COUNTRY REPORT
RUSSIAN FEDERATION

DESKTOP STUDY

1. BACKGROUND INFORMATION

1.1 GENERAL ENERGY SITUATION

The electric power complex of Russia was transformed from the state-owned structure into joint stock and partially privatised utilities, which employ about 1 million people. The Russian Joint Stock company "United Power System of Russia" (RAO EES of Russia) was established to control the system. Shares of 186 joint stock companies form the company's authorised capital stock. The Federal All-Russia Wholesale Power Market (FOREM) was created. The Federal legal basis and the state regulatory system for power and heat tariffs are being developed. The Government owns 52.5% of RAO EES's stock of which 70% is owned by the Federal Government and the remaining 30% by local Government. Foreign investors own 29% of RAO EES's stock, and Russian investors own 18.5%.

However, for various different reasons the incorporation and privatisation of the power sector did not result in complete fulfilment of all plans. A number of regional power systems supported by local administrations did not bring their power plants, or their intersystem grids and facilities, into the common market. Control over electricity generation used to be governed by Presidential Decrees, Government Decrees and Orders but there is now a gap in the legislation which has not been completely bridged.

The present status of power generation is characterised by a number of problems; non-payments (which account for up to 25% of the total volume of production), ageing of assets (more than 1/3 of the industrial assets have exceeded their designed service life), lack of investment, significant loss of power markets, imperfection of the governmental pricing policies, cross-subsidisation and poor liaison between the federal and regional authorities.

The distribution of installed capacity over the different sources is shown in the table below.

1999	**%** **Installed capacity**
Nuclear	10
Gas	41
Hydro	22
Oil and coal	27
Total	**100**

1.2 STATUS AND PERSPECTIVES OF NUCLEAR POWER

In 1999 the Russian NPP's generated 120 TWh of electricity which constituted 116% of the 1998 generation. The installed capacity factor was 64,5%, which is 8,9 % higher than that of 1998.

All power industry development scenarios give a prominent place to nuclear power in Russia. The main task for the current period is upgrading and modernisation of NPP's. Taking into account the expenditure incurred by this process and the economic situation in the country, one can not consider the commissioning of new large NPP power capacities in the near future. The priority is to finalise construction of the power units which have been "moth-balled" and having the highest readiness degree, in particular, Rostov-1, Kalinin-3 and Kursk-5. The State Environmental Expertise of the Russian Federation approved the commissioning of the Rostov-1, which could be put into operation in the year of 2000.

Depending on the progress in developing new generation reactors, the next decade shall provide a solution to the issue of the pace of decommissioning operating NPP's and also commissioning new NPP power capacities in the western, central and far eastern regions of Russia. Nuclear power is seen as the most competitive compared to other branches of power industry in these regions. Depending on the UPS development scenario and the economic situation in Russia, the power generation by NPP's in the country will be 125-160 TWh, i.e., the NPP share in the total power generation will remain steady.

The Government of the Russian Federation has approved "The Programme of Nuclear Power Development in the Russian Federation for 1998–2005 and for the period till 2010" (hereinafter referred to as "the Programme"). The Programme has two structural phases. In the course of the first phase (1998–2005) it is planned to continue the activities started earlier to upgrade operating NPP's with the aim of extending their safe operation and increasing the available power capacity by completing the construction of units which have already been started, developing and starting construction of the new generation power units on the basis of the developed technologies. In the course of the second phase (2001–2005 and the period till 2010) the main trend will be to build up power capacity based on new generation power units, improve technical and economic indexes of operating NPP's including their service life extension, decommissioning power units with exhausted service lives, and starting large-scale development of nuclear power on the basis of the new generation power units beyond 2010.

2. PERFORMANCE OF EVALUATIONS

2.1 GENERAL INFORMATION ON THE PLANT

WWER-440:

Six WWER-440 NPP units are in operation in the Russian Federation, including two units of each of the types V-179 (Novovoronezh 3,4), V230 (Kola 1,2) and V-213 (Kola 3,4). The types V-179 and V-230 are of the first generation and the type V-213 is of the second generation of WWER-440 units.

WWER-1000:

Seven WWER-1000 NPP units are in operation in the Russian Federation, including four V-320 power units at Balakovo nuclear power plant (units 1-4), and NPP units of "small series" such as two V-338 power units at Kalinin nuclear power plant (units 1-2), and one V-187 power unit at Novovoronezh nuclear power plant (unit 5).

Pilot WWER-1000 at Novovoronezh NPP and WWER-1000 designs of so-called "small series" are the first of the kind in Russia. Units 1 and 2 of the Kalinin nuclear power plant and unit 5 of the Novovoronezh nuclear power plant were commissioned between 1981 and 1987. In terms of their design features and safety characteristics, the units comply with the safety standards and regulations applicable at the time of their construction.

WWER-1000 units of the third generation include all four power units at the Balakovo nuclear power plant, which were commissioned between 1986 and 1993. The third-generation power unit designs were developed on the basis of more recent safety requirements and principles (e.g., OPB-82).

RBMK:

The development of the boiling water cooled graphite moderated pressure tube reactor system (RBMK) came out of the Soviet uranium-graphite Pu production reactors, the first of which began operation in 1948. In 1954 a demonstration 5 MW_{el} reactor began operation in Obninsk and subsequently a series of reactors were developed using the combination of graphite moderation and water cooling in a channel design.

Currently there are 11 RBMK reactors in operation in Russia. The connection to the electric power grid of these units took place from 1973 (Leningrad 1) to 1990 (Smolensk 3).

Over the course of the 20 years of development, three generations have emerged which have significant differences, particularly with respect to the safety provisions built into design. The electric power of the RBMK reactors is 1000 MW_{el} except for Ignalina NPP whose one unit power is 1500 MW_{el}. The development of the Kursk Unit 5 has led to many design changes, hence it can be thought of as a fourth generation.

The first generation units (Leningrad 1 and 2, Kursk 1 and Chernobyl 1 and 2) were designed and built before 1982 when new standards OPB-82 for the design and construction were introduced in the Soviet Union. Since than other units have been designed and constructed in accordance to OPB-82 requirements. However, the safety standards in the USSR were revised again in 1988 (OPB-88).

Fast Reactors:

The world's first prototype fast reactor power plant was the BN-350 at Aktau in Kazakhstan. The 350 MW_{el} uranium oxide fuelled reactor was built on the Caspian shore. In 1976, construction began on the BN-600 reactor, a 600 MW_{el} plant, at Beloyarsk in Russia; The construction was completed even before the BN-350 at Aktau. Unlike the previous reactors, BN-600 is a pool type design. Criticality was achieved in 1980. The reactor uses a mixed uranium-plutonium oxide fuel in annular pellets. Further fast reactors were planned in the Newly Independent States (NIS): BN-800 and BN-1600 plants reached the design stage but have been suspended due to lack of funding and the collapse of the former Soviet Union.

Out of the 3 units at the Beloyarsk nuclear power plant, units 1 and 2 were shutdown due to problems with the reactor channels; Only unit 3 is still operating.

NPP Unit	Reactor Type	Start of Operation	End of Lifetime by Design
Balakova 1	WWER 1000/V320	1986	2016
Balakova 2	WWER 1000/V320	1988	2018
Balakova 3	WWER 1000/V320	1989	2019
Balakova 4	WWER 1000/V320	1993	2023
Beloyarsk 1	AMB 100	1963	Shutdown in 1980 Start decomm. 1983
Beloyarsk 2	AMB 160	1967	Shutdown in 1989 Start decomm. 1990
Beloyarsk 3	BN 600	1980	2010
Beloyarsk 4	BN 800	Planned	
Bilibino 1	EGP 6	1974	2004
Bilibino 2	EGP 6	1974	2004
Bilibino 3	EGP 6	1975	2005
Bilibino 4	EGP 6	1976	2006
Kalinin 1	WWER 1000/V338	1985	2015
Kalinin 2	WWER 1000/V338	1987	2017
Kalinin 3	WWER 1000	Construction start 1985	

NPP Unit	Reactor Type	Start of Operation	End of Lifetime by Design
Kola 1	WWER 440/V230	1973	2003
Kola 2	WWER 440/V230	1974	2004
Kola 3	WWER 440/V213	1981	2011
Kola 4	WWER 440/V213	1984	2014
Kola 5	WWER 640	Planned	
Kola 6	WWER 640	Planned	
Kola 7	WWER 640	Planned	
Kursk 1	RBMK 1000 -gen.1	1976	2006
Kursk 2	RBMK 1000 -gen.1	1978	2008
Kursk 3	RBMK 1000 -gen.2	1983	2013
Kursk 4	RBMK 1000 -gen.2	1985	2015
Kursk 5	RBMK 1000 -gen.4	Construction start 1985	
Leningrad 1	RBMK 1000 -gen.1	1973	2003
Leningrad 2	RBMK 1000 -gen.1	1975	2005
Leningrad 3	RBMK 1000 -gen.2	1979	2009
Leningrad 4	RBMK 1000 -gen.2	1981	2011
Novovoronezh 1	WWER 210/V1	1964	Shutdown 1984 Start decomm. 1988
Novovoronezh 2	WWER 365/V3M	1970	Shutdown in 1990 Start decomm. 1990
Novovoronezh 3	WWER 440/V179	1971	2001
Novovoronezh 4	WWER 440/V179	1972	2002
Novovoronezh 5	WWER 1000/V187	1981	2011
Novovoronezh 6	WWER 1000	Planned	
Novovoronezh 7	WWER 1000	Planned	
Rostov 1	WWER 1000	Construction start 1981	
Rostov 2	WWER 1000	Construction start 1983	
Smolensk 1	RBMK 1000 -gen.2	1982	2012
Smolensk 2	RBMK 1000 -gen.2	1985	2015
Smolensk 3	RBMK 1000 -gen.3	1990	2020
South Ural 1	BN 800	Construction start 1993	
Sosnovy Bor 1	WWER 640	Planned	
Voronezh 1	AST 500	Construction start 1983	
Voronezh 2	AST 500	Construction start 1985	

The finalisation of the construction of the power units which have been “moth-balled” and having the highest readiness degree, in particular Rostov-1, Kalinin-3 and Kursk-5, has a high priority.

2.2 PLANT DESIGN

2.2.1 Review of Safety Aspects of the Original Design

Safety Philosophy and Design Basis:

WWER-440/230:

The WWER-440/230 plants were designed in the 1960s with the objective of producing electric power with high plant availability. This intent is evidenced in design features such as the low heat production with respect to the fuel weight, a reactor protection system that has three levels of response before the full scram, six primary coolant loops containing a hot and a cold leg isolation valve, horizontal steam generator designs with relatively large water inventories, two turbine generators for each unit permitting operation at reduced power and the possibility to utilise unit tied systems for neighbouring units (system intermeshing). Plant parameters with large margins between operating conditions and safety limits provide flexibility to cope with operational transients. The design features also offer a potential for on-line repairs or maintenance facilitated by measures (e.g. the primary coolant purification system) to keep the radiation fields low.

The safety concept of the WWER-440/230 NPP’s was based on the fact that primary circuit failures which would result in severe core damage were not taken into consideration. Therefore, the original design does not include any special provisions to protect against a large failure of the primary circuit boundary. The original bounding LOCA design basis accident (DBA) was the loss of integrity of the primary cooling circuit equivalent to a break of a connection line (max. 32 mm diameter).

The safety concept of the confinement for accidents exceeding the design basis aims at the possibility of dumping (via flaps) steam-air mixtures (with the normal radioactivity of the primary circuit) from the confinement into the atmosphere at the beginning of an accident before any significant fuel damage occurs.

The main safety deficiencies of the original design are:
- Insufficient capacity for emergency cooling,
- Insufficient confinement,
- Poor physical separation of redundant systems,
- Insufficient instrumentation and control,
- Insufficient fire protection measures.

The safety concept includes no design features against external hazards (e.g., seismic hazards). Further, the design of the safety systems does not consider common cause failures. Compared with current practice for most other plant types, the DBA analysis is very limited.

WWER-440/213:

The WWER-440/213 NPP's were put into commercial operation between 1977 (Loviisa NPP Unit 1) and 2000 (Mochovce Unit 2). In the design of this second generation of WWER type 440 NPP's significant safety improvements were introduced compared to the V440/230. The characteristics and the layout of the main components remained the same. The WWER-440/213 NPP's were built with modules of two units, in a single reactor building, each unit with six primary coolant loops, isolation valves in each loop, horizontal steam generators and two 220 MW_{el} steam turbines.

The inherent safety capacity of the WWER-440 (213 and 230) gives considerable safety margins (large volume of primary water, SG water ensures residual-heat removal without feeding for 4-5 hours, stable natural circulation for residual-heat removal up to 9 % of nominal power).

As concerns safety, the bounding LOCA DBA was defined as a double-ended guillotine break in the primary circuit piping. Redundancy of safety systems and their support systems was also increased, compared to the situation in the WWER-440/230 plants. The ECCS was designed in accordance with the new bounding LOCA DBA and covers the entire range of primary piping break sizes. It includes high head and low head pumps as well as accumulator tanks connected directly to the reactor vessel. The confinement function is performed by a pressure-suppression containment with bubbler condenser. Other differences between WWER-440/230 plants and WWER-440/213 plants are detailed in IAEA technical documentation.

However, due to the lack of specific nuclear safety standards in certain areas at the time the WWER-440/213 units were designed, some deficiencies still remained in the design of these plants, in particular in areas such as:

- protection against potential common cause failures,
- high energy pipe breaks,
- fire,
- earthquake,
- component classification and qualification,
- bubbler condenser integrity under DBA conditions.

WWER-1000:

WWER-1000 nuclear power plants come in four different models. The designs of earlier models 187, 302 and 338 were started in 1972 and were completed in 1979. The design standard used was the OPB-73. These early models have historically been called the "small series" because only five units have been constructed (two units at Kalinin NPP and three units at South Ukrainian NPP). With respect to the model 320 design, the concept of defence-in-depth is realised by general design criteria including the use of redundancy, diversity, independence and single failure criterion for safety systems.

The WWER-1000 plants are more similar to non-Soviet Pressurised Water Reactors (PWRs) in operation in many countries. The nuclear steam supply system of all WWER-1000 units is completely enclosed by a full pressure dry containment with relatively high leaktightness. All WWER-1000 design versions have a steel lined, pre-stressed, reinforced concrete containment shell. The containment is designed to accommodate a double-ended rupture of any single primary system pipeline with 850 mm diameter. Corresponding design overpressure is 0.41 MPa.

The reactor core is designed based on the same type of fuel as used in WWER-440 reactors. However, the dimensions and the number of fuel assemblies are different. The control assemblies are composed of 18 cylindrical pins. The WWER-1000 plant also incorporates a different control rod drive mechanism (an electromagnetic type).

The standard WWER-1000 unit has four primary coolant loops. The majority of WWER-1000 units, except for the first model 187 (Novovoronezh unit 5) and "small series", have no main isolation valves in the primary system loop. The steam generators are horizontal type similar to those used in WWER-440 plants.

In comparison with the WWER-440 models, the sensitivity of the WWER-1000 plant to operational disturbances is higher. With respect to plant response to operational transients, the use of horizontal steam generators is a positive feature. The thermal capacity of the heat transport system of the WWER-1000 plant, as compared to similar plants with vertical steam generators, is relatively large. This has a positive effect on the plant behaviour under transient conditions.

The main engineered safety features of WWER-1000 are similar to those of WWER-440/213 reactors. Emergency core cooling, containment spray system and emergency feedwater system as well as their electrical power supply system have 3 x 100% redundancy. There are 4 hydro-accumulators designed with high operating pressure. There are 3 independent emergency feedwater trains, each containing an emergency feedwater electric driven pump and an emergency feedwater tank.

The secondary side of WWER-1000 units is also different from WWER-440 units since a single turbine generator is used. The main feedwater system incorporates three-stage centrifugal turbine driven pumps and one-stage centrifugal booster pumps.

Some differences are noted in the "small" series of WWER-1000 models 187, 302 and 338 as compared to the later models (320 and 392). The most relevant differences include: the lack of high pressure boron injection system, the extent of separation between the redundant parts of safety systems and of the essential service water system, the design of the electrical power supply and instrumentation and control, seismic design and fire protection features. Many deficiencies identified in the "small" series were resolved in the later design (320 model).

RBMK:

In 1954, a demonstration 5-MW_{el} RBMK-type reactor for electricity generation began operation in Obninsk. Subsequently a series of RBMKs were developed representing distinct generations of reactors having significant differences with respect to their safety design features.

The RBMK reactor is a heterogeneous, pressure-tube type thermal neutron power reactor with a graphite moderator and boiling light water as the coolant with on-line refuelling capability. The heat flow diagram is a typical of one for a single circuit boiling water reactor. Refuelling at full power is accomplished by means of the refuelling machine. Under normal operation and nominal reactor power, generally two fuel channels are refuelled per day.

The RBMK design philosophy resulted in significant deviations from current safety standards and practices:

- The main circulation circuit contains a lot of pipework with many welds, bends, headers, valves, which significantly increases the scope of in-service inspection and maintenance.
- A part of the main circulation circuit is located outside the confinement area, which may result in unacceptably high off-site doses in case of ruptures of the reactor coolant circuit in these compartments.
- Due to the high initial temperature of graphite and high heat accumulation capacity of graphite stack, cooldown of an RBMK reactor takes considerable time.
- There is a lack of a full containment.

The grouping of the RBMK NPPs in generations is generally made based on differences in systems of core control emergency core cooling, reliable power supply and accident localisation.

Four plants (Leningrad NPP Units 1-2 and Kursk NPP Units 1-2) are generally considered as the first generation units because they were designed before 1973 when the first standards on the design, construction and operation of Nuclear Power Plants (OPB-73) were introduced in the Former Soviet Union (FSU). This generation of RBMK units was designed, constructed and operated mostly in accordance with general industrial standards and rules. Special standards were used with respect to radiation protection and utilisation of radioactive materials.

Second generation RBMK units (Leningrad NPP Units 3-4, Kursk NPP Units 3-4 and Smolensk NPP Units 1-2) were designed in accordance with the OPB-73 standards. These standards introduced safety principles such as multiple barrier protection and single failure criteria. They required accident analysis to be performed for engineered features and organisational measures to ensure NPP safety based on examination of accident initiating events. The ultimate DBA, which was considered at that time, was an instantaneous break of a pipeline of the main circulation circuit with coincidence of a single failure of safety systems. Special systems dedicated to perform safety functions were required by these standards.

In 1982, revised safety standards were introduced into practice. The basic safety requirements that were contained in OPB-73 remained practically unchanged. In addition to the previous standards, OPB-82 required that the technical means and organisational measures stipulated by the design of the NPP must guarantee safety for any event, taking into account the design, together with a single failure (independent of the initial event) at an active or passive element (containing mechanical moving parts) of the safety systems. Accidents for which technical safety measures were not provided by the design were considered to be hypothetical. For these hypothetical accidents, it was required that plans for protection of personnel and the public be developed and implemented in accordance with the requirements imposed by other regulatory documents, e.g., on health regulation. Second generation RBMK units in many aspects meet the OPB-82 requirements.

In 1988 new safety regulation OPB-88 was put into practice. This regulation took into account not only the experience accumulated in the FSU but the international experience as well. One RBMK NPP unit (Smolensk NPP Unit 3), which is considered as belonging to the third generation, has been built taking into account these standards. Additional design changes are now being incorporated in the construction of Kursk NPP Unit 5, which is considered as belonging to the fourth generation of RBMK NPPs.

Fast Reactors:

The sole operating unit of the BN-600 reactor at Beloyarsk, unit 3, is a sodium-cooled breeder reactor that generates new fuel during its operation. BN-600 is a three-loop "pool" design. The reactor, coolant pumps, and intermediate heat exchangers are all located in a common sodium pool. The piping connecting these major components is also contained in the sodium pool. Component size has been increased from BN-350, not only to handle the higher power, but also in response to a design change, where the number of coolant loops has been reduced from six in BN-350 to three in BN-600. Improvements (over the BN-350) were performed in the secondary system, and the fuel discharge burn-up was doubled. These measures decreased the capital investment. However, the BN-600 electrical generation cost is still considerably higher than that of a WWER-1000 reactor.

The power generation system in BN-600 is more conventional than for BN-350, with steam used only to generate electricity. In addition to the guard vessels around the reactor vessel and piping, as in BN-350, the use of a pool-type design, without penetrations in the reactor vessel which could lower the sodium level, is also considered an engineered safety feature. The reactor system is housed in a concrete rectilinear building, and is provided with the same filtration and gas containment features as the BN-350 plant.

Seismic:

For the Rovno site the original assessments (by Atomenergoprojekt of Russia) resulted in an earthquake with a maximum intensity of MSK 6, corresponding to a ground acceleration of 0.05g.

On the NPP's Kola and Novovoronezh there is no information concerning seismicity. Kola and Novovoronezh have not been reviewed by the IAEA. This does not mean that there is no concern for their seismic safety. In fact, work is being performed related to the seismic input for both plants by Russian specialists. It is certain that seismic safety assessment for the structures, equipment and distribution systems is necessary but no review of these plants was performed.

Safety Concerns of the Original Design:

WWER-440/230:

In February 1992 the WWER 440/230 Safety Issue Book was produced, containing an overview of WWER-440/230 nuclear safety and a compilation of about 100 generic safety issues. The report presents for each safety issue its description, the related safety items of the database, its ranking and related justification, and recommendations for safety improvement. The report also provides an overview of safety on the basis of the successive barriers for the confinement of radioactive material and the related main safety functions: controlling the power, cooling the fuel and confining the radioactive material within the barriers.

In addition to the Safety Issue Book, an overview of the major findings of the EBP on the safety of WWER-440/230s was published in May 1992. Early reviews of the design of WWER-440/230 plants revealed a number of inherent safety features as well as major safety concerns. The latter are summarised below.

The most important safety concern was the integrity of the primary circuit boundary (third barrier) and particularly, the embrittlement of the RPV. There was a lack of information concerning the manufacturing data, the actual status of the vessels and the rate of RPV embrittlement under neutron flux.

The integrity of the primary circuit piping, part of the third barrier, was also a significant safety concern, because the DBA of the WWER-440/230 plants was a LOCA resulting from a small primary pipe break of a diameter equivalent to only 32 mm. Hence the importance of the implementation of an LBB concept and of efficient in-service inspection techniques.

The integrity of the confinement structures, the 4th and last barrier, was also a safety concern due to the limited size of the design basis LOCA. In addition, confinement structures of the WWER-440/230 NPP's presented an unusually high leak rate (about 5000% per day at 70 kPa).

Other significant issues concerned the safety and support systems to protect the integrity of barriers:

- Safety systems (except emergency feedwater) required to fulfil the main safety functions had limited capabilities because they were designed for a small LOCA.
- Safety systems and their support systems were not sufficiently protected against potential external and internal hazards. In some areas such as I&C or Electrical Power Supply, redundancy was poor.
- Among the support systems, I&C reliability and performance were found to be particularly limited.

Insufficient accident analyses was also a major issue related to WWER-440/230 safety. The lack of any independent peer review to check and approve the SAR had led to a general inadequacy of accident analyses.

WWER-440/213:

The WWER-V213 Safety Issue Book presents a consolidated list of generic safety concerns, called safety issues, ranked according to their safety significance and the corresponding corrective measures proposed to resolve them and improve safety. The conclusions of the WWER-440/213 Safety Issue Book can be summarised as follows.

There are no category IV issues in the WWER-440/213 NPP's, which confirms that WWER-440/213 safety has been improved in all areas of major concern, compared to the WWER-440/230 plants.

The issues of high safety concern are the following (category III) issues:

- Insufficient qualification of equipment for anticipated ambient and seismic conditions for DBAs.
- Non-destructive testing for reactor coolant system in the framework of in-service inspection (ISI) presents deficiencies and deviations from current standards. The ISI approach used so far is not adequate for a timely detection of degradation,
- In the area of systems, some issues already existing in the WWER-440/230 NPP's still remain in the WWER-440/213 NPP's. Two of them are of high safety concern:
  - ECCS sump screen blocking may result in a common cause failure of the whole ECCS following a large break LOCA.
  - The layout of the EFWS, which is located in the turbine hall, is such that it might be exposed to common cause failure by fire, flooding, high energy pipe break or earthquake when it is needed to cool the core.
- Bubbler condenser behaviour at maximum pressure difference (double-ended guillotine break of the primary piping) is also of high safety concern. The regulations pertaining to strength calculations in force at the time of the bubbler condenser design did not correspond to Western practice and have been changed in Russia itself. New calculations

from IAEA programmes show that the strength of some structural elements of the bubbler condenser is questionable.

- In the area of internal hazards, two issues are considered of high safety concern:
  - Fire protection, which is all the more important as redundant safety related equipment is insufficiently separated in some areas such as the EFWS in the turbine hall, and power cables (or control cables) of redundant safety related components follow the same route or are located in the same compartments.
  - High energy pipe breaks in the intermediate building at 14.7 m could result in multiple failures of safety related systems and, in some cases, to the loss of EFWS when it is needed.

In the area of external hazards, seismic safety is also considered of high safety concern since the original seismic design basis is generally not in accordance with current international practice.

WWER-1000:

In the framework of the IAEA Extrabudgetary Programme on Safety of WWER and RBMK reactors, safety issues were identified for WWER-1000 model 320 reactors and ranked according to their importance to safety; The identification and ranking of safety issues was also performed for the "small series" nuclear power plants.

Altogether, 84 safety issues were identified; 71 are related to design aspects, and 13 are related to operation. Of the design related issues, 11 are in category III for WWER-1000/320 models, and 12 category III items have been identifies for the "small series". In the case of operational safety issues, no ranking is provided.

The 11 category III issues for WWER1000/320 reactors are summarised as follows:

- *Qualifications of equipment:*
  This is a generic safety issue common to WWER nuclear power plants. In the original WWER design the components and systems were classified according to their functions as required by OPB-73 and OPB-82. They were not classified according to importance to safety, i.e. safety class, as required by OPB-88 and the IAEA Nuclear Safety Standards (NUSS).
- *Control rod insertion reliability/fuel assembly deformation:*
  Structural deformation of fuel assemblies affecting the reliable insertion of control rods and leading to water gap change between the fuel assemblies was identified as the most important safety issue that impacts the function of power control. The problem has been solved by the new fuel assembly design.
- *Reactor Pressure Vessel (RPV) embrittlement:*
  The RPV integrity of WWER-1000 plants has been recognised of high safety concern due to relatively high Ni concentration in the vessel beltline area welds, which may lead to higher than anticipated embrittlement rate.

- *Non-destructive testing (NDT):*
  Techniques and tools for NDT at the plants have been found inadequate. No qualification requirements for methods, personnel and equipment have been established.
- *Steam generator collector integrity:*
  The integrity of steam generators for core cooling at WWER reactors can be affected by supplying cold emergency water to degraded steam generator collectors which can lead to unacceptable stresses. A major primary to secondary leak due to steam generator collector failure would quickly overfill the steam generator and the main steam line which has not been demonstrated to be qualified for hot water load.
- *Steam and feedwater piping integrity:*
  Strength analyses of steam lines do not include the assessment of the response to large primary to secondary leaks, such as leaks due to a steam generator collector break.
- *Emergency core cooling system (ECCS) sump screen blocking:*
  The potential of clogging the filters of the sump screens and/or the heat exchangers by insulation material, preventing cooling of the fuel in the recirculation phase after a medium or large LOCA.
- *Steam generators safety and relief valves qualification for water flow:*
  The lack of qualification of relief and safety valves to operate with water or water-steam mixture can lead to their failure to re-close after opening, resulting in containment by-pass leakage in case the integrity of the reactor coolant system and steam generator boundary is lost.
- *Reactor vessel head leak monitoring system:*
  The leak detection system is not tested or inspected periodically. The humidity monitoring system in the upper reactor block is not sensitive enough to detect leaks in the bolted joints to the vessel head penetrations. Undetected leaks could lead to a severe corrosion of the vessel head from the outside.
- *Emergency battery discharge time:*
  The designed discharge time for the three redundant batteries for WWER-1000/320 unit is in the order of 30 minutes. This is not in compliance with modern requirements, where the trend goes towards an extension of the battery discharge time to better cope with accident management and station blackout requirements.
- *Fire prevention:*
  Fire protection should be achieved through a defence-in-depth concept. Safety reviews of WWER nuclear power plants have identified several weaknesses, such as lack of qualified fire doors, redundant cable trains that are too close to each other, and lack of qualification of penetrations.

For the "small series" WWER-1000 plants, additional three category III issues and one category IV issue was identified:

- *Boron injection system capability:*
  The original design of the "small series" WWER-1000 units is not equipped with a high boron injection system for shutting the reactor down during transients and accidents. For Kalinin NPP a high boron injection system has been designed and installed during the

erection and commissioning phase of the plant. The system configuration and water storage is comparable to the design of standard model 320 units. Novovoronezh unit 5 (model 187) does not have a high pressure boron injection system. The emergency power back-up makeup pumps cannot be accepted as a safety classified system due to the lack of physical separation and functional isolation.

- *Emergency feedwater supply vulnerability:*
  At Novovoronezh unit 5, the existing emergency feedwater system with three pumps is used to supply feedwater to four steam generators in emergency conditions as well as in start-up and shutdown conditions. The pumps are separated by walls that cannot provide real separation in case of flooding or fire.
- *Physical separation and functional isolation of the emergency core cooling system (ECCS):*
  Some basic principles, such as physical separation and functional isolation between redundant systems important to safety, have not been fully applied due to the lack of proper rules and standards during the design phase of "small series" WWER-1000 NPP's.
- *Reactor protection system redundancy (category IV):*
  The technological part of reactor protection (e.g. trip signals from pressure, temperature, level, etc.) consists only of one protection set. This set consists of 3 independent channels for each parameter. No information could be made available about the structure of this single set. Explanations given do not allow assessing whether the structure of this single set meets criteria required on redundancy, functional isolation and segregation for the technological part of reactor protection. This type of design is different from WWER-1000-320 units. The Russian regulatory document "Nuclear Safety Rules of Nuclear Power Plant Reactor Facilities" requires at least two independent sets for all variables that are required to prevent postulated initiating events.

RBMK:

The safety review of RBMK NPP in the IAEA resulted in 59 safety issues and recommended measures for improving the safety of RBMK reactors in the following areas:

- core design and core monitoring;
- pressure boundary integrity,
- accident analysis,
- support and safety systems,
- fire protection,
- operational safety.

The international practice reflected in the IAEA NUSS publications, the Russian regulations and national practices were used by the experts for identification and assessment of the safety issues, taking into account the safety improvements already underway or implemented. This assessment was prepared on the basis of safety reviews of Smolensk 3, Leningrad 2 and Ignalina NPP.

The main safety issues are:

- *Reactivity control and shutdown systems*
  As demonstrated during the Chernobyl NPP Unit 4 accident in 1986, the RBMK design had some serious deficiencies related to its reactivity control and shutdown system. Some of the more significant concerns were: the positive scram effect of the control rods in case of their moving down from the topmost position, a large positive void coefficient and slow insertion of negative reactivity. Since the accident, a number of modifications have been made to all RBMKs to improve the ability to control the power and rapidly shut down the reactor. Additional changes and refinements are still being considered, the most significant being an additional shutdown system.
- *Fuel cooling in emergency conditions*
  The lack of an adequate emergency cooling system is one of the most significant deficiencies of the first generation RBMKs. The design basis for these early generations is limited to a small break in selected locations of the reactor coolant piping. The design basis also assumes that normal electric power is available. There are concerns relative to the ability of the ECCS of all generations to provide essential cooling water to those portions of the core where it is needed the most. The ability of the protection system to identify the need for ECCS and automatically respond in a timely manner to a wide range of LOCAs and interface LOCAs has also been questioned.
- *Pressure boundary integrity*
  Main safety concerns in the area of pressure boundary integrity are related to the fuel channel integrity, break of critical components (including LBB concept application, seismic design, ageing assessment) and in-service inspection.
- *Support system functions*
  In order to ensure proper operation of the various safety systems, the various systems supporting those safety systems must also be highly reliable and capable of operating under potentially severe conditions. Most significant problems that affect defence in depth are those related to insufficient separation between different trains or buses of equipment; insufficient separation between operational and safety functions; insufficient diversification of components and systems; poor reliability and poor maintenance; and lack of equipment qualification.
- *Fire protection*
  There have been many fires at the various Soviet-designed reactors. One of the most damaging occurred at Chernobyl NPP Unit 2 on 11 October 1991 when a fire started in the turbine-generator. Before the fire was brought under control, the turbine generator had been destroyed, and portions of the turbine building roof were damaged to the point that it collapsed and then disabled part of the ECCS (fortunately, the normal feedwater pumps and water lines were not affected). In general, fire risks were not adequately considered during the design of the RBMK reactors. The poor degree of separation of the safety and safety support systems increase the potential for relatively minor fires to disable entire safety systems.

- *Seismic safety*
  It should be noted that structurally speaking, RBMK type NPPs are very similar to WWER-440 type NPPs and their vulnerabilities to external events in general (seismic included) are the same. Mainly due to the fact that most RBMK type NPPs are located in low seismic hazard areas, little was done in relation to seismic safety of these plants in the previous years. However, it is recognised that these plants have structural vulnerabilities for extreme external loads, such as blast and impact.

Quality and Reliability of Systems and Components:

The WWER-440/230 plants were designed according to industrial norms and standards, with little emphasis on principles like redundancy, diversity, physical separation, defence in depth and single failure criterion, etc. For the V213 plants this was no longer considered sufficient and standards specific to the nuclear industry started to be developed and implemented (such as OPB-73 and PBYa-74). This marked the beginning of a transition to the generally accepted international practice in nuclear safety although these principles were still not fully taken into account.

The WWER-1000 plants of the first and second generation were designed according to the standard OPB-73. The third generation was designed according to OPB-82 which requires issues like active and passive single failure and (to a limited extend) beyond design mitigative measures.

The RBMK plants of the first generation were designed according to the standard OPB-73. The second generation was mainly designed according to OPB-82 and the third generation RBMKs to OPB-88, which takes also international experience into account.

Concerning material selection a main issue is the higher content of impurities in the WWER reactor pressure vessels, which gives rise to a higher level of embrittlement due to neutron irradiation, especially in the older plants.

2.2.2 Level of Improvement and Remaining Design Safety Issues

Major Resolution of Design Safety Issues:

WWER-440/230:

Novovoronezh NPP Units 3-4:

Concerning RPV integrity, the reactor vessels of both units were annealed (unit 3 twice because of a too low temperature the first time). In the framework of the TACIS programme, templates were taken in 1995 from the vessel of each unit. Based on the results of the analysis of these templates, OKB Gidropress performed RPV integrity assessments and concluded that the integrity of the RPV was demonstrated until the end of the design lifetime, i.e., up to 2001 and 2002 for Units 3 and 4, respectively.

The prevention of cold overpressure or overcooling of the primary circuit is improved by installation of closing, check and safety valves.

Concerning primary circuit integrity, the applicability of the LBB concept was demonstrated in 1997 under normal operating conditions for pipe diameters of 200 mm and above. In the framework of the EC's TACIS programme, finance was provided to perform studies for extension of the LBB concept to the whole range of conditions including the maximum design earthquake.

Confinement leaktightness has been improved by a factor of 1.5 to 2. For further improvements, fast acting isolation valves were to be installed in 1999 on all ventilation ducts connected to the confinement.

Major safety upgrading of the confinement is still planned, on the basis of a jet condenser, developed by All Russian Research Institute for Nuclear Power Plant Operation (VNIIAES), and a 200 m^3 tank installed in place of the hermetic compartment flap valves. The jet condenser would allow limiting the releases of radioactive material outside the confinement as well as maintaining the integrity of confinement structures in the event of a primary pipe break up to 200 mm in equivalent diameter.

The following improvements of safety systems are implemented:
- The steam dump valves to the atmosphere were changed at Units 3 and 4. The new ones ensure steam and water flow rate control under all conditions.
- Protection of ECCS components against common cause failures (including internal hazards) was improved.

The following improvements of safety systems are planned:
- An additional EFWS was to be installed in 1998 on Units 3 and 4, outside the turbine hall, capable of being connected to various sources of water.
- Unit 4 steam generator safety valves were to be replaced at the end of 1998, in the framework of the EBRD programme.
- A mobile diesel-pump station, to be connected to the EFWS, was planned for 1998-1999, to cope with beyond-the-design-basis accidents.

Support systems are also being improved:
- On I&C, the implementation of improvements is progressing, although slowly.
- On the SWS, short-term improvements to prevent common cause failures were implemented.
- Ventilation and air cooling were improved in the main control room and in the electrical equipment rooms

- In the area of electrical power supply physical separation and fire and seismic resistance are improved.

In the area of internal hazards:
- several fire protection improvement measures have been implemented, but measures resulting from the fire risk analysis performed remain to be implemented;
- protection of ECCS against flooding in the boron rooms was implemented; and
- pipe whip analysis remains to be implemented.

Concerning seismic safety:
- work is under way to verify the site seismic studies.

In the framework of the TACIS programme, accident analyses are being performed to support the licensing of the major safety upgrading measures.

Kola NPP Units 1-2:

Kola NPP Units 1-2 RPVs were annealed based on the analysis of the templates taken in 1995 from the vessels of Novovoronezh NPP Units 3-4. The Kurchatov Institute confirmed that the critical brittle temperature will not exceed the maximum acceptable value at the end of Kola NPP Units 1-2 design lifetime (2003 and 2004, respectively). To reduce the loads on the vessel, fast-closing main steam isolation valves have been installed and ECCS hot leg injection put in place. Further, the boron acid tanks were equipped with a heating system. To reduce the neutron flux on the vessel wall, dummy fuel elements had been installed in 1985 and a low leakage load pattern was adopted in 1992. The pressuriser safety valves were changed four years ago and they are used to prevent cold overpressurisation during shutdown periods. During other periods, protection against cold overpressure transients other than steam line breaks is provided only by operator actions based on procedures.

The IAEA has been informed that the LLB concept was implemented at Kola NPP in May 1998. Diagnostic systems are put in operation – vibro-acoustic monitoring of reactor internal equipment, leakage diagnostic, monitoring of exterior subjects and modern NDT equipment for components and pipelines in the primary circuit. In the framework of EBRD programme, N16 primary to secondary circuit leakage detection system was to be installed in 1998.

Confinement leaktightness has been improved by a factor of 5 to 6 and measures to increase it are still being implemented. Fast acting cut-off valves on confinement ventilation ducts were installed at Unit 2 and are to be installed at Unit 1.

The project involving major confinement improvements based on the jet condenser conducted at Novovoronezh, is also planned at Kola.

In the area of safety systems the following improvements were implemented:

- Improvements to prevent ECCS common cause failures were implemented such as: prevention of flooding in the boron room, prevention of ECCS sump clogging.
- The motors of the main coolant loop isolation valves were changed in 1995 for new motors qualified to operate under LOCA conditions.

The following improvements of safety systems are planned:

- In the framework of the EBRD programme, the steam generator safety valves were to be replaced in 1998 by new ones, qualified to operate in water steam or water flow;
- Installation of a new EFWS, outside the turbine hall, has been delayed (cancelled by EBRD);
- Emergency gas removing system from reactor and SG collectors;
- Emergency drainage system of primary circuit hot leg;
- Computer system replacement with the new system and SVTRK implementation;
- Reactor Protection System and flux monitoring system replacement is implemented at Unit 1, and is carried out at Unit 2 in 1998.

On the support systems, the following measures were implemented:

- The reactor protection system was replaced by a new one, based on the ‘two train concept’ on Unit 1 in 1996. This was to be done on Unit 2 in 1998. Control equipment of the confinement spray system is based on the two separate independent trains concept since 1996 on both units. In both units the initial process computer has been replaced by a more modern unit.
- Protection of the SWS against common cause failures has been improved. In addition, it is now possible to supply Units 1 and 2 from the system of Units 3 and 4.
- The emergency electric power supply systems are now organised in two independent trains. All electric components reaching the end of their life, or of insufficient reliability, have been replaced. A standby movable emergency diesel engine, qualified for arctic conditions, has been donated by the Norwegian Government in 1996. It can be connected rapidly to any electrical motor of the safety systems.

On the support systems, the following measures are planned:

- In I&C, post-accident monitoring instrumentation was to be installed in 1998 in the framework of the EBRD programme.
- An SPDS was to be installed in the control room of Units 1 and 2 in 1998, in the framework of a Norwegian Government safety assistance programme.
- A system of air purification is to be installed in the control rooms in the framework of the EBRD programme.

In the area of internal hazards, a fire risk evaluation was conducted in the framework of TACIS. Some of the resulting measures have been implemented and others are planned; the real extent of implementation is not known.

Concerning accident analysis, many scenarios have been analysed in the framework of TACIS to prepare the major safety upgrading of the plant. Additional analyses will be required once the major safety upgrading programme is finalised.

WWER-1000:

The resolutions to some of the Category III issues are summarised below:

- *Qualifications of equipment:*
  All safety-important equipment were subject to qualification tests in line with the standards valid in the Russian Federation. According to the results of studies on beyond-design-basis accidents, it was found necessary to perform additional qualification of a series of equipment.
- *Control rod insertion reliability/fuel assembly deformation:*
  Control rod problems refer mainly to exceeding the normal control rod dropping time (4 seconds), and to incomplete insertion of individual control rods. In 1994, a comprehensive programme was initiated to reveal and eliminate the causes of these disturbances. It was found out that the problems were related to fuel assembly deformation. Results of the study revealed that the root cause of the fuel assembly deformation was axial load on fuel assemblies.
- *Reactor Pressure Vessel (RPV) embrittlement:*
  During plant operation, periodic inspection of the RPV needs to be performed by non-destructive tests. RPV embrittlement analyses were performed for Balakovo units 1 and 2. Similar analyses should also be performed for Balakovo units 3-4, Kalinin units 1-2, and Novovoronezh unit 5.
- *Non-destructive testing (NDT):*
  Recognising the importance of an accurate knowledge of the status of the metal condition of equipment and pipelines, efforts were made to improve test procedures, methods and tools.
- *Steam generator collector integrity:*
  Measures to improve operational reliability of WWER-1000 steam generators were elaborated and implemented. The measures include upgrading of steam generator water supply and blowdown system, establishing more strict standards and requirements for maintaining water chemistry, and performing periodic operational non-destructive tests.
- *Steam and feedwater piping integrity:*
  Two measures have been elaborated to exclude potential damage of more than one pipeline: the development and implementation of a system for dynamic fastening of pipelines (SDFP), and of the "leak-before-break" concept for the secondary pipelines.
- *ECCS sump screen blocking:*
  Activity for improving serviceability of the sump strainers are carried out, including advanced thermal insulation on pipelines and equipment. In the frame of the TACIS programme, general technical requirements for the design of an upgraded filtering system for WWER-1000 power units were elaborated in co-operation with Imatran Voima Oy (IVO), Finland.

- *Reactor vessel head leak monitoring system:*
  A prototype of a special leak control system to ensure early detection of the leak and its location was introduced in one of the units of the Balakovo nuclear power plant.
- *Emergency battery discharge time:*
  The design documentation has been prepared for replacement of the existing batteries by batteries that provide discharge time of at least 1 hour.
- *Fire prevention:*
  For performing a comprehensive analysis of fire safety and for establishing the required measures, methodologies for deterministic and probabilistic analysis of fire safety were developed in the Russian Federation.

  Despite the lack of comprehensive analyses of fire safety, partial analyses have been performed along with the implementation of measures to eliminate revealed non-conformities:
  - Installation of high pressure fire-fighting hoses in certain areas;
  - Development of smoke removal system;
  - Elaboration of project proposals for gas fire-extinguishing systems;
  - Application of non-combustible coatings on the turbine building roofing and on the evacuation paths;
  - Other unit-specific organisational and technical measures.
- *Boron injection system capability (Novovoronezh nuclear power plant):*
  The installation of an additional high-pressure emergency boron injection system, consisting of three independent trains, is envisaged. Each train shall comprise a storage tank of concentrated boron solution, a boron injection pump, piping and valves.
- *Emergency feedwater supply vulnerability:*
  The installation of three additional emergency feedwater pumps with characteristics similar to the existing pumps is envisaged. All the pumps will be located in a separate building, thus minimising the risks of common cause failures. This building shall also contain independent emergency feedwater tanks.
- *Physical separation and functional isolation of the ECCS:*
  Two types of measures are envisaged:
  - To reduce the risk of equipment disability of more than one train of the safety system due to a fire, installation of fire partitions is envisaged between all pump sets, providing fire resistance for 1.5 hours.
  - To reduce the risk of equipment disability of more than one train of the safety system due to flooding, installation of drain pumps is envisaged.

Reactor-Specific Improvements (WWER-1000):

The following lists some important reactor-specific measures that were completed in the recent past.

Balakovo Nuclear Power Plant, Units 1-4:

- Ball cleaning system for turbine condenser piping and piping of booster pump condenser

- Supply of eddy current testing equipment
- Supply of spare parts for specific valves
- Upgrade of the plant's information centre
- Development of a Quality Assurance (QA) Programme (phase 1)
- Supply of equipment for primary and secondary coolant control (chemical and volume control equipment)
- Local adaptation of the QA system (phase 2)
- Personnel training at RWE Training Centre, Germany
- Supply of accumulator batteries for safety systems and control and protection systems (units 1, 2).

Novovoronezh Nuclear Power Plant, Unit 5:

- Upgrading of turbine-generators (including replacement of water-cooled rotor with new hydrogen-cooled one) has been implemented
- Oil cooling system has been installed at TG-14
- Booster pump of TPN-1 type has been replaced with a new cladded pump
- In-core monitoring complex of SVRK-0l,02 type has been replaced with the new one of SVRK-05,06 type
- Neutron flux monitoring system of AKNP-03 type has been replaced with a system of AKNP-7-02 type
- A system for gas removal under emergency conditions from primary circuit equipment (the PGS system) has been implemented
- Connection pipes between boron solution storage tanks and suction lines of high-pressure emergency boron injection pumps have been installed
- The 1st phase of upgrading the steam generator blowdown system has been fulfilled
- Steam generators of PGV-1000 type have been replaced with steam generators of PGV-1000M type
- Upgrading of the power operated relief valves of the pressuriser has been carried out
- Safety valves in the primary emergency and conventional cool-down system have been replaced
- Sensors of acoustic-emission leakage monitoring system have been installed on the upper unit
- High-pressure fire-fighting system for the turbine hall has been implemented
- Moisture separator re-heaters, low-pressure feedwater heaters, coolers of the LP HTR-4 drainage, as well as main and gland ejectors of TA-13 have been replaced with stainless steel ones
- Control and protection systems of turbine-generator sets TA-13,14 have been upgraded
- Measures ensuring reactor pressure vessel (RPV) brittle strength have been implemented
- Cable lines have been covered with fire-protective covering
- Non-interruptible power supply units (ABP - l500 type) of the first generation have been replaced with units of the second generation for three safety systems
- Changes in emergency protection system have been implemented

- New measuring system for steam generator level has been installed as well as a number of protections related to steam generator level
- Modernisation of the Computerised Information System has been carried out.

Kalinin Nuclear Power Plant, Units 1 and 2:

- Equipment for secondary circuit water chemistry measurements has been supplied
- Spare parts for safety valves have been supplied
- Low-voltage electric cable penetrations have been supplied
- Upgrading of steam generator header "dead-ends" blowdown system and piping has been fulfilled (unit 1)
- Booster pumps TPN–1, 2 have been replaced with new ones (unit 1)
- Maintenance and testing on unit 1 containment pre-stressing system has been performed (unit 1)
- Replacement of six steam dump units with upgraded ones (unit 1)
- Repair of circulation pumps has been carried out (unit 1).

RBMK:

Since the Chernobyl accident, in 1986, a considerable amount of work has been either completed or is under way to improve RBMK NPPs safety. This overview of safety improvements to RBMK NPPs has been made, attempting to follow the same topical areas which have been used in the safety review of these reactors.

Major safety improvements have been implemented in all RBMK units to remedy design weaknesses which had been recognised as a result of the 1986 Chernobyl accident. The majority of these modifications addressed the reactor core. All of these modifications aimed at reducing the magnitude of the void reactivity effect and of increasing the speed and effectiveness of the shutdown system. These modifications have improved the situation, as far as the reactivity-induced accident is concerned, significantly.

Core design and core monitoring
The designer's efforts were directed at decreasing the void reactivity coefficient and at improving the design of the control rods.

Void reactivity coefficient
The main measures taken to reduce the void reactivity coefficient are the following:

- loading of additional absorbers. The number of additional absorbers varies from 85 to 103 depending on the reactor. The technical specifications require at least 81 additional absorbers.
- increasing the fuel enrichment from 2.0 to 2.4%. This increase is underway in all the Russian RBMK reactors.
- controlling the operational reactivity margin (ORM) value between 43 and 48 equivalent control rods.

Control rod design
Before the Chernobyl accident, when the Control Rods (CRs) were withdrawn out of the core, there was a column of water (neutron absorbing material) at the bottom end of RCPS channel, under the displacer. During the insertion of the CRs, this column of water was, in a first step, replaced by the graphite displacer, causing an increase in the reactivity. In addition, the CR drop-time was too long.

Three safety improvements were carried out to improve the efficiency and to increase the speed of response of the emergency protection system:

- The manual control rods were replaced by rods of improved design, without the water columns at the bottom end of the channels but with a larger absorber section.
- The RCPS rod drives were also retrofitted, reducing the time required to insert the rods fully into the core from 19s to 12s.
- A fast-acting emergency protection system was developed and installed in all operating reactors.

In addition, the number of the bottom rods has been increased (except for the first generation plants) from 24 to 32 and they are now inserted when a scram occurs.

Other measures
Following the Chernobyl accident, other measures have been taken to improve the control and monitoring system:

- operator aid display at the control desk based upon information from the SCALA system
- manual reactor trip when power falls below 700 MW_{th}
- manual trip if the ORM is less than 30 equivalent control rods.

Further measures are planned:

- increase in the number of detectors for LAR-LAZ
- increase in the number of axial flux detector assemblies.

Instrumentation and control
There have already been three significant steps in upgrading the data processing systems on the RBMK NPPs:

- Introduction of commercial computer systems, some automatic transfer for warning set points to the indication systems, and the introduction of colour displays for 2D and 3D imaging of the power and temperature profiles.
- Addition of a data transfer facility at Smolensk 3 which allowed the row data to be processed by an auxiliary computer, a PC in the control room. This system still relies on the original SCALA for data collection and processing.
- At Leningrad NPP the SCALA-M system is introduced. This system uses Intel processors. However, the system retains the original SCALA data collection equipment.

Pressure boundary integrity
Several modifications have been implemented to enhance the pressure boundary integrity at RBMK NPPs:

- Some steam/water pipes supports have been added to deal with the situation observed related to piping vibration.
- A simplified engineering approach, the strain intensity factor concept and limit stress approach have been used to develop tables of allowable flaw sizes. These regulate which flaws must be repaired upon discovery during in-service inspection;
- Probabilistic fracture mechanics calculations have been performed for the 800 mm pipe to predict leak and rupture probabilities.
- A new design of flow control valve is being installed at all plants, as a measure to prevent ruptures of fuel channels that have been caused by lack of coolant flow when valves have malfunctioned.
- Development of defect visualisation (determination of geometrical dimensions) systems based on multi-frequency acoustic holography.

Safety and support systems
The main improvements have been carried out in the Emergency core cooling system (ECCS), accident localisation system (ALS) and reactor cavity overpressure protection system.

ECCS
Several different improvements have been implemented:

- increasing the number of emergency feedwater pumps from 3 to 5 and the number of ECCS lines from 1 to 2 for NPPs of the first generation.
- installing additional ECCS pumps (3 for damaged core side cooling and 3 for undamaged core side cooling) and the associated 3 divisions of piping.
- installing check valves between the distribution group headers (DGH) and the main coolant pump discharge header installing additional, larger capacity accumulators.

Accident Localisation System
The reactor coolant system of 1st generation RBMKs is not enclosed in a leaktight accident localisation system (ALS) as is the case in the 2nd and 3rd generation plants. Even in the 2nd and 3rd generation NPPs, only a main part of the reactor coolant circuit is confined by a system of pressure compartments of an ALS. The rooms where the steam/water lines, the steam drum separators and the upper parts of the downcomers are located are not included in the ALS.

For RBMK plants of the 1st generation, a decision was already made to construct a separate building housing a pressure suppression system. The building shall be connected to the reactor building. Therefore, this system. shall allow the decrease of radioactive release to the atmosphere during DBA for these units.

Furthermore, the installation of a leaktight compartment system for the rooms of the steam/water pipelines, the steam separators and the central reactor hall is being considered.

Reactor cavity overpressure protection system
Protection of the reactor cavity against overpressurisation is an important safety feature of the RBMK. The existing overpressure protection system has the capacity for two or three channel tube ruptures (for first and second generation units, respectively) which reflects a safety margin over the design basis accident of one channel tube rupture. The existing steam discharge system vents the steam/gas mixture from the cavity to a condenser with subsequent gas hold-up and release through the gas clean-up system/stack for first generation units. For second and third generation units, the discharged steam/gas mixture is routed to the bubbler/condenser pools where the steam is condensed, and gas is retained in the leaktight spaces. There is an intention to improve the capacity of the cavity overpressure protection system with additional relief capacity and, for first generation units, new buildings containing bubbler/condenser pools in sealed areas.

Summary of Remaining Significant Design Deficiencies:

A significant part of the IAEA safety issues is addressed. Because the safety improvement programmes of the different plants are still in progress, and the reports concerning fulfilled issues are from 1997/1998, it is not clear if they are resolved and to what extend, and which design deficiencies still remain. The actual work of the safety upgrading programmes is in many cases delayed due to financial problems.

Site-related Issues:

No relevant information has been collected.

2.2.3 Areas for Design Safety Upgrading and Perspectives

Ongoing and/or Proposed Safety Upgrading Programmes:

The implementation of the measures on safety improvement is executed in accordance with the schedules of technical re-equipment and modernisation developed for each NPP unit. The schedules of re-equipment and modernisation of Russian Nuclear Power Plants are developed basing on the following documents:

- Concept of Safety Improvement for Novovoronezh NPP, Units 3 and 4,
- Concept of Safety Improvement for Kola NPP, Units 1 and 2,
- Concept of Safety Improvement for Kola NPP, Units 3 and 4,
- Concept of Safety Improvement for operating WWER-1000 Nuclear Power Plants Equipped with Reactor Plants of V-320 type", volume l,
- Concept of Safety Improvement for operating WWER-1000 Nuclear Power Plants Equipped with Reactor Plants of V- 187 and V-338 types", volume 2,

- Concept of Safety Improvement for operating Nuclear Power Plants Equipped with Channel Type Reactors (RBMK's).

These documents were developed basing on the results of Russian experts, gained in the area of investigation of departures of the operating NPP units from the safety requirements of up-to-date national regulations and taking into account the IAEA recommendations. The safety upgrading programmes are still in progress. Some of the issues are fulfilled and some are planned or delayed. The actual work is in many cases delayed due to financial problems.

Assessment of the Safety Upgrading Programmes:

All safety upgrading programmes aim at fulfilling (most of) the IAEA safety issues. The level of fulfilment now and after the completion of the programmes is only partly clear from the available documentation. The actual work of the safety upgrading programmes is in many cases delayed due to financial problems.

2.3 PLANT OPERATIONS

2.3.1 Operational History

Plant Operational Limits and Conditions:

In accordance with the requirements stated in OPB-88 the operating organisation provides for supervision of all activities important to safety. The principal document that defines the safe operation is the process specifications. This contains rules and main procedures and limits and conditions for safe operation. This document must be in accordance with the SAR and is needed (amongst other documentation) to get an operating license.

Operational Statistics:

Investigation of malfunctions in operation of nuclear stations is carried out in Russia on the basis of specially developed procedures with due account of IAEA recommendations. Information on erroneous actions of personnel and other malfunctions caused by human factor is documented and used in personnel training. Information on malfunctions in operation of nuclear stations is introduced into the training materials and used in developing the programmes for the training of operational personnel, including accident prevention exercises.

An information system on operation experience feedback of nuclear power plants is in force in Russia. This information system covers all nuclear power plants in operation and under construction, operating organisations as well as design, scientific, research and other organisations providing support to NPP operation. The primary registration, accumulation and analysis of operational information are conducted at nuclear power plants in the established order in accordance with the valid provisions and regulatory documents. VNIIAES (Research

Institute for NPP Operation) is the leading organisation in the branch to ensure functioning of the information system on NPP operation experience feedback.

VNIIAES participates for Russia in the IAEA information programmes (ISI, PRIS, and INES) and is the interface organisation of the WANO Moscow Centre. It receives and distributes information on operation experience, incidents etc. to the NPP's and other relevant organisations. The usage of Russian and foreign NPP operation experience is used to prevent disturbances in operation of NPP's and enhance their safety.

On the basis of analysis of disturbances in operation of NPP's the VNIIAES issues and sends the following information materials to NPP's, operating organisations, Gosatomdanzor of Russia, designers of reactor plants and NPP's as well as to all interested organisations:

- quarterly reviews of disturbances in NPP operation,
- information reports on NPP operation disturbances influencing safety; data cards for assessment of events by INES,
- annual analytical reports on disturbances in NPP operation containing descriptions of disturbances, causes of disturbances and their effect on NPP safety, assessment of personnel's actions as well as corrective measures planned for elimination of similar disturbances at other NPP's,
- recommendations for equipment upgrading.

The number of operational disturbances in Russian NPP's is presented in figure 1. There is a clear decrease in the number of the disturbances through the years. The increase in 1998 is caused by a new, more stringent regulation on the registration of disturbances and by additional ultrasonic inspections in 1998.

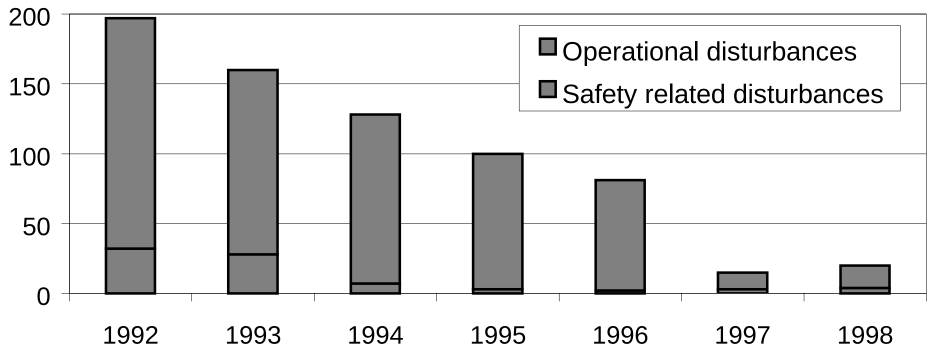

Figure 1 Operational disturbances

In figure 2 the safety related disturbances of figure 1 are presented according to the INES-scale. Again a clear decrease can be seen, although the number of occurrences in 1995-1998 seems to stabilise. No safety related disturbances in 1997 and 1998 occurred at WWER NPP's. The level 2 incident in 1998 occurred at Bilibino NPP.

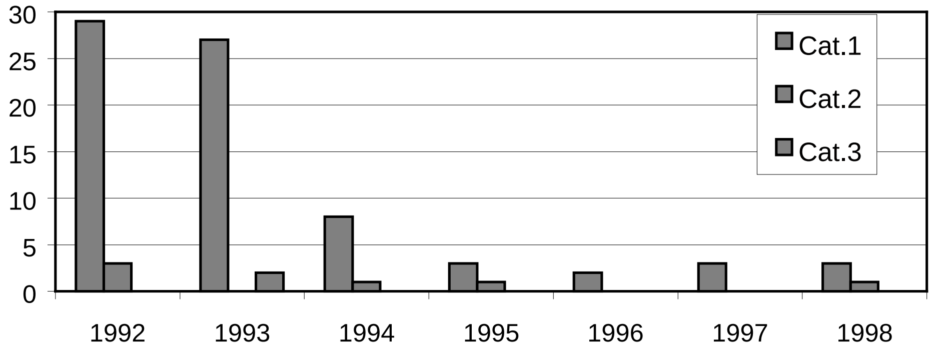

Figure 2 Safety related disturbances according to INES

In-service Inspection:

The inspection system being implemented by the operating organisations is aimed at early identification and prevention of deficiencies in NPP operation. Inspection of operability of NPP safety systems and other systems important for safety is carried out periodically according to the requirements of regulatory documents. Results of the inspection activities carried out by the operating organisations are reflected in reports which are submitted to Minatom (Ministry for Nuclear Energy) and Gosatomnadzor (Nuclear Regulatory Authority) according to the established procedure.

Some improvements have been achieved in the performance of in-service inspection, through the provision of training to the relevant personnel, upgrading of the procedures for and improving the practice of in-service inspection. Operating experience at the international level has also been applied.

2.3.2 Management of Plant Operations

Status of Management of Plant Operations with Focus on Safety:

The IAEA concludes that a wide exchange of operating practices between Eastern and Western plants has taken place. In the process, management abilities as well as knowledge of the operating staff have improved. More notably the following developments were set in motion:

- new organisational structures favouring clear responsibilities have been established on all the sites
- the safety culture has improved, in particular through the cleanliness and good material conditions of the plants
- quality assurance programmes have been developed and are being implemented on all the sites
- new procedures have been or are being established in the areas of plant operation, surveillance testing and maintenance
- predictive maintenance programmes have been developed
- a systematic approach to the training process has been adopted and computer-assisted training developed
- emergency planning is progressing on all the sites.

In short, progress has been observed on the operational safety issues. Nonetheless, efforts have to be pursued on several sites to upgrade the procedures, especially emergency operating procedures, prepare plant specific SARs, and improve training in the maintenance area. It would also be worthwhile to develop the use of computers for assistance to the operator in case of emergency; to centralise the storage and distribution of documents; to improve the recording and feedback of operating experience and to address remaining problems in emergency planning.

In some parts, the effect of the very difficult political transition and economical situation has slowed down the expected progress. The missions found a management still behaving in a traditional Soviet style, prescriptive and authoritarian, practising weak monitoring and overseeing personnel with a passive attitude; the concept of safety culture was often known but not yet really alive in the management. However, such situations are becoming increasingly rare.

Safety Culture Aspects and Human Performance:

The actual implementation of safety culture is closely related to the operating organisation responsibility and to all aspects of regulations and control of NPP operation with respect to NPP safety.

The following documents establish the legal basis for operating organisation activities in the area of the safety culture:

- Federal Law "Use of Atomic Energy,
- Program of Operating Organisation Activities aimed at Safety Culture Improvement,
- Methodological Guidelines for Development of Safety Culture Improvement Program at "Rosenergoatom" Nuclear Power Plants, Institutions and Organisations.

The improvement of safety culture at the Nuclear Power Plants is accomplished by:

- development and implementation of the program for qualitative rearrangement of the system and methods for NPP management,
- development and implementation of NPP personnel professional growth program,
- development and implementation of program for identification of the root causes of disturbances due to human errors.

As an experiment annual safety culture reports are prepared using indicators.

Quality Assurance and Management:

The former practice of quality assurance and the criteria and methodology of quality assurance programs development did not comply with modern practices. However in Russia an Operational Quality Assurance Program exists for all Russian NPP's, based on national regulations and IAEA recommendations.

The 35-th Article of the Russian Federal Law "Use of Atomic Energy" requires from nuclear power plant operating utilities such as Rosenergoatom to organise and co-ordinate the activities aimed at quality assurance at all the stages of a nuclear installation, including design and development, commissioning, operation and de-commissioning. The same law defines the scope of legal responsibilities for proper performance of its requirements.

The scope of responsibilities in the area of quality assurance includes the utility, contractors and subcontractors, design and development institutions, operation support organisations, and manufacturers.

Availability of Engineering and Technical Support:

Since Russia was the original designer of the WWER and RBMK NPP's, most of the know-how and technical experience is situated in Russia. The following Russian institutions are involved in the development of the design projects and safety justifications for WWER and RBMK NPP's:

- Moscow Atomenergoproject Institute and St-Petersburg AEP Institute, which are the WWER general architect designers,
- Experimental and design office Gidropress, which is the WWER plants general designer,
- Research and Development Institute for Power Engineering (RDIPE), which is the general designer for the RBMK-plants,
- Moscow subdivision of AEP Institute, which is the RBMK General Architect Designer.

The Russian Research Center (RRC) Kurchatov Institute is the research leader for NPP design developments. The main operation support contracting organisations are:

- All-Russia Research Institute for NPP Operation (VNIIAES Institute),
- Production Corporation Atomenergoremont,

- Atomtekhenergo Company.

Staff and Recruitment Policy:

No relevant information has been collected.

Information to the Public:

No relevant information has been collected.

2.3.3 Remaining and Emerging Operational Safety Issues

The following findings of the IAEA were elaborated in the course of the Extrabudgetary Programme (1990-1998). Some weaknesses were observed at almost all plants, especially a complex plant organisation with little communication; a reward and reprisal system not favouring individual and collective performance enhancement; a weak QA organisation; development and revision is needed with respect to normal and emergency operating procedures, including the 'limits and conditions of safe operation'; and operating experience feedback is insufficiently structured to be fully effective.

Various measures were already taken, and it was possible to appreciate the evolution of operational safety practices and management at the plants through visits, meetings and in particular, follow-up visits of previous reviews.

The effect of the very difficult political transition and economical situation has slowed down the expected progress. The missions found a management still behaving in a traditional Soviet style, prescriptive and authoritarian, practising weak monitoring and overseeing the personnel with a passive attitude. The concept of safety culture was often known but not yet really alive in the management. However, the situation has improved at several plants.

Operating Procedures:

WWER-440:

Kola NPP:

The work on procedures is improving but still very few modern step by step procedures are in use in control rooms. Situation was planned to be improved in 1998. Symptom-based procedures will be developed only for Units 3 and 4. Full scope simulator for Units 3 and 4 will start operating in 1999. For Units 1 and 2 it should be reconsidered whether to produce symptom-based procedures or to write new format (more user-friendly) for design and beyond design event-based procedures.

Novovoronezh NPP Units 3-4:

Concerning the development of new operating procedures and (system based) emergency procedures there is satisfactory progress.

WWER-1000:

Actions of personnel during accidents and emergency situations at nuclear power plants are specified in the national regulation entitled: "Procedure for emergency alarm annunciation, operative information transfer and organisation of urgent aid for nuclear power plants in case of radiation-dangerous situations".

The so-called "Symptom-Oriented Emergency Operating Procedures" are currently being developed at Kalinin (based on French methodology) and Balakovo (based on U.S. methodology).

The activities of the operating personnel during beyond-design basis accidents are regulated by the "Procedure for Management of Beyond-Design Basis Accidents". The Emergency Operating Procedures and Beyond-Design-Basis Accident Management Manuals were developed on the basis of the scenarios for the postulated accidents.

Management of Continuous Plant Operations:

Since 1991 all operating Russian NPP's have been carrying out annual assessments of the current operational safety status of each unit. Such assessments are conducted under the supervision of the operating organisations and followed by preparation of a special report. Provisions on the scope of assessments to be conducted and requirements for reports on assessment of current safety status of NPP units as agreed by Gosatomnadzor of Russia are available.

The main objectives of assessment of current safety status of NPP units are the following:

- check of actual status of safety systems and other systems and equipment important for safety,
- analysis of status of physical safety barriers and accident localisation systems,
- estimation of the state of NPP and environmental radiation,
- check of implementation of works on modernisation and reconstruction of systems and equipment and assessment of safety related effects caused by works being implemented,
- inspection of NPP nuclear, radiation, technical and fire safety status,
- review of violations occurring in operation and mistakes made by personnel,
- determination of measures for improving reliability and safety of further NPP operation.

Annual reports on the current NPP safety status assessment approved by operating organisations are forwarded to Gosatomnadzor of Russia for consideration and taken into account in regulatory activity.

Maintenance:

A plant-specific "Maintenance and Repair Programme" has been developed for the plants, which is based on the current "Regulations for Arranging Maintenance and Repair of Nuclear Power Plant Systems and Equipment". Maintenance is performed in accordance with the schedules and requirements of operation manuals approved by the plant management, specifying the scope and procedures of these activities. The pre-maintenance operational tests are performed prior to taking equipment out of operation for repair to estimate the equipment technical state and to clarify the scope of necessary repair.

Kola NPP Units 1-2:

Good progress has been achieved in the development and implementation of a maintenance programme. Standard procedure (general document) for maintenance has been put in place. Approximately half of the work on safety-related procedures is also in use. Maintenance history recording has been started. Training of maintenance personnel is improved. There are still some problems with the warehouses. Computer planning of maintenance work and outages has been implemented.

A number of equipment has been replaced with new, but problems with material condition can still be found in the field. Improvements in material condition area are possible and necessary. Although good progress has been achieved on all issues, attention to the restoration of good equipment material conditions and maintaining them should be the first priority in this area.

Novovoronezh NPP Units 3-4:

Maintenance area is being systematically improved. Major documents have been developed and implemented, such as: safety systems and safety significant systems maintenance regulations, as well as maintenance quality assurance programme.

Maintenance procedures are being upgraded both in the process of current procedure revisions, and issue of new ones. In the framework of joint efforts between NV NPP and EdF (France) a programme is being implemented of planning organisation upgrading and computer-based outage work control.

Training of Plant Personnel:

The table below contains the data on the status of different type of simulators existing at Russian Nuclear Power Plants.

Training Centre	Simulator Type	Status mid 1999
Balakovo NPP	Full scale WWER- 1000 (V-320)	Commissioned in 1994. The modernisation is under way. The work completion and commissioning is scheduled for the beginning of 2000.
	Analytical WWER-1000 (V-320)	The manufacturer test is completed. Commissioning is scheduled for the 2nd quarter of 1999.
Beloyarsk NPP	Analytical BN-600	The manufacturer test is currently underway. The commissioning is scheduled end of 1999.
Kalinin NPP	Full scale WWER-1000 (V-320)	The development was completed in 1996. The commissioning is planned for the end of this year (delay due to non-preparedness of the simulator rooms.
	Full scope WWER- 1000 (V-338)	The development is under way. The completion and commissioning at NPP is planned in 2000.
Kola NPP	Small size WWER-440 (V-213)	Commissioned in 1994.
	Functional analytical WWER-440 (V-230)	Commissioned in 1997.
	Multifunctional WWER-440 (V-230/V-213)	The manufacturer test is completed. Commissioning is scheduled for the 2nd quarter of 1999.
	Full scale WWER-440 (V-213)	Manufacturer test has been initiated. Completion and commissioning are planned end of 1999.
Kursk NPP	Functional analytical RBMK- 1000	Commissioned in 1997.
	Analytical RBMK-1000	Commissioned in 1997.
	Full scale RBMK- 1000	Commissioned in 1998.

Training Centre	Simulator Type	Status mid 1999
Novovoronezh NPP	Functional analytical WWER-1000 (V-187)	Commissioned in 1994.
	Analytical WWER-440 (V-179)	Commissioned in 1998.
Novovoronez Training Center	Full scale WWER-440 (V-230)	Commissioned in 1982. Modernisation activities have been initiated. Completion is planned for 2000.
	Full scale WWER- 1000 (V-187)	Commissioned in 1990.
	Multifunctional WWER-440 (V-179)	Manufacturer tests are completed. Commissioning is planned for the 2nd quarter of 1999.
	Full scale WWER- 1000 (V-320)	Commissioned in 1996 (Russian and Japanese Co-operation Program).
	Full scale WWER-1000 (V-320)	Commissioned in 1997.
Smolensk NPP	Full scale RBMK-1000	The development is underway. The development completion and commissioning is planned for 1999.
Smolensk Training Centre	Full scope RBMK-1000	Commissioned in 1989. Modernisation activities have been initiated. Completion is planned for 2001.

Management of Ageing:

In accordance with regulations the operating organisations developed a programme in which the operability of systems and components is verified. Equipment that exhausted its life is replaced and an assessment of the processes of ageing is performed. The programme KOPUR (verification, assessment, prediction and control of life characteristics of NPP units) is performed to assess the state and control of equipment life.

In 1998, "Rosenergoatom" issued the following regulations intended to formalise the processes of monitoring and predicting system/component lifetime at the plants:

1 "Methodological Requirements for Management of Lifetime Characteristics of Nuclear Power Plant Systems and Elements";
2 "Standard Provisions for Lifetime Management of Nuclear Power Plant Systems and Elements";
3 "Programme for Development of Top Priority Methods Necessary to Perform the Processes of Monitoring, Estimation, Prediction and Lifetime Management of Plant Components", including the list of relevant methodologies.
4 "Standard Technical Requirements for Methodologies for Assessment of Technical Condition and Residual Life of Nuclear Power Plant Unit Components".

The lists of elements requiring evaluation of their physical ageing are developed at nuclear power plants during performance of the activities in this area. These activities are also followed with determination of ageing parameters, analysis of the technical condition, and development (selection) of the methods for evaluation and prediction of lifetime characteristics. Options aimed at compensation of ageing effects are modification of maintenance programmes, performing repair, replacement of obsolete equipment, modernisation of equipment, modification of conditions of operation, and re-assigning the lifetime characteristics.

Plant Decommissioning:

In Russia a number of first generation power units are approaching the end of their thirty-year operational period. A decision on their future operations, in particular on continuation of operation, will be made after thorough consideration of the results of repair, upgrade and safety improvement activities.
Despite the decisions taken, the utilities have started to study technical and economic aspects of the decommissioning. The internal resources of the utilities are expected to ensure the funding of all such operations.

Fast Reactors:

The main steps for decommissioning Beloyarsk units 1 and 2 are as follows:

- Management of spent fuel, in particular of damaged spent fuel;
- Preservation of units 1 and 2 on the basis of the existing concept developed by NIKIET;
- Processing of radioactive waste;
- Construction of:
  - Onsite storage for solidified liquid radioactive waste;
  - Onsite storage for solid radioactive waste;
  - Interim storage for metal bullion smelted in the existing experimental smelter.

Management of Spent Fuel and Radioactive Waste:

At present there is no single NPP in Russia furnished with a complete set of radioactive waste (RW) conditioning facilities. All NPP's employ evaporation technique for liquid RW and the resulting concentrate is stored in metal vessels or is bituminized; solid RW is placed in special storage facilities without pre-treatment. Three NPP's have compacting facilities and two NPP's are equipped with incinerators for solid RW. The liquid and solid RW storage facilities of NPP's are practically full.

In accordance with the strategy adopted in Russia for handling the spent nuclear fuel (SNF) of nuclear stations spent fuel of nuclear power plants with WWER-440 reactors is removed from NPP and processed at radiochemical plant RT- 1 (Chelyabinsk). The reprocessing of SNF generated by WWER-440 and BN-600 reactors and those of moveable nuclear power plants is done at the "MAYAK" Production Association which is the only facility of this kind in Russia and also vitrifies high-level waste. SNF generated by WWER-1000 reactors is sent to the storage facility of Krasnoyarsk Mining and Chemical Combine. The construction of RT-2 plant for reprocessing such SNF has been suspended due to lack of funding. SNF generated by RBMK reactors is not reprocessed and is stored on-site.

To resolve the issues of radioactive waste (RW) and spent nuclear fuel (SNF) generated in the course of nuclear operations, the Russian Government has approved a programme "Management, Utilisation and Disposal of Radioactive Waste and Spent Nuclear Fuel for 1996-2005". With regard to NPP's, the Programme envisages:

1. Management of radioactive waste:
   - to furnish all NPP's with facilities to condition all kinds of RW being generated;
   - to modernise and/or construct on-site solid and solidified RW storage facilities, which will ensure safe storage of RW during the whole of an NPP's service life;
   - to develop technologies and equipment for conditioning RW generated in the course of NPP and nuclear facilities decommissioning;
2. Handling of SNF:
   - to develop shipment containers, means of transportation and supporting structures for safe transportation of various SNF;
   - to develop conditioning facilities for all RW generated in the course of SNF reprocessing;
   - to develop technologies and equipment for containerisation of SNF subject to a long-term storage and/or disposal;
   - to modernise existing, and construct new, on-site storage facilities which would ensure compact and safe storage of SNF during the whole of an NPP's service life.

At the international level, special attention is paid to the situation in the north-west of Russia where a large amount of RW and SNF has accumulated as a result of operation of civil and military marine vessels equipped with nuclear power installations. The western donors propose various initiatives to improve the environmental situation in this region.

Fast Reactors:

The most urgent problem at the present time with respect to decommissioning Beloyarsk units 1 and 2 is the spent fuel. The fuel channels are corroded, and some channels are damaged. The spent fuel cooling pond is also corroded, and the cooling water is contaminated. Therefore, the risk of radioactive release from the cooling pond is not negligible. Taking into account these concerns, a project entitled "Feasibility study and technology transfer for Beloyarsk nuclear power plant on long-term management of spent fuel (R4.01/95)" has been included in the European Commission's TACIS Programme.

Spent fuel from Beloyarsk unit 3 is reprocessed at the Radiochemical Plant (RT-1) at Chelyabinsk-65, located in the Russian Federation.

2.3.4 Programmes and Plans for Improving Plant Operational Safety

Programmes and/or Proposals for Further Improvement of Plant Operations:

The following recommendations of the IAEA were elaborated in the course of the Extrabudgetary Programme (1990-1998). The measures recommended intend to stimulate the operating organisations and plant management to correct the deficiencies identified and to achieve a better alignment with international practices. Among the proposals the most important ones are:

- Operating procedures are key elements of plant safety both for the normal and emergency modes of operation. Improving the format and content of normal operating procedures and elaboration of state- or symptom-oriented emergency operating procedures are considered to be very important.
- The justification of limits and conditions of safe operation needs to be developed systematically on the basis of reliability and accident analyses and operational experience, and included in the Technical Specifications.
- Many of the elements of safety culture are established at the plants. The principles of safety culture should be incorporated into the daily activities and incident prevention through training and qualification programmes.
- In spite of the wide variety of approaches used to gain feedback from operating experience, several improvements are recommended, including reporting criteria, the application of a root cause analysis methodology, setting up multi-disciplinary engineering support groups and improving co-operation between operators.
- The importance of quality assurance is generally recognised by plant management. Review and improvement of the QA programmes are recommended in order to determine department responsibilities and to maintain an independent system for verification and approval of all procedures prior to implementation, and to monitor that the procedures are followed.
- The management of the plants should devote great attention to the improvement of maintenance procedures and maintenance programmes. Errors in maintenance and testing can result in erroneous functioning of safety systems or degradation of defence in depth.
- The configuration management is crucial for safety to ensure the plant is operated in accordance with the design basis. In this respect, the records and data related to different plant activities (e.g. maintenance, surveillance tests, backfitting) should be stored so that they are easily accessible and retrievable, preferably through the use of electronic data. Moreover, the control of plant modifications should be strict and systematic at every step of the process. This is especially important in units which are undergoing far reaching changes in the course of safety improvement programmes.
- The surveillance programmes of the plants need to be reviewed and improved to detect degradation or hidden failures taking into account equipment history and operating experience feedback, and to identify procedural deficiencies. Test intervals should be

considered carefully in order to ensure functionality of equipment and to avoid unnecessary tests that would result in decreasing equipment availability.

- Operational and maintenance staff needs to be trained to develop, maintain and improve their abilities for their activities and, in particular, to diagnose and cope with any safety-related events at the plant.

2.4 SAFETY ANALYSIS

2.4.1 Performance of Safety Analyses

Safety Analysis Report:

For obtaining a license for operating an NPP in Russia a Safety Analysis Report must be submitted. Since 1985 the format and content of this SAR must be in accordance with the document TOB AS-85. The license of Kola 3-4 is based on a SAR in accordance with this document. The first generation WWER-440's (Kola 1,2 and Novovoronezh 3,4) have no SAR in conformity with this document. Their license was based on a different set of safety documentation. The scope of the document TOB AS-85 is in accordance with NRG RG 1.70, but the content is different. Since 1995 a new document is in force (TOB AS-95) which format and content are in accordance with RG 1.70. The first generation WWER-440's have at present temporary operating licenses (for 1 year). Their licenses must now be based on a safety assessment document (OUOB AS) in accordance with the format and content of OUSB AS-97. The relation of this document to TOB AS-95 (and RG 1.70) is not clear.

Deterministic Safety Assessment:

WWER-440:

Novovoronezh 3-4:

A plan of backfitting and modernisation has been developed, including the scope of the accident analysis to be performed for the licensing of the major modernisation. The systematic accident analysis for the major modernisation license should be performed as soon as possible to identify the most adequate safety improvements.

Accident analysis has been performed in the framework of the TACIS programme. Radiological consequences of loss of coolant accidents have been calculated by Gosatomnadzor, with the result that for reactor coolant system breaks over 100 mm piping, additional radioactive material containment features would be required. Analyses performed by Gidropress show that there is no need for additional scram signals (high and low pressurizer pressure and low pressurizer level were included in the original design). Instructions have been included in the operating procedures to shut down the reactor in case of spray system actuation or low level in two steam generators.

A list of 14 beyond-design basis accidents was developed and approved by Gosatomnadzor. VNIIAES, OKB Gidropress, Kurchatov Institute, using conservative assumptions, using NPP data, developed calculational justifications and issued accident management procedures for operators for these accidents.

Analyses have been made of primary pipe breaks of up to 200 mm diameter. The conclusion is that if safety systems function as intended, the reactor core will not be damaged. The existing accident localisation system will assure the containment structures integrity. Thermohydraulic assessment has been made of modernisation measures for the accident containment system. A new containment structural analysis is being made for 2 x 500 mm LOCA, with due account of the new proposed accident containment system. The preliminary results of thermohydraulic calculations for 2 x 500 mm LOCA in the cold leg show that an accident containment system with jet condensers can cope with this beyond-design basis accident.

Mitigating BDBA situations with the implementation of Jet condenser systems are scheduled.

Kola 1-2:

In nearly all IAEA safety issues concerning safety analyses progress was made since 1994 with respect to scope and quality of transient and accident analysis which is required for the safety analysis report (SAR) and the evaluation of modification. In addition to national work and international assistance, the plant has established its own capabilities with respect to thermohydraulic analyses by means of the code APROS. Even if work of the major upgrading is still not implemented it should be emphasised that Kola NPP has contributed to the necessary in-depth investigations to specify the project before the engineering design can be started.
More efforts are certainly necessary for licensing modifications and desirable in the area of severe accidents and shutdown situation. In this respect, it is recommended to the plant management to develop in parallel a plant specific full Level 1 PSA to complement the deterministic approach.

Although the on-going plans to perform accident analysis are well established with broad international support and adequate tools, results are still to be completed.

Loss of coolant accident analyses have been performed for reactor coolant system breaks up to 200 mm. The analyses showed that improvements in the emergency core cooling system are needed for large breaks. The performed containment structural analyses show that the existing containment structure will withstand the pressure transient resulting from 200 mm breaks. More detailed analysis and feasibility studies are still required to define the adequate improvement of the emergency core coolant system. Containment analyses are required for the largest loss of coolant accident breaks, even in the case of additional jet condenser system for pressure reduction. Severe and shutdown accidents are still under way.

RBMK:

The analysis of postulated accidents available in the TOB for Smolensk NPP Unit 3 has been found to be limited and in general does not provide a clear description of the assumptions used in performing the analysis. While these technical justifications were prepared in accordance with the national regulations effective at the time the individual plants were put into service, they do not meet current international practices. The computer codes used at the time of RBMK design had limited modelling capability and there was little experimental data available against which to validate these computer codes.

Since the Chernobyl accident there has been a significant programme underway to upgrade the computer codes for safety analysis of the RBMK NPPs. Modern Western codes like RELAP 5 and ATHLET have now been acquired and the advanced models of the RBMK reactors were developed using the RELAP5/mod3 Code for Leningrad Units 1 and 2 and Smolensk Unit 3.

The small breaks of the DG-headers were studied using the RELAP5/mod3 and ATHLET Codes. These investigations involved the numerical analysis of the sensitivity and study on the influence of a break nodalisation on the critical parameters of a channel (temperature of fuel rods and pressure tubes).

The first version of three-dimensional mathematical model, TRIADA, was developed by late 1986. The version describes three-dimensional neutron kinetics with 140 effective channels considering that up to 60 horizontal layers are utilised. The model was used to analyse the RBMK safety improvement measures and the first stage of the Chernobyl accident.

Probabilistic Safety Assessment (PSA):

WWER:

It is envisaged to carry out full-scale Level 1 and 2 PSA for the complete lists of internal and external initiating events for the base units of operating nuclear power plants with different types of WWER reactors. At present, the development of Level 1 PSA considering internal initiating events and the operating conditions at a nominal power has been completed or is close to its completion.

The following units were determined as the base units for WWER reactors:
- Novovoronezh NPP unit 3 with WWER440/V179 reactor,
- Kola NPP unit 3 with WWER440/V213 reactor,
- Novovoronezh NPP Unit 5 with a WWER1000/V187 reactor;
- Balakovo NPP Unit 4 with a WWER1000/V320 reactor,
- Kalinin NPP Unit 1 with a WWER1000/V338 reactor.

Each base (reference) unit of the above-mentioned sites represents a certain category of nuclear power unit with WWER reactors, which were constructed in accordance to the safety concepts adopted for the period of their design.

Novovoronezh 3:

Level 1 PSA, internal initiators and hazards incl. fire and floods, standard PSA methodology, including common cause failures and human interactions, based on plant specific and generic data, Total plant CDF: $2{,}02.10^{-3}$ (state 1996).

Kola 3:

Level 1 PSA, internal initiators, planned to be finished end of 2000.

Novovoronezh Unit 5:

The PSA has been developed for the main groups of internal initiating events with the reactor operating under load. The resulting value of the Core Damage Frequency (CDF) of unit 5, summed up over all initiating events, amounts to 5.6E-03/year. More than 95% of this value is attributable to the failure of the function of emergency removal of heat through the secondary circuit, which is explained by the differences of this unit from WWER-1000 plants with a V-320 reactor.

Balakovo Units 1 to 4:

A limited Level 1 PSA was performed by specialists from Atomenergoprojekt Institute for unit 4. The PSA was performed in the framework of the TACIS Programme. The CDF for all groups of initiating events considered was calculated to be 1.13E-05/year. In 1998, the PSA was revised with a view to carry out studies of the possibility of increasing the testing period of equipment of the safety systems from one to two months. The resulting CDF was 1.32E-05/year.

Kalinin Units 1 and 2:

Level 1 PSA of unit 1 for operation at a rated power level was performed in 1996. The CDF for the considered initiating events is estimated to be 1.3E-04. The CDF for unit 2 was calculated as 1.2E-4/year.

An in-depth probabilistic safety analysis for unit 1 and 2 has been carried out in the framework of the "BETA" project. The completion of the analysis of internal initiating events was scheduled for 1999.

RBMK:

Systematic studies of RBMK PSA were started in 1988. The PSA methodology was developed and software was accomplished taking into consideration RBMK features in 1988-1990 (PSA-0). The second stage (1991-1992), devoted to implementing PSA for Leningrad NPP Unit 1, has incorporated categorisation of states with RBMK core damage under severe accidents, analysis of severe accidents, development of NPP models before and after upgrading.

PSA activities were a significant part of the EC sponsored programme on "Safety of RBMK reactors" where in the framework of the "Task Group 9", a Pilot Risk Study (PRS) for Leningrad NPP Unit 1, Smolensk NPP Unit 3 and Ignalina NPP Unit 2 were performed. A second PRS of Leningrad NPP Unit 1 was performed within the UK/RF bilateral programme to consider in more detail the value of the reconstruction measures. The RDIPE pioneered the PSA for RBMKs by performing a Level 0+ study for Leningrad NPP Unit 1. Except for Ignalina PSA, no other RBMK type NPP has a full-scope Level 1 PSA completed or in progress.

In 1995, agreement was reached with Sweden and the United Kingdom to sponsor a joint in-depth risk assessment of the Leningrad (Unit 2) plant. This is the pilot project of the RBMK plant-specific safety assessments planned under the plant safety evaluation activities. The technical work for this assessment is performed by the Leningrad plant and Russian design and scientific institutes, with technical assistance from U.S., Swedish, and British experts. Sweden and the United Kingdom are funding the probabilistic risk assessment of Unit 2; the United States is providing the necessary deterministic analysis, system descriptions, and selected system engineering assessments to support the assessment. Project objectives are to assess the impact of recent safety improvements to Unit 2 and to establish a common perspective pertaining to RBMK severe accident risk and mitigation.

2.4.2 Impact of Safety Analyses

Impact of Safety Analyses on Plant Design and Operation:

In general the safety analyses are performed for obtaining the license for the upgrading and for the identification of the most adequate safety improvements.

At Novovoronezh unit 5 (WWER1000), implementation of rather simple recommendations has been partially implemented based on PSA findings and results. The implementation of the measures led to a significant reduction of the CDF. Among the measures are the following:

- Developing alternative ways of feeding water to the steam generator, and appropriate actions of personnel.
- Substantiating the possibility of using the safety valve of the steam generator for cool-down at a low pressure in the steam generator.

- Determining the necessary activities of plant personnel to ensure make-up of the primary circuit in case of a small leak.
- Determining the necessary activities of plant personnel for using the blow-down make-up system to ensure injection into the pressuriser and steam removal from the pressuriser circuit to reduce primary circuit pressure.

2.5 INTERFACE BETWEEN THE OPERATOR AND THE REGULATOR

In general, it was felt that more detailed investigations would be necessary for a sound evaluation of the interface between the operator and the regulator. Site visits and interviews with the relevant representatives of the utility and the regulatory body would be necessary to provide more substantive information on the issues proposed in the Performance Evaluation Guide:

- Definition of the role of the utility and the regulatory body for nuclear safety;
- Status and the character of regulatory documents;
- Frequent exchange of information; and
- Efficiency of co-ordination within the regulatory body.

3. LEGAL AND REGULATORY INFRASTRUCTURE

3.1 NUCLEAR LEGISLATION AND REGULATIONS

Status of Legislative Framework:

All activities to ensure safety of nuclear power usage in the Russian Federation are implemented according to the laws of the Russian Federation, acts of the President of the Russian Federation and the Government of the Russian Federation, federal regulations in the field of the use of atomic energy, regulatory documents issued by state regulatory bodies as well as regulatory documents issued by the bodies for state control over the use of atomic energy, standards, construction norms and rules.

Status of Regulatory Documents:

Federal laws:

The basic laws that establish the ensuring of the safety of atomic energy usage are the following:
- Federal Law "On the Use of Atomic Energy" (1995),
- Federal Law "On Radiation Safety of the Population" (1996).

The Federal Law "On the Use of Atomic Energy" establishes legal relations between all the parties involved in nuclear energy usage and guarantees compensation for damage caused by radiation effects.
The Law establishes the independence of the bodies for state regulation from the other state bodies as well as organisations whose activities are connected with atomic energy usage.

The Federal Law "On Radiation Safety of the Population" sets out fundamentals and principles for ensuring radiation safety of the population for protecting its health, measures to ensure radiation safety, authorities of the Russian Federation and subjects of the Russian Federation in the area of ensuring radiation safety; rights and responsibilities of citizens and public associations in the field of ensuring radiation safety.

Presidential acts and Governmental Decrees of Russia:

18 regulations are needed for the purpose of enforcement of the Federal Law "On Atomic Energy Use". Most of them have been already developed and approved. In particular, "Provisions on licensing of activities in nuclear energy usage" was approved by Decree of the Government of the Russian Federation in 1997 and set up procedures and terms of licensing of activities in nuclear energy. These Provisions specify Gosatomnadzor as the body responsible for licensing activities in nuclear energy. Other bodies for state regulation are

involved in licensing of activities carried out at nuclear installations according to their competence.

Federal regulations in nuclear energy use area:

Federal regulations in nuclear energy usage to be approved by Gosatomnadzor of Russia comprise regulatory documents on nuclear and radiation safety and setting up requirements for all stages in the life cycle of a nuclear installation, requirements for systems important for safety of a nuclear installation and their equipment, procedures for accounting for violations and investigation of violations and accidents occurring in nuclear installation operation as well as other provisions on ensuring nuclear safety.

Regulatory guides and guidelines on safety:

In exercising its powers and according to requirements of the federal regulations in nuclear energy usage, Gosatomnadzor develops, approves and puts into force regulatory guides which determine a set of documents needed for ensuring nuclear and radiation safety of nuclear installation and requirements to their content, procedures for checking reliability of information contained in the documents submitted for license obtaining and review of these documents.

Standards and industrial regulatory documents:

This group of documents applied in nuclear energy usage comprises industrial regulatory documents and documents developed for regulating various aspects of activities in nuclear energy use.

Basic References and Special Emphases:

No relevant information has been collected.

Processes for Approval and Issuance:

The laws, acts and decrees are to be approved by the Government. The federal regulations and regulatory guides and guidelines are issued and approved by Gosatomnadzor.

3.2 REGULATORY BODY AND SUPPORTING ORGANISATIONS

Legal Status and Mandate of the Regulatory Body:

The Federal Nuclear and Radiation Safety Authority (Gosatomnadzor) is a federal executive body implementing state regulation of safety in nuclear energy usage. Nuclear and radiation safety regulation in NPP siting, designing, construction, operation and decommissioning is one of the main areas of activities carried out by Gosatomnadzor. This activity includes:

- regulation;
- licensing of objects of nuclear power engineering;
- state supervision of compliance with requirements of federal regulations and licence conditions.

In the Russian Federation all activities, associated with nuclear safety, are realised on the basis of Constitution of the Russian Federation, federal laws, normative legal acts of the President and Government of the Russian Federation, federal norms and rules in the field of nuclear energy, regulatory documents of the state safety regulation bodies, and also regulatory documents of bodies, controlling the use of nuclear energy.
State regulation of nuclear safety and technical aspects of radiation safety is entrusted to the Federal Nuclear and Radiation Authority (Gosatomnadzor). Statute of Gosatomnadzor is approved by the President of the Russian Federation.

Gosatomnadzor is a federal executive body and realises state safety regulation in peaceful and defence use of nuclear energy (regulation of activities related to nuclear weapons and nuclear military installations is excluded). It determines conditions to ensure radiation protection of the personnel, population and environment and prevention of unauthorised proliferation and use of nuclear materials, is independent of other state executive bodies and organisations working in the field of nuclear energy, works in co-operation with other executive bodies and is financed from the federal budget.

The main objectives of Gosatomnadzor, established by the Federal Law "On the Use of Nuclear Energy", are the following:
- to take part in establishment of legal basis for state nuclear safety regulation;
- to arrange development, to develop, approve and put in force federal norms and rules in the field of nuclear energy;
- licensing in the field of nuclear energy for safety;
- to supervise safety in production and peaceful and defence use of nuclear energy,
- nuclear materials, radioactive substances and radioactive wastes;
- guarantees of non-proliferation of nuclear technologies and nuclear materials;
- physical protection of nuclear materials, nuclear facilities, radiation sources, storage facilities for nuclear materials, radioactive substances and radioactive wastes;
- to control implementation of international contracts and agreements of the Russian Federation in this area;
- to arrange scientific research to justify safety principles and criteria, norms and rules in the use of nuclear energy;
- to inform state authorities and population about changes in nuclear and radiation safety at nuclear facilities, radiation sources and storage facilities.

By 1 January 1999 the staff of Gosatomnadzor amounted to 1634 employees, including 145 people in the headquarters, 1296 people in the region offices and 193 in the SEC NRS (Scientific & Engineering Centre for Nuclear & Radiation Safety).

Advisory Committees and Technical Support Organisations:

The Scientific & Engineering Centre for Nuclear & Radiation Safety (SEC NRS) can be seen as a technical support organisation (TSO) for the rest of Gosatomnadzor. It is a separate division which is positioned directly under the central staff body of Gosatomnadzor.

3.3 LICENSING PROCESS

Licensing Practice and Requirements:

According to the Provisions on licensing, an operating organisation should obtain a licence for siting, construction, operation and decommissioning of nuclear installations. While applying for permits (licences) for one or other stage of NPP siting and construction, an operating organisation (an applicant) submits a set of documents defined by Gosatomnadzor justifying NPP nuclear and radiation safety in accordance with the existing Provisions.

The following documents should be submitted to Gosatomnadzor by an operating organisation to obtain a permit (licence) for NPP unit siting:
- feasibility study of siting of the object to be constructed;
- safety analysis report covering justification of the selected site according to the existing regulatory and technical documentation, conceptual description of NPP and safety assessment.

Licensing of Plant Modification/Upgrading Activities:

All operating Russian NPP's have Gosatomnadzor permits for operation. Gosatomnadzor issues licences for operation only on the basis of the NPP unit safety assessment carried out taking into account the documents submitted and results of inspections related to the NPP's safe operation. In conjunction with the new "Provisions on licensing in the nuclear energy use area" put into effect in July 1997, permits issued earlier by Gosatomnadzor are now invalid and new licences for operation are being issued in a systematic way.

Operating organisations have submitted applications and the necessary documentation as well as additional materials justifying NPP safety to Gosatomnadzor to obtain licences.

Licensing of Reactor Operators:

No relevant information has been collected.

3.4 INSPECTION AND ENFORCEMENT

Inspection Scope and Practice:

Gosatomnadzor carries out inspection activity including the organisation and performance of inspections related to the status of NPP safety at different stages in the life cycle in order to assess:

- NPP compliance with requirements of regulatory documents on safety,
- nuclear and radiation safety status,
- implementation of activities on NPP safety improvement by the operating organisations,
- measures being undertaken to eliminate revealed violations of requirements of regulatory documents on safety and compliance with licence conditions.

Inspections are also carried out when applications for Gosatomnadzor licences and implementing licensed activities are considered.

Duties of and Techniques Applied by Regulatory Inspectors:

While considering documents submitted for obtaining Gosatomnadzor licences inspections are performed:

- to carry out detailed (in-depth) assessment of NPP safety or safety in organisations whose information was used while preparing materials justifying safety;
- to check reliability of information contained in materials justifying safety;
- to evaluate capabilities and available conditions of an applicant to implement activities to be licensed.

Enforcement:

If violations of safety requirements are revealed during inspections at an NPP, prescriptive orders should be developed in an established format reflecting the results of the inspections.
Such prescriptive orders are transferred to the relevant operating organisations for them to undertake appropriate measures, ensure implementation of prescriptions and provide information on the implementation of these prescriptions. If an NPP or an operating organisation does not implement the prescriptions in due time and/or provide the required information on implementation of the prescriptions, Gosatomnadzor will enforce sanctions established in the legislation of the Russian Federation.

3.5 INTERNATIONAL ASSISTANCE AND REMAINING ISSUES

Major International Assistance and Co-operation Programmes:

Since it was established, Gosatomnadzor is supported by different international organisations in the improvement of its activities. The main forms of international co-operation are:

- exchange of information and documents,
- exchange of experience (joint seminars, conferences, inspections and so on);
- consultations (in development of norms and rules, review reports, review guides and so on),
- technical assistance (delivery of equipment, computers and so on).

With this co-operation, the system of regulatory documents has been modernised and a number of basic regulatory documents, guides and recommendations has been developed. A long-term programme of revision and development of regulatory documents has been established and is being carried out in Gosatomnadzor. Carrying out of this programme is also planned to be co-ordinated with future international co-operation.

Review of a number of upgrading NPP's is carried out jointly with western experts. In the frames of this work Russian experts have received and mastered main western codes for accident analysis and other important calculations. All this has improved validity of the Russian NPP's safety and is used by Gosatomnadzor to improve its regulatory activities.

An important direction of improvement in the field of licensing and supervision was and continues to be the increase of the role of the operating organisation in NPP safety.

International Regulatory Review and Assessment:

No relevant information has been collected.

Major Remaining Issues of Nuclear Safety Regulation:

No relevant information has been collected.

3.6 PERSPECTIVES OF THE REGULATORY BODY

Carrying out of the long-term programme of revision and development of regulatory documents is planned to be co-ordinated with future international co-operation. To increase the responsibility of the operating organisations in nuclear safety, the role of these organisations in licensing and supervision will be further increased.

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Abbreviations/Acronyms:

AEP	AtomEnergoProjekt
ALS	Accident Localisation System
CDF	Core Damage Frequency
CR	Control Rod
DBA	Design-Basis Accident
EBP	Extrabudgetary Programme (IAEA)
EBRD	European Bank for Reconstruction and Development
EdF	Electricité de France
EFWS	Emergency Feedwater System
EC	European Commission
ECCS	Emergency Core Cooling System
FORUM	Federal All-Russia Wholesale Power Market
FSU	Former Soviet Union
GAN	Gosatomnadzor (Federal Nuclear and Radiation Safety Authority of Russia)
IAEA	International Atomic Energy Agency
INES	International Nuclear Event Scale (IAEA)
ISI	In-Service Inspection
LBB	Leak Before Break
LOCA	Loss of Coolant Accident
MW_{el}	Megawatt electric
MW_{th}	Megawatt thermal
NDT	Non-Destructive Testing
NIS	Newly Independent States
NPP	Nuclear Power Plant
NUSS	Nuclear Safety Standards
OPB	Russian regulatory requirements for the design of nuclear power plants
PSA	Probabilistic Safety Assessment
QA	Quality Assurance
RAO EES	United Power System of Russia
RBMK	Boiling Water Cooled Graphite Moderated Pressure tube type reactor
RCPS	Reactor Control and Protection System
RDIPE	Research and Development Institute for Power Engineering
RPV	Reactor Pressure Vessel
RRC	Russian Research Centre
RW	Radioactive Waste
SAR	Safety Analysis Report
SDFP	System for Dynamic Fastening of Pipelines
SG	Steam Generator
SNF	Spend Nuclear Fuel
SPDS	Safety Parameter Display System
SWS	Service Water System
TACIS	Technical Assistance to the Community of Independent States

TSO	Technical Support Organisation
TWh	Tera (10^{12}) Watt hour
UPS	United Power System (of Russia)
VNIIAES	All Russian Research Institute for Nuclear Power Plant Operation
WANO	World Association of Nuclear Operators
WWER	Water Cooled, Water Moderated Energy Reactor