to 61 at model V-338 compared to 109 at model V-187;**
- **modernization of reactor vessel cavity.**

4. Main design and operational distinctions of model V-320 (7 reactors in Russia, 11 reactors in Ukraine, 2 reactors in Bulgaria, 2 reactors in Czech Republic plus 5 operating VVER-1000 reactors of V-320 modernized model in China, India and Iran) from V-338 are as follows:

- **modernization of reactor pressure vessel head;**
- **using titanium dioxide instead of ion-exchange resins in reactor water cleanup system;**
- **optimization of equipment arrangement in reactor area;**
- **absence of main isolating valves at primary circuit pipe (there are 2 main isolating valves at every loop or 8 valves at every V-187 and V-338 reactor)**

CONCLUSIONS (continuation)

5. There is some trend of decreasing annual and outage collective dose for majority of Russian VVER-1000 model V-187, 338 and 320 reactors in the period 2009-2011 compared to 2000-2002 (*).
(*) – period of three first operation years was taken for reactors with first power after 2000.

6. Maintenance works over the planned outages define the main (80-90%) contribution to the annual collective doses. Different outage durations and amounts of maintenance works have a considerable influence.

7. Development the ALARA programme at every plant as well as workers education and training to implement the ALARA approach serve as the main organizational method of occupational exposure decreasing

8. Monitoring and analysis of occupational exposure indicators for different systems and jobs based on Russian dose control computer based system and ISOE database make possible to estimate the saving of collective dose during implementation of technical methods

Thank You for Attention!