Lithuanian Energy Institute – Ignalina Safety Analysis Group
in cooperation with
The Swedish Radiation Protection Institute
and
The Swedish International Project Nuclear Safety

HANDBOOK ABOUT THE IGNALINA NUCLEAR POWER PLANT

FOR THE EMERGENCY PREPAREDNESS ORGANIZATIONS AROUND THE BALTIC SEA

Printed in LITHUANIA

Kaunas ∗ Lithuanian Energy Institute ∗ 1997

ABSTRACT

This Handbook gives an overview of the emergency preparedness and principles for protection of the public in the Baltic States in the event of a nuclear or radiological accident at the Ignalina nuclear power plant. The subject covered includes the description of site, main processes and features of the RBMK-1500 reactors, the operating organization and the Safety Upgrading Program of the Ignalina NPP. Particular emphasis has been placed on the RBMK-1500 main safety functions and systems. An extensive section deals with the “rule of thumb” formalism for use in emergency organization to provide an early prediction of an imminent release of radioactive materials to the environment as a result of a nuclear accident. Also accident management principles on site, as well as emergency preparedness organization and principles for protection of the public in Lithuania, Latvia and Estonia are presented.

This Handbook was prepared by the Ignalina Safety Analysis Group of the Lithuanian Energy Institute in Kaunas, and funded by the Swedish Government. The funds were allocated for the Swedish Radiation Protection Institute (SSI) project to cooperate with the Baltic States in matters involving Emergency Response Planning and Preparedness issues. This project was carried out during 1994-1997 and included the following eight subprojects:

- National emergency response planning
- Radiation measuring and countermeasures/intervention levels
- Public information
- Nuclear emergency exercises
- Model accidents for the Ignalina NPP
- RBMK reactors, design and safety
- Planning of on-site rescue and recovery operations
- Review of the INPP’s emergency preparedness plan

Additional funds for the two last subprojects were allocated by the Swedish International Project Nuclear Safety.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

LIST OF APPENDIXES

LIST OF ABBREVIATIONS

ACS	Accident Confinement System
AZ-1...AZ-4	Emergency Protection "AZ-1"..."AZ-4"
BDBA	Beyond Design Basis Accident
CC	Condensate Cleaning
CD	Civil Defence
CD&ER	Civil Defence and Emergency Response
DCD	Department of the Civil Defence
C&I	Control and Instrumentation
CPS	Control and Protection System
DBA	Design Basis Accident
EBRD	European Bank for Reconstruction and Development
ECCS	Emergency Core Cooling System
EFWS	Emergency Feedwater System
EOC	Emergency Operating Center
FAS	Fast Acting Scram
FP	Fission Products
GESC	Governmental Emergency Situation Commission
HDC	Head of Civil Defence
HDD	Hydrological Diverting Dam
IAEA	International Atomic Energy Agency
INES	International Nuclear Event Scale
LOCA	Loss-Of-Coolant Accident
MCC	Main Circulation Circuit
MCP	Main Circulation Pump
MSV	Main Safety Valve
NDT	Non-Destructive Testing
NPP	Nuclear Power Plant
NSA	Nuclear Safety Account
OP	Operational Group
PCS	Purification and Cooling System
QA	Quality Assurance
RCP	Radiation and Chemical Division
RBMK	Russian Acronym for "Channelized Large Power Reactor"
RIA	Reactivity Initiated Event
SAR	Safety Analysis Report
SBU	Special Branch Unit
SDV-A	Steam Discharge Valve to ACS Pool

SDV-C	Steam Discharge Valve to Turbine Condenser
SIP	Swedish Acronym for Swedish International Project Nuclear Safety
SKI	Swedish Acronym for Swedish Nuclear Power Inspectorate
SMHI	Swedish Acronym for Swedish Meteorological Institute
SSI	Swedish Acronym for Swedish Radiation Protection Institute
SUP	Safety Upgrading Program
VATESI	Lithuanian Acronym for Lithuanian Nuclear Power Safety Inspectorate

ACKNOWLEDGMENTS

We gratefully acknowledge financial support provided by the Swedish Radiation Protection Institute (SSI) with fund of Swedish Government. Special thanks are due to Mr. B. A. Persson, SSI, and Mr. E. Jende, SIP, who have made it possible to prepare this Handbook. Their assistance was significant and is deeply appreciated. Our thanks are also given to Mr. A. Paulikas, Department of Civil Defence of the Republic of Lithuania, Mr. I. Brunenieks, Civil Defence Center of the Republic of Latvia, Mr. A. Salmins, Ministry of the Environmental Protection and Regional Development of the Republic of Latvia, Mr. P. Konts, Estonian Rescue Board, for their valuable assistance and advice, and Mr. K. Johansson, Kojkon AB, Sweden, who prepared Chapter 4 of this Handbook. At the plant, valuable advice was provided by Mr. A. Dvoretsky, Head of Safety and Quality Assurance Department.

E. Ušpuras
R. Pabarčius

1. Brief Description of the Plant

1.1 Site Structure

1.1.1 Population and Nearby Industrial Surroundings

The Ignalina nuclear power plant is located on the northeast corner of Lithuania, close to the borders with Belarus and Latvia, Figure 1.1. The plant is situated on the southern shore of Lake **Drūkšiai**, 39 km from the town of Ignalina. The nearest cities are the Lithuanian capital Vilnius (130 km away) with a population of approximately 575,000, and the city of Daugavpils, in Latvia (30 km away), population 126,000. The plant's closest neighbor is the town of Visaginas, the residence of the Ignalina nuclear power plant personnel. The town is located 6 km from the plant and has a population of about 32,600. All distances given above are flight distances. The main information about the distribution of population in the region is presented in Table 1.1.

The density of the population inside 15 km radius is 14.4 people/km^2, excluding Visaginas, and 63.1 people/km^2, including Visaginas. Within 25 km the density of the population is 18.6 and 35.6 people/km^2, respectively.

The plant uses lake Drūkšiai as a natural reservoir for cooling water. The shape of lake Drūkšiai and location of Ignalina NPP are presented in Figure 1.2. Dash line shows circulation of cooling water in lake Drūkšiai. Other lakes and rivers in the vicinity of the plant are:

- lake Visaginas,
- lake Apyvardė, 8 km south,
- lake Alksnas, 13 km south,
- lake Disnai, 16 km south,
- lake **Smalvės**, 11 km west,
- the Daugava River passes 30 km north of the plant.

Fig. 1.1 Location of Ignalina NPP

Table 1.1 Population distribution

Populated area	Distance from INPP, km	Direction	Population
Villages and farmsteads	inside 15 km radius inside 25 km radius	- -	11,400 30,400
Visaginas	6.5	southwest	32,600
Turmantas	12	northwest	0,400
Dukštas	15	southwest	1,200
Zarasai	25	northwest	8,900
Daugavpils	30	north	126,000
Ignalina	39	southwest	7,200
Utena	64	west	37,000
Ukmergė	120	west	30,800
Vilnius	130	southwest	575,000
Panevėžys	140	northwest	132,100
Jonava	158	west	36,900
Kėdainiai	168	west	34,500
Kaunas	186	west	415,300
Radviliškis	192	northwest	21,000

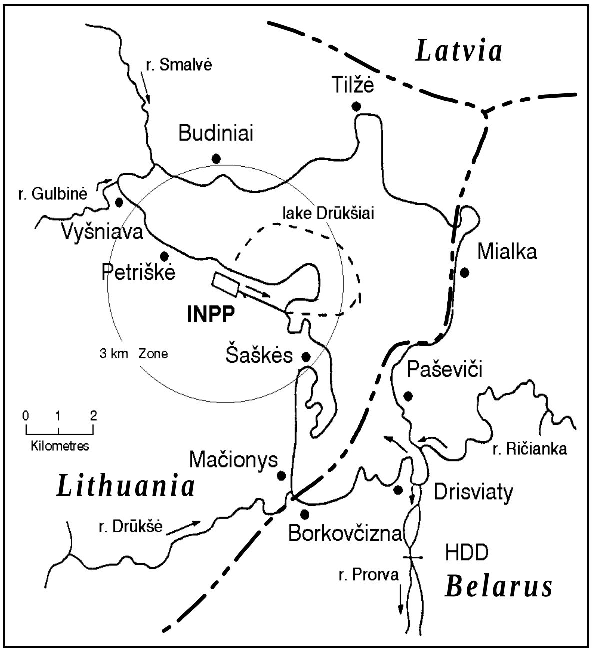

Fig. 1.2 The shape of lake **Drūkšiai** and location of Ignalina NPP [1]

Dash line - circulation of cooling water

The nearest highway passes 12 km west of Ignalina NPP. This highway links the town of Ignalina with those of Zarasai and Dukštas, and has an exit to the highway connecting Kaunas and St. Petersburg. The entrance of the main road going from Ignalina NPP to the highway is near the town of Dukštas. The extension of the road from Ignalina NPP to Dukštas is about 20 km.

The main railroad line Vilnius - St. Petersburg passes 9 km west of Ignalina NPP. A single track extends from Visaginas to Dukštas. The rest of the main line connecting Vilnius and St. Petersburg is double-track. The weight limit of the train is 3500 tons. The railway station Dukštas is used for cargo traffic as well as for passenger transportation.

1.1.2 Meteorology

The Ignalina NPP is situated in the temperate climate zone. The region climate can be considered as homogeneous in the global sense. But on the regional scale it is rather unstable, because of the prevalent intrusion of air flows from the adjacent geographical zones. In comparison with other Lithuanian areas, this area is marked by a big variation of air temperature over the year, the colder and longer winters with abundant snow cover, and warmer, but shorter summers.

The average annual air temperature in the region is 5.5°C. In the spring (March - May) the average temperature is 5.1°C, in summer (June-August) is 16.1°C, in autumn (September-November) is 6.1°C and in winter (December-February) is -5.5°C. January is the coldest month with an average monthly temperature of -6.5°C, and June is the warmest one with 17.8°C. Annual amplitude of average monthly temperatures is 24.1 degrees. Absolute maximum of recorded temperature is 36°C, and absolute minimum is - 40°C [2].

During the year about 170 atmospheric fronts pass over the Ignalina territory. Winds from west and south predominate. The strongest winds are directed from west and southeast. The average annual wind speed is 3.5 m/s, and the maximal (gust) speeds can reach 28 m/s. In the spring the average wind speed is 3.1 m/s, in summer - 2.7 m/s, in autumn - 3.4 m/s, and in winter - 3.7 m/s.

The average annual precipitation with correction on moistening of draught gauge is 638 mm. Minimum of precipitation occurs in February (around 31 mm), and the maximum - in July (around 85 mm). The snow cover in the region is about 100-110 days per year. The average height of snow cover is 30-40 cm [2].

The average annual relative humidity of air reaches 80%, and is around 90% in the winter. The minimum relative humidity (53-63%) is observed in June, and the maximum - in January [2].

In the Ignalina NPP area fog is observed virtually all year round. The average number of days with fog is 45 and the maximum - 62 days.

1.1.3 Site

The Ignalina NPP site arrangement is shown in Figure 1.3, as well as in Appendix 1. The plant site is approximately 0.75 km^2. The buildings take up about 0.22 km^2.

The Ignalina NPP has two similar reactor units (Figure 1.4). Each unit consists of five buildings designated as A, B, V, G and D. There are two separate reactor buildings A1 and A2 adjacent to a common building D1 and D2 housing the main control rooms, electrical instrumentation and deaerators. The last building is adjacent to a common turbine building, G1 and G2. The distance between the main buildings of the plant and the shore of lake **Drūkšiai** is around 400-500m.

Both units have the following common facilities:

- low-level waste storage;
- medium and high level waste storage;
- liquid-waste storage tanks;
- switchyard;
- nitrogen and oxygen supply facility;
- other auxiliary systems.

The building which houses the 12 emergency diesel generators (six diesel generators per unit) is physically separated from other buildings. A separate service water pump station is also built for each unit serving the needs of an uninterrupted supply of cooling water.

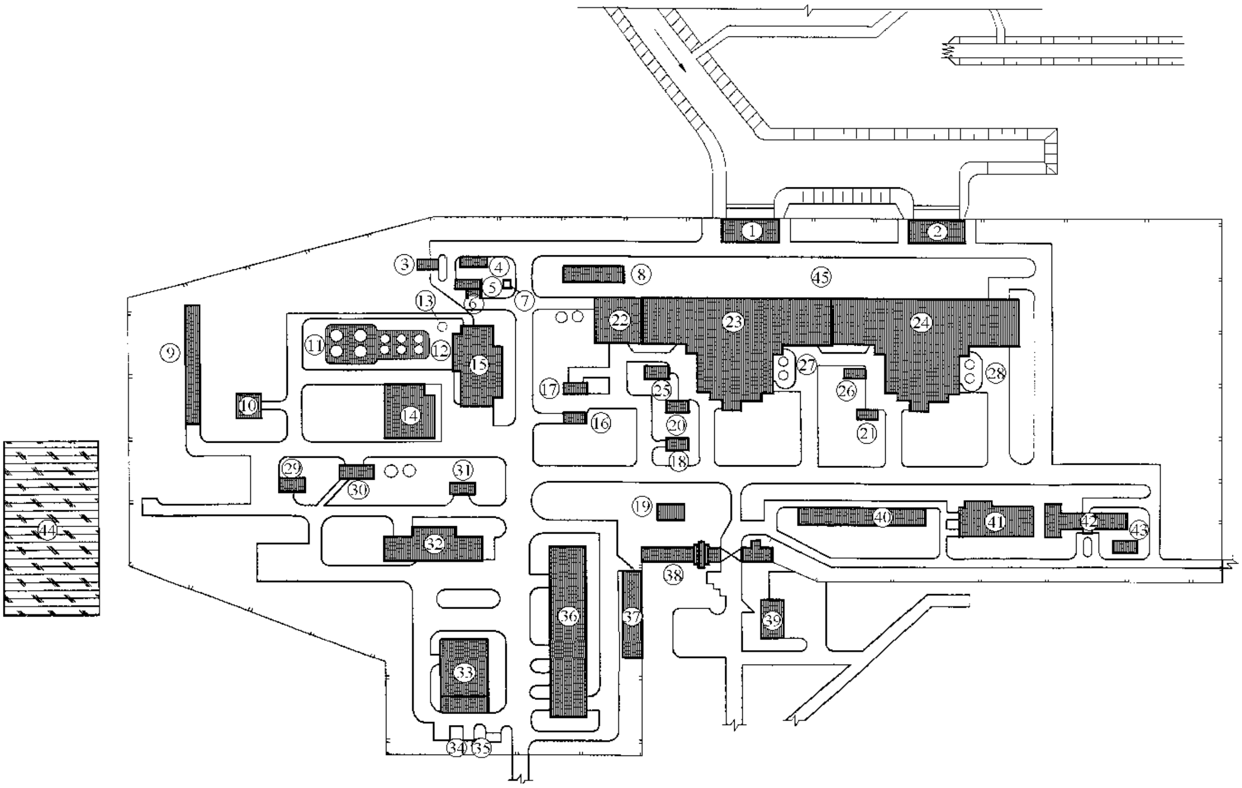

Fig. 1.3 Ignalina NPP site arrangement [3]:
1,2 - service water pump stations; 3 - acetylene bottle depot; 4 - oil depot; 5 - oil system equipment; 6 - transformer equipment ; 7 - sewage pump station; 8 - hydrogen/oxygen receiving; 9 - low-level radwaste; 10 - medium and high level waste; 11 - shower water tanks; 12 - waste water tanks; 13 - radwaste processing building vent stack**;** 14 - bitumen store; 15 - liquid waste storage; 16 - chemical water treatment building; 17 - chemical water treatment tanks; 18,19 - changing facilities; 20, 21 - gas purification systems; 22 - heat supply station; 23,24 - Units 1 and 2, respectively; 25,26 - ECCS accumulator; 27,28 -tanks for clean low-salt water; 29 - vehicle wash; 30 - bitumen depot; 31 - special laundry; 32 - chemical reagent depot; 33 - equipment store; 34 - noble gas bottle depot; 35 - reservoir with artificial evaporation; 36 - repair shop; 37,38 - administrative buildings; 39 -cafeteria; 40 - diesel generators; 41 - compressor and refrigeration station; 42 - nitrogen and oxygen building; 43 - liquid nitrogen tank; 44 - 110/330 kV switchyard

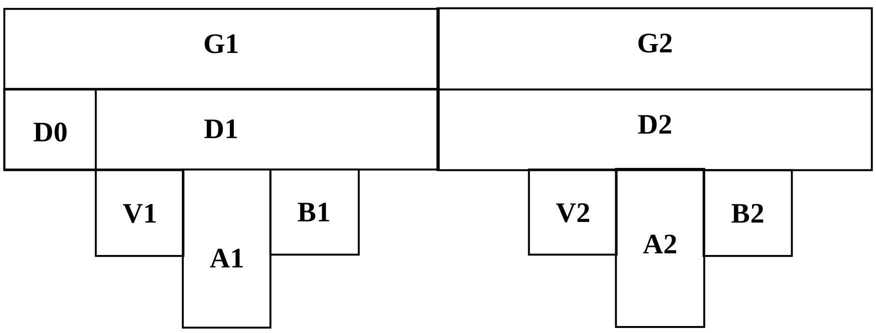

Fig. 1.4 General units arrangement:
A1, A2 - reactor buildings; B1, B2- low salt water and MCC bypass water treatment facilities; V1, V2 - reactor gas circuit and special venting system; G1, G2 - turbine generators with auxiliary systems, feed facilities and heat supply facilities; D1, D2 - control rooms, electrical equipment and deaerators; D0 - heat pipe service and fire fighting facilities

Table 1.2 Status of the RBMK plants

Unit	Generation	Status
Ignalina 1	2	operating
Ignalina 2	2	operating
Chernobyl 1	1	operating
Chernobyl 2	1	closed down
Chernobyl 3	2	operating
Chernobyl 4	2	closed down
Leningrad 1	1	operating
Leningrad 2	1	operating
Leningrad 3	2	operating
Leningrad 4	2	operating
Kursk 1	1	operating
Kursk 2	1	operating
Kursk 3	2	operating
Kursk 4	2	operating
Kursk 5	3	under construction
Smolensk 1	2	operating
Smolensk 2	2	operating
Smolensk 3	3	operating

1.2 RBMK Generations and Main Processes

The Ignalina NPP is a 2 unit RBMK-1500 reactor. This is one of the most advanced version*s* of the RBMK design series. There are presently RBMK-type plants at Ignalina, Chernobyl, Leningrad (Sosnovy Bor), Kursk and Smolensk, Table 1.2. All operating RBMKs represent three generations of reactors having significant differences with respect to their safety design features. The six first generation units were built all RBMK-1000s. Of the ten second generation units, eight were RBMK-1000s and two were RBMK-1500s. Unit 2 at Ignalina contains safety features beyond those other second generation units. One third generation RBMK-1000 unit has been built at Smolensk, which is Unit 3. And one third generation unit is currently under construction at Kursk. The principal design differences between RBMK generations are summarized below.

First generation units were designed and brought on line in the early-to-mid-1970s, before new standards on design and constructions of nuclear power plants issued in 1973 were introduced in the Soviet Union. Units brought on line since late 1970s and early 1980s are generally grouped as second generation RBMKs. These plants were designed and constructed with updated safety standards issued in 1982. The third generation units were originally designed in accordance with these updated safety standards, and to a large extent already comply with the latest safety regulations issued in 1988 after the Chernobyl accident.

The unmodified first generation units do not comply with current safety requirements in a number of respects. Therefore**,** they operate under such a mode which provides for the operation of reactor at a reduced capacity to reduce power density and linear rating of the fuel, increase the volume of primary circuit pipework that is inspected in service, implement measures for beyond DBA management and to improve the reliability of primary circuit isolation valves. The main advantages of the second generation units over the first generation units are the accident confinement system and advanced functionality of the emergency core cooling system. The second generation units are very similar to the third, the most obvious difference being in the two-storey design of ACS pressure suppression pool of these units. The main factors needed to bring the

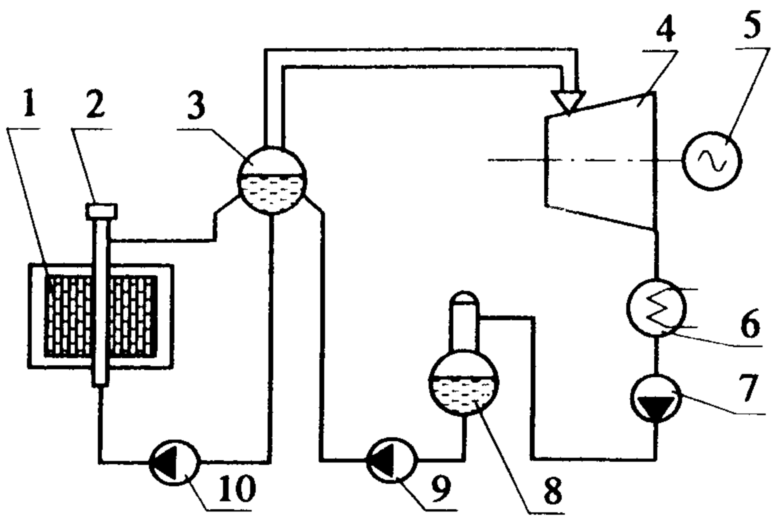

Fig. l.5 Simplified Ignalina RBMK-1500 heat flow diagram:
1 - reactor; 2 - fuel assembly; 3 - steam separator; 4 - turbine; 5 - generator; 6 - condenser; 7 - condensate pump; 8 - deaerator; 9 - feedwater pump; 10 - main circulation pump

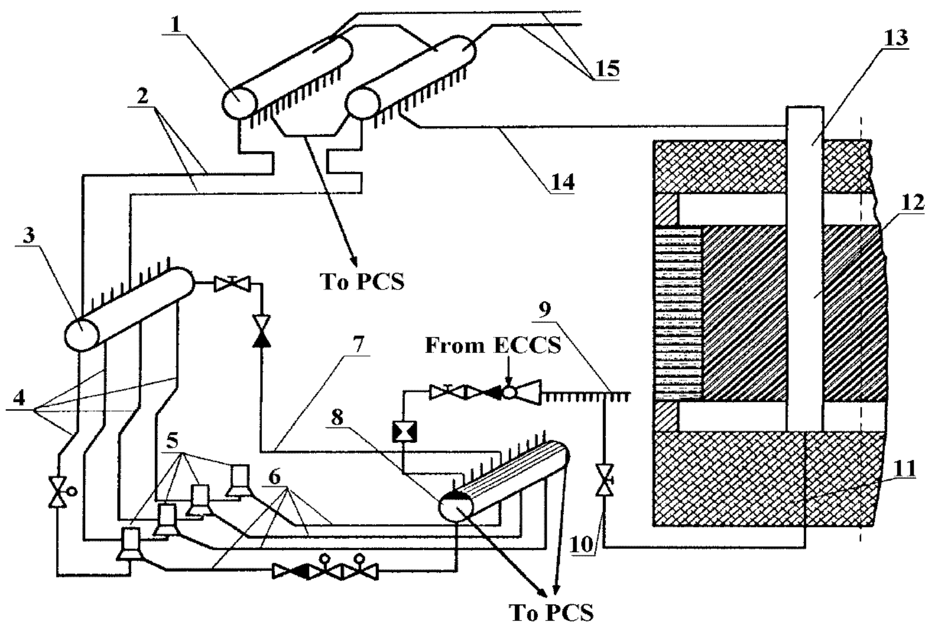

Fig. 1.6 Simplified schematic of the main circulation circuit:
1 - steam separator; 2 - downcomers; 3 - suction header; 4 - suction piping of the MCP; 5 - MCP tanks; 6 - pressure piping of the MCP; 7 - bypass between headers; 8 - pressure header; 9 - GDH with flow limiter, check valve and mixer; 10 - water piping; 11 - channel to core; 12 - fuel channel; 13 - channel above core; 14 - steam-water pipes; 15 - steam pipelines

second generation plant into line with latest regulations of 1988 include seismic safety, improved fire protection and upgrading of safety systems. Ignalina NPP safety upgrading program is discussed in Section 1.5.

In many respects, the Ignalina NPP is quite similar to it predecessors. It belongs to the category of “boiling water” reactors, a simplified heat flow diagram of which is provided in Figure 1.5. The detail reactor flow diagram of the Ignalina NPP is given in Appendix 2. The reactor cooling water, as it passes through the core, is subjected to boiling and is partially evaporated. The steam-water mixture then continues to the large steam separator (3), the elevation of which is greater than that of the reactor. Here the water settles, while the steam proceeds to the turbines (4). The remaining steam beyond the turbines is condensated in the condenser (6), and the condensate is returned via the deaerator (8) by the feed pump (9) to the water of the same steam separator (3). The coolant mixture is returned by the main circulation pumps (10) to the core, where part of it is again converted to steam.

The Ignalina NPP uses a RBMK-type channelized reactor. This means that each nuclear fuel assembly in this type of an RBMK-type reactor is located in a separately cooled fuel channel (pressure tube). There are a total of 1661 of such channels and the cooling water must be equally divided among that number of feeder pipes. Past the core, these pipes are brought together to feed the steam-water mixture to the above-mentioned separator drums.

Each reactor is divided into two halves. Each half is cooled by a main circulation circuit provided with flow from three operating main circulation pumps. A fourth MCP on each side of the reactor is normally in standby mode. The MCPs feed common pressure header of each side of the reactor. Each pressure header provides flow to 20 group distribution headers, each of which in turn feeds 38-43 pressure tubes. The reactor fuel assemblies are contained within these pressure tubes. Core exit piping connects pressure tube to one of four steam separators. The steam from both sides of the reactor is combined in the main steam lines prior to entering the two high pressure 750 MW turbines. Liquid is recirculated to the MCPs through downcomer pipes from the separators to a common pump suction header on each side. Feedwater is provided to the steam separator to make up for the steam flow to the turbines. Figure 1.6 provides a schematic of the RBMK-1500 main circulation circuit.

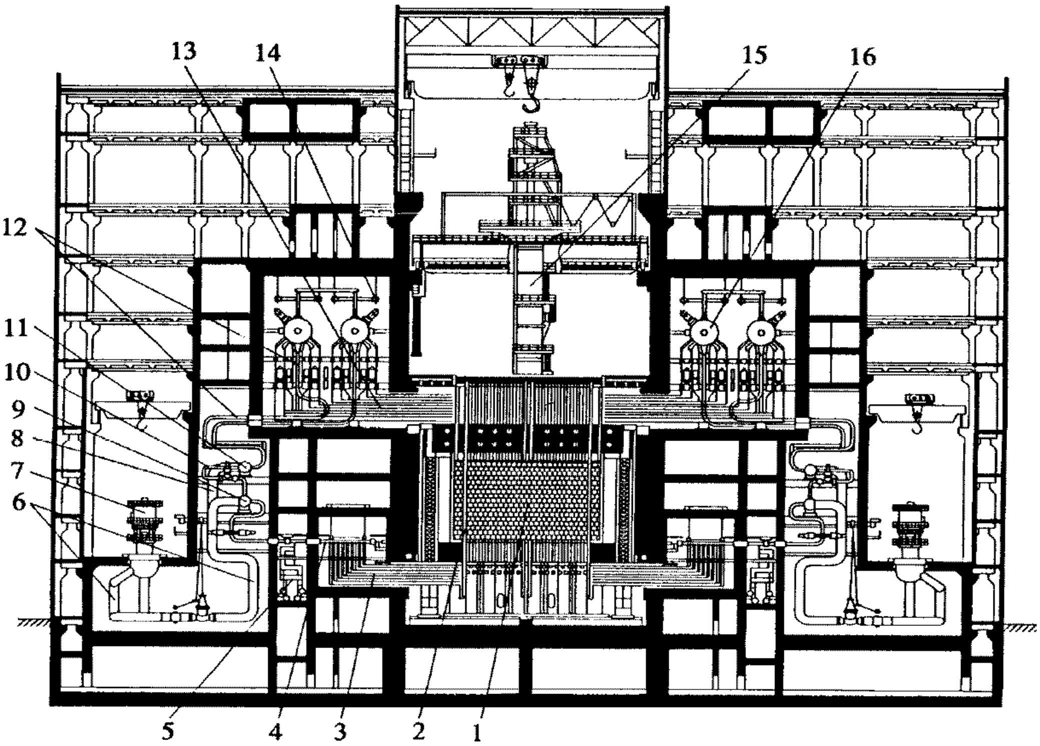

Fig. 1.7 Schematic cross-section through the main reactor building [4]:
1 - graphite stack; 2 - fuel channel feed pipes; 3 - water pipes; 4 - group distribution header; 5 - emergency core cooling pipes; 6 - pressure pipes; 7 - main circulation pump; 8 - suction pipes; 9 - pressure header; 10 - bypass pipes; 11 - suction header; 12 - downcomers; 13 - steam/water pipes**;** 14 - steam pipes; 15 - refueling machine; 16 - separator drum

Table 1.3 Principal parameters of the RBMK-1500 reactor [3,4]

• Coolant	water (steam-water mixture)
• Heat cycle configuration	single circuit
• Power, MW:	
thermal (design)	4800
thermal (actual)	4200
electrical (design)	1500
• Core height, m:	7
• Core diameter, m	11.8
• Thickness of reactor's graphite reflector, m:	
end	0.5
side	0.88
• Lattice pitch, m	0.25 x 0.25
• Number of channels:	
fuel	1661
control and shutdown system	235
reflector-cooling	156
• Fuel	pellets of uranium dioxide
• Initial fuel enrichment, % of U_{235}	2.0
• Fuel burn-up, MWd/kg	21.6
• Temperatures:	
maximum fuel center temperature, °C	2100
maximum graphite stack temperature, °C	750
maximum fuel channel temperature, °C	350
channel inlet temperature, °C	260-266
feedwater temperature, °C	177-190
• Steam pressure at separators, MPa	6.47-6.96
• Core coolant flow rate at 4200 MW, m^3/s	10.83-13.33
• Steam produced in reactor at 4200 MW, kg/s	2056-2125
• Core exit void fraction, %	23-29
• Maximum fuel channel parameters:	
channel power, kW	4250
coolant flow rate, m^3/s	0.011
void fraction at fuel channel outlet, %	36.1
• Number of main circulation pumps	8
• Capacity of main circulation pumps, m^3/s	1.805-2.22
• Coolant inlet/outlet pressure, MPa	7.5/7.0

1.3 Main Features of the RBMK-1500 Reactor

The RBMK-1500 is a graphite moderated**,** channel-type, boiling water nuclear reactor. Its design thermal rating is 4800 MW. However, for safety reasons, these reactors are currently running at a reduced capacity of maximum 4200 MW. The most important reactor parameters are presented in Table 1.3. The position of the reactor core and its main components in a RBMK-1500 plant is shown in the schematic cross-section of the main reactor building provided in Figure 1.7. The core is 11.8 m in diameter with an active length of 7 m. It consists of stacks of graphite blocks penetrated with 2052 channels, 1661 of which are pressure tubes. The remaining core channels contain control rods or various types of instrumentation. Each fuel channel contains a stack of two fuel bundles. Each fuel bundle is approximately 3.5 meters long and consist*s* of 18 fuel rods arranged in two concentric circles around a central carrier rod, Figure 1.8. The fuel rods are made up of enriched uranium dioxide pellets contained within zirconium alloy tubes. The principal technical parameters of a fuel assembly are summarized in Table 1.4. Each pressure tube is located within graphite blocks, which provide neutron moderation. At operating conditions, approximately 5% of the reactor power is deposited directly in the graphite. This heat is removed from the graphite primarily by conduction through the

Table 1.4 RBMK-1500 fuel assembly parameters [3,4]

Fuel pellet	
Fuel	Uranium dioxide
Fuel enrichment, % of U^{235}	2
Edge pellet enrichment, %	0.4
Fuel pellet density, kg/m^3	10400
Fuel pellet diameter, mm	11.5
Fuel pellet length, mm	15
Pellet central orifice diameter, mm	2
Maximum fuel center temperature, ^oC	2100
Fuel element	
Cladding material	Zr + 1%Nb
Outside diameter, mm	13.6
Length, m	3.64
Active fuel length in cold state, m	3.4
Cladding thickness, mm	0.825
Pellet/clad gap, mm	0.22-0.38
Mass of fuel pellets, kg	3.5
Helium pressure in the cladding, MPa	0.5
Maximum permissible operating temperature, ^oC	700
Average linear heat generation rate, W/cm	218
Maximum linear heat generation rate, W/cm	485
Fuel assembly	
Number of bundles	2
Number of fuel rods per bundle	18
Total length, m	10.015
Active length, m	6.862
Diameter (in the core), mm	79
Mass without bracket, kg	185
Total mass with the bracket, kg	280
Total steel mass, kg	2.34
Total mass of zirconium alloy, kg	40
Mass of uranium within fuel pellet, kg	111.2
Mass of uranium within edge fuel pellet, kg	1.016
Maximum permissible power of fuel channel, MW	4.25
Authorized fuel assembly capacity, MWd/assembly	2500
Authorized fuel assembly lifetime, year	6

graphite back to the pressure tube wall, where the heat is convected to the reactor coolant. The graphite blocks are also cooled by a moderator cooling system, consisting of a helium-nitrogen gas mixture flowing within gaps between the blocks and between the blocks and the pressure tubes. The core of the reactor is housed in a 25 m deep, 21 x 21 m cross-section concrete vault, Figure 1.9. The core volume is dominated by a large cylindrical graphite stack. The graphite stack is located in a hermetically sealed cavity consisting of cylindrical walls and top and bottom metal plates. In the radial direction as well as above and below the reactor it is surrounded by the primary biological shield structures. The graphite stack of the RBMK-1500 reactors serves several functions.

The primary one is neutron moderation and reflection, but it also provides structural integrity and, in the event of a temporary cooling malfunction, a relatively large heat capacity.

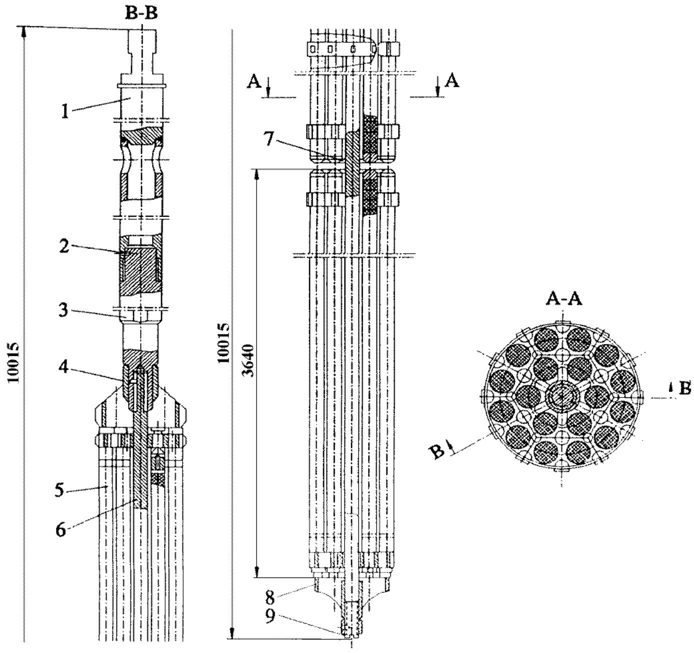

Fig. 1.8 Fuel assembly:
1 - suspension bracket; 2 - top plug; 3 - adapter; 4 - connecting rod; 5 - fuel rod; 6 - carrier rod; 7 - end sleeve; 8 - end cap; 9 - nut. (Dimensions in mm)

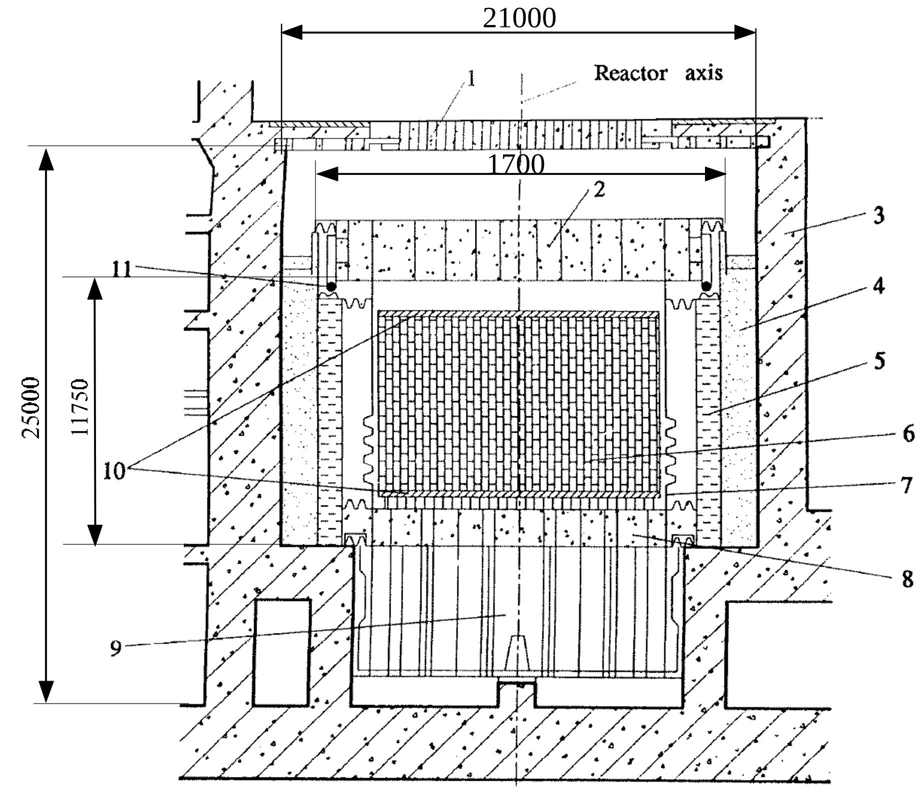

Fig. l.9 Cross-section of the reactor vault:
1 - top cover, removable floor of the central hall; 2 - top metal structure filled with serpentinite; 3 - concrete vault; 4 - sand cylinder; 5 - annular water tank; 6 - graphite stack; 7 - reactor vessel; 8 - bottom metal structure; 9 - reactor support plates; 10 - steel blocks; 11 - roller supports. (Dimensions in mm)

The shield and support plates have a similar purpose namely, they consist of steel and, in addition to their fundamental function of joining the intermediate elements of the graphite stack, also ensure thermal insulation of the top and bottom metal structures, and in part serve as biological shielding. When the reactor is in operation, all the components listed above are subjected to conditions of high temperature and intense neutron/gamma radiation. For example, the temperature of the support structures in the top part of the bottom biological shield reaches 350°C. The temperature of the bottom support plates reaches 440°C, while the maximum calculated graphite temperature is 750°C.

All of the structures surrounding the core region contribute to some extent to biological shielding. The principal structures serving the shielding function include the graphite reflectors, the internal spaces of the metal structures, the gap between the concrete vault and the outer surface of the core support metal structures. With respect to the center of the core, the biological shields can be divided into three parts: top shield (in the direction of the refueling hall), bottom shield (in the direction of the lower coolant channel banks), and radial shielding.

Biological shielding in the direction of the refueling hall encompasses the 0.5 m thick upper graphite reflector, 0.25 m high steel shielding blocks, the upper metal structure which is filled with a mixture of serpentinite chips and gallium (weight ratio of 3:2), and the top shield cover. The density of the fill material is 1700 kg/m^3, its height is 2.8 m, and the thickness of the steel foundation plates of the structure is 40 mm.

The radial shield consists of the radial graphite reflector (average thickness 0.88 m), the shell of the core, the annular water-filled steel tank, sand filling between the tank and the walls of the reactor vault, and the 2 m thick concrete walls of the vault. The walls of the vault are made from ordinary construction concrete with a density of 2200 kg/m^3.

Design criteria for shielding below the core include the requirement to reduce gamma radiation during shutdown in order to allow personnel access for maintenance, and the necessity to minimize activation of the metal structures and coolant feeder pipes. The bottom shield consists of the 0.5 m thick graphite reflector, 0.2 m of steel blocks, and the bottom biological shield, filled with a mixture of serpentinite chips and gallium. The density of the mixture is 1700 kg/m^3. There are 0.1 m thick steel screens under the annular water tank (above the bottom water piping) and between the reactor vault and the water tank.

The maximum allowable pressure within the reactor cavity is 0.31 MPa. This pressure just offset the weight of the reactor top metal structure. To avoid this in case of pressure tube ruptures, the concept of confinement is used with reactor cavity overpressure protection system, which is a part of ACS. The reactor overpressure protection system vents the steam/gas mixture into the pressure suppression pools where steam is condensated, and gas is retained in the leaktight spaces. The main functions and limitations of the accident confinement system and reactor cavity overpressure protection system are discussed in Chapter 3.

1.4 Operating Organization

The Ignalina NPP organizational chart is given in Figure 1.10. Operating functions involve the executive decision making and actions relating to the operation of the plant both during normal operation and in emergencies. The responsibility for the safe operation of the plant lies with Director General. The Technical Director is a technical manager of the key workshops, departments and services which perform operations and maintenance. He bears the ultimate responsibility for essential decision making as applies to the operation of the plant. The Technical Director deputy for operations provides technical control over the key plant departments involved in on-line operations. He is also in charge of industrial, radiological and fire safety in operations. All operating staff is under his authority. The Plant Shift Supervisor provides the administrative control of the composite shift staff consisting of control room operators and shift operators in workshops.

Operation is a complex of activities and operations performed by the operating staff to ensure safe and reliable operation of the plant equipment. The operating staff is an authorized shift personnel on duty, including managers, operators and technicians who maintain operational control over technological processes at the plant and configuration change-overs. Control room operators are responsible for the safe and reliable operation of the equipment and systems controlled from the plant’s two main control rooms. Field operators are responsible for reliable operation of the equipment and systems under their authority. The plant is staffed with the operating personnel in accordance with industrial standards. All operating staff is grouped into seven shifts. Five shifts work on regular basis. The sixth shift stand in for the main shift and the seventh shift undergo periodic training and review operating procedures. Each shift consists of about 150 persons. For each shift position the initial and improved training program, including emergency training, is established.

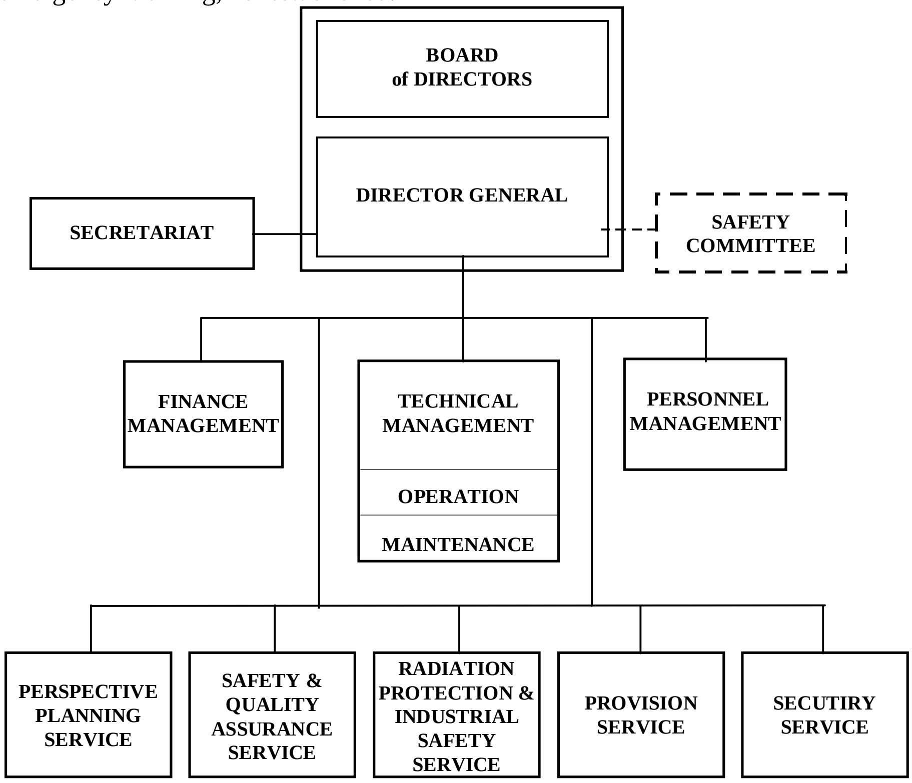

Fig. 1.10 The Ignalina NPP organizational chart

The program includes theoretical training, training in the use of plant systems, simulator and on-the-job training. At the present time, the full-scope simulator at Smolensk NPP is used for basic training of operators, but the project to built up the full-scope simulator at the Ignalina NPP is underway and will be completed in 1998.

At the Ignalina NPP the operation is based on the workshop system. There are eight workshops: Reactor, Turbine, Electrical, Instrumentation and Control, Chemical, Process Nitrogen and Oxygen, District Heating and Underground Communication Services, and Decontamination workshops. Each workshop is led by a manager, who reports directly to the plant chief engineer. Each workshop is technically responsible for the safe operation and maintenance.

Review functions are those involving critical monitoring of the performance of the operating and supporting functions, such as quality assurance and independent safety review. The responsibility for quality assurance rests with all managers. The Safety and Quality Assurance department is responsible under the Director General for development and putting into practice at the Ignalina NPP the effective quality assurance program. Specific responsibility for independent review of nuclear safety is assigned to two organizations: the Safety and QA department and the newly formed plant Safety Committee. Both organizations report directly to the Director General. The Safety and QA department performs independent safety review of specific production activities and work products performed by workshops, departments and services of the plant, suggests revisions and improvements to these organizations. The plant Safety Committee performs more strategic reviews of the plant safety-related activities. The Committee is composed of experienced individuals from the plant and outside organizations. The Committee holds regular monthly meetings to discuss safety issues arising from review of various plant reports and observation of safety-important events.

Radiation Protection and Industrial Safety department is responsible for managing activities aimed at safe and healthy labor conditions at the plant, prevention of accidents, limiting personnel exposure to radiation, and control of environmental effects. About 80 specialists are working with radiation protection related problems. The responsibility for industrial, radiological and fire safety within plant departments lies with department managers.

Operating procedures are used to ensure control over in-service systems and components under normal conditions, incidents and accidents. Operating procedures shall allow for all aspects of operation and ensure reliable, efficient and safe operation of the plant. There are four types of operating procedures:

1. Normal Operating Procedures
2. Abnormal Operating Procedures
3. Operator Response Procedures
4. Emergency Operating Procedures.

Normal Operating Procedures specify normal operation of the plant systems and components, tests and trials, configuration control, removal and restoration of equipment. Abnormal Operating Procedures has been developed for elaborating procedures for coping with deviations from normal operating modes. Operator Response Procedures specify main control room operator actions in response to small deviations. The Emergency Operating Procedures currently used at the plant make use of an event-based approach to accident management. Weaknesses of this approach are well-known. One is that the operators have to correctly diagnose the event, select the proper procedure and perform all required actions. In some cases, the diagnosis and selection of the appropriate procedure may be difficult and the required actions may not be carried out in time. This may lead to more serious consequences of the event. Also, the approach does not take into account possible human failure, as well as malfunctions or failures of equipment or systems that may occur in the course of accident sequences. Thus, new symptom-based emergency operating procedures are being developed.

1.5 Safety Upgrading Program

After the Chernobyl accident, a number of technical and organizational changes were developed and implemented in order to improve the operational safety of all RBMKs. These changes were made primarily to:

- reduce the positive void reactivity coefficient;
- increase the prompt effectiveness of the shutdown system;
- install computer programs for calculating the effective reactivity margin and display it on the operator's panel;
- eliminate the possibility to disconnect the reactor protection system when the reactor is on power;
- eliminate modes which could cause the reduced coolant temperature margin to boiling at the reactor inlet.

The aim was to improve the neutronic characeristics of the reactor and to increase the emergency protection system effectiveness and thus diminish the changes of an uncontrolled increase in reactor power.

In the necessity to provide safe operation of the Ignalina NPP, the management of the plant together with the Lithuanian Ministry of Energy and assisted by Western experts prepared a plan to implement the Ignalina NPP Safety Upgrading Program. It was approved by VATESI in 1993. The objective of the safety upgrading program is to maintain the Ignalina operational safety level until it is permanently closed. The program recognizes the need for better fire-protection system, procedures for proper documentation of plant equipment and improved reactor protection system.

Lithuania's original intention was to contribute about $5 million of its own money to plant improvements. But the program could not be implemented without technical and financial assistance of the Western countries. For this reason, a Grant Agreement was signed on February 10, 1994 in London between the Lithuanian Government, Ignalina NPP and the European Bank for Reconstruction and Development (EBRD) on behalf of the Nuclear Safety Account (NSA). This agreement is the first significant Western financial aid to an RBMK plant from the NSA. The accord provides for a grant of about 33 million ECU pledged by 13 Western donor countries and the European Union. The EBRD money will be used to fund 18 items. The program is due to be completed during 1996. The whole project consists of the following three parts:

- Operational Safety Improvements;
- Near-Term Technical Safety Improvements;
- Provision of Services.

The operational safety improvements include non-destructive examination, seals for pressure tubes, routine maintenance equipment, radioactive release and monitoring and a full scope simulator. Near-term technical improvements include seismic upgrading, fire protection equipment and hydrogen monitoring system. These improvements will also include a diversed reactor protection system, neutron flux monitoring system, improved operational data processing, and emergency core cooling system backfits. Services include project management, design and engineering work.

In addition to the safety upgrading program, an in-depth safety assessment of the Ignalina NPP will be undertaken by the end of 1996. A plant-specific Safety Analysis Report (SAR) is produced which will form the basis for decisions on future operation of Ignalina NPP. The SAR aims to:

- assess the current level of safety of the plant through an analysis and its review comparable to that commonly performed for Western nuclear power plants;
- identify and evaluate any factors which may limit the safe operation of the plant in the foreseeable future;
- assess the Ignalina NPP safety standards and practices;
- recommend any additional improvements which are reasonably practicable and provide estimates of their cost and schedule.

The safety analysis will consider a safety assessment of both units at the Ignalina NPP. The main reference plant for the project is Unit 1, but a survey is included which defines the differences between Unit 1 and Unit 2 and assesses their safety.

As well as the EBRD-funded Safety Upgrading Program, Ignalina NPP has the ongoing bilateral cooperative projects with Sweden, Germany, USA, UK, France, Belgium, Italy, Switzerland, Canada, Finland and Japan. Sweden is especially active in Lithuania. The two RBMK reactors at Ignalina NPP across the Baltic sea are the closest to Sweden. It makes Ignalina NPP a natural focus-point for Swedish interest. The most important technical safety projects include the fire protection equipment and installation of a pressure relief pipe from the reactor cavity to the accident confinement system. The object of the latter project is to enhance the relief capacity from the reactor cavity by using a remote equipment to install a 600 mm penetration into the cavity. This will make the cavity able to withstand multiple ruptures of 3 up to 9 pressure tubes. Other projects include NDT testing, development and implementation of the plant quality assurance system, physical security and communications system upgrades.