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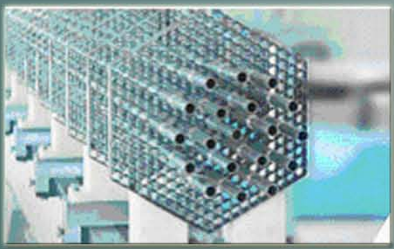

Russian & NIS Nuclear Fuel and Fuel Assemblies Production Industry

2009

Department of Nuclear Power & Nuclear Fuel Cycle
International Business Relations, LLC (IBR™)

Moscow 2009

ABOUT INTERNATIONAL BUSINESS RELATIONS, LLC (IBR™)

INTERNATIONAL BUSINESS RELATIONS, LLC (IBR™) was set up in 1991 by a group of researchers and engineers who previously worked at enterprises under the USSR Ministry of Atomic Power and Industry. IBR™ is specialized in consulting & engineering along with project management in nuclear power and nuclear fuel cycle. Leading Russian and foreign companies, as well as state organizations, are constant clients of IBR™. The IBR™ successful activities are based on high professionalism of the company staff, which implies:

- **Deep knowledge of technologies and operational experience in nuclear power and nuclear fuel cycle;**
- **Knowledge of the tools for economic and investment analysis of nuclear technologies;**
- **Experience in successful management of “nuclear” projects.**

IBR™ strives for expansion and intensification of cooperation with its constant clients and welcomes collaboration with new clients in the interests of further improvement of safety and efficiency of nuclear technologies.

PROJECT TEAM

- **The IBR™ staff**
- **Selected experts from state & private institutions**

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Moscow, 2009

Russian & NIS Nuclear Fuel & Fuel Assemblies Production Industry, 2009

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CHAPTER 1

RUSSIAN FA FABRICATION INDUSTRY: CORPORATE STRUCTURE AND INDUSTRIAL COOPERATION

1.1 Russian Nuclear Complex Reforms

On June 8, 2006 RF President Vladimir Putin approved the “Program of the RF Nuclear Sector Development”. The Program targets are:

- Extended reproduction of the Russian nuclear sector products based on the nuclear weapons, nuclear energy, scientific and technical complexes along with nuclear and radiation safety assurance complex development;
- Maintenance of the production & technological chains based on innovation development;
- Improvement of the product competitiveness, strengthening of the Russian enterprises positions on the world market of nuclear materials, equipment, technologies and services.

The Program states that attaining of the formulated objectives necessitates:

- Development of a new “nuclear” regulatory and legal framework harmonized with the international law norms and general approaches used for regulation of activities in peaceful applications of nuclear energy in the country;
- Effective reforms in the Russian Nuclear Complex;
- Employment of the Program-targeted approach for developing all components of the Russian Nuclear Complex.

As of late 2009 the Russian nuclear sector achievements in implementation of the “Program of the RF Nuclear Sector Development” are:

- A new “nuclear” regulatory and legal framework has been formed, which permits legal entities to own nuclear materials and nuclear facilities and which regulates the relevant procedure for granting the right to legal entities;
- The State Atomic Energy Corporation “Rosatom” (SC “Rosatom”) – authorized body in management of nuclear energy applications in the RF - was set up. JSC “Atomic Energy and Industrial Complex” (JSC “Atomenergoprom”), where all civil assets of the Russian Nuclear Complex are concentrated, was established. The 100% shareholding of JSC “Atomenergoprom” is transferred to SC “Rosatom” ownership. Privatization (incorporation) of over 95% of federal unitary enterprises to be integrated into JSC “Atomenergoprom” has been completed.
- The “Program of the State Atomic Energy Corporation “Rosatom” Long-term (2009-2015) Activities” was approved by resolution of the RF Government No. 705 dated September 20, 2008;
- A number of holding companies, specializing in certain trends of activities in nuclear power engineering and nuclear fuel cycle, have been reorganized, established or are being set up.

In the course of general reforms in the Russian Nuclear Complex the corporate structure of JSC “TVEL” holding company responsible for FA fabrication, has also been modified. The reforms in the JSC “TVEL” corporate structure consisted in:

- Divestiture (buying-out) of uranium-producing assets from JSC “TVEL” and their transfer to JSC “Atomredmetzoloto” holding company specializing in uranium mining;
- Providing of a more rigorous JSC “TVEL” management system from the side of SC “Rosatom”/JSC “Atomenergoprom”, which consists, above all, in the need for a more detailed concurrence of the holding company activities with SC “Rosatom”/JSC “Atomenergoprom” (large transactions, company planning, personnel policy, etc.).

The experience in the functioning of the reformed Russian Nuclear Complex in 2008-2009 suggests that the devised corporate structure of the Complex and its management system is exceedingly awkward and it requires further improvement (reforms). In September-October 2009 top management of SC “Rosatom” has made the following decisions directly concerning JSC “TVEL”:

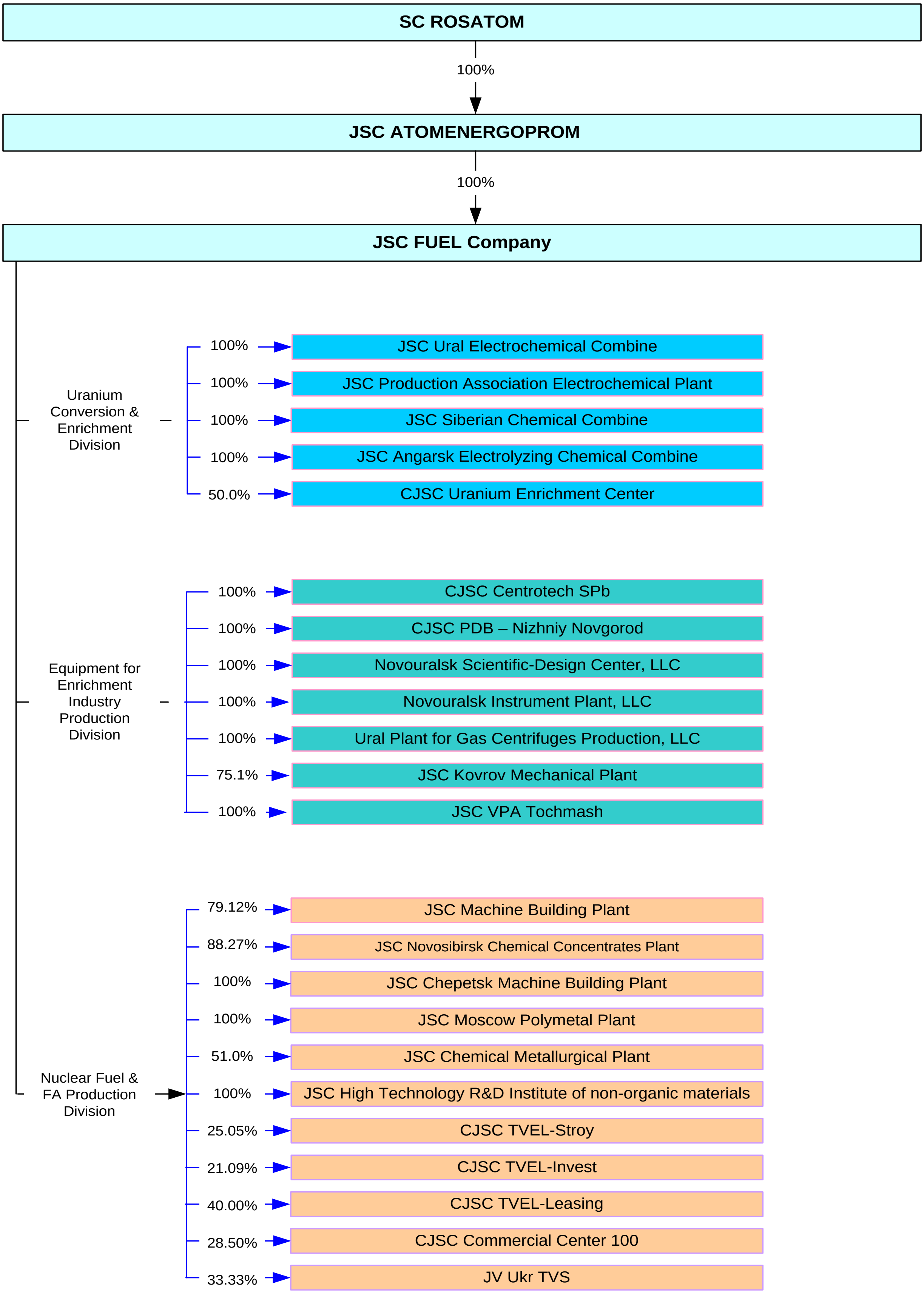

Figure 1.2

Predicted corporate structure of the Russian industry engaged in FA fabrication by the end of 2010

CHAPTER 2

PROGRAM OF THE RUSSIAN FA FABRICATION INDUSTRY DEVELOPMENT

The following documents constitute the program base for the Russian FA fabrication industry in the period of 2009-2030:

- “Energy Strategy of Russia in the Period Through 2030”, approved by the RF Government resolution No. 1715-r dated November 13, 2009;
- “Program of the Russian Federation Nuclear Sector Development”, No. 4483 dated June 8, 2006, approved by President of the Russian Federation;
- “Program of State Atomic Energy Corporation Rosatom Long-Term (2009 - 2015) Activities”, approved by regulation of the Russian Federation Government No.705 dated September 20, 2008.

Measures envisaged by the “Program of State Atomic Energy Corporation “Rosatom” Long-Term (2009 - 2015) Activities” are grouped into five major trends of SC “Rosatom” activities. The program measures dictating the Russian FA fabrication industry development are referred to trend 3 in the Program “Russian Nuclear Energy and Industrial Complex Development”. Measures stipulated in trends 3 of the Program “Russian Nuclear Energy and Industrial Complex Development” include measures envisaged by Federal Targeted Program “Development of the Russian Nuclear Energy and Industrial Complex in 2007 - 2010 and Through 2015 “, along with measures implemented by organizations within the nuclear energy and industrial complex aimed at developing the nuclear fuel cycle capacities. Measures devised within Federal Targeted Program “Development of the Russian Nuclear Energy and Industrial Complex in 2007 - 2010 and Through 2015 “ define the development of the Russian industry engaged in fabrication of FA with nuclear fuel produced on the basis of natural and reprocessed uranium.

The Concept of Federal Targeted Program “New Generation of Nuclear Power Technologies in the Period of 2010 - 2015 and Through 2020” was approved by resolution of the RF Government No. 1026-r dated July 23, 2009 (SZRF 09-31 0308). It is predicted that the program as such will be approved before the end of 2009. “Development of technologies for producing promising types of fuel for fast neutron reactors” will become one of the trends in the program mentioned, namely:

- Development of technologies for uranium-plutonium oxide fuel production for fast neutron reactors;
- Development of technologies for high-density fuel production for fast neutron reactors.

Major parameters of the JSC “TVEL” new production strategy are determined by the following documents:

- “Strategic Vision of Enterprises[1] Development Up To2030”;
- “Complex Program of Enterprises Development”;
- “New Image of Enterprises Through 2020”;
- “Program of Production Extension and Cost Reduction Through 2015”;
- “Plan of Measures Aimed at Floor Space Reduction And Personnel Optimization Through 2010”;
- “Main Trends in Technological Development And Technical Re-equipment of Enterprises In the Period of 2007-2009 And Through 2020”.

The documents provide for specific measures, including introduction of new technologies and identification of the funds, investment activities and manpower policies. The development strategy for each of the enterprises integrated into JSC “TVEL” holding company envisages a number of subprograms, specifically:

- Production Expansion and Cost Reduction Program;
- Program of Nuclear And General Industrial Activities Development;
- Program of Investment Activities, Research and Engineering, Technology Implementation and People ware Development.

[1] Enterprises within JSC “TVEL” holding company are implied.

Table 2.2

JSC "TVEL" plans for developing the capacities to be engaged in nuclear fuel and FA fabrication and demand for nuclear fuel and FA fabrication capacities in the period of 2008-2020 predicted by JSC "TVEL", tons of uranium per year

Parameter	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Installed capacity, tons of uranium													
Demand, tons of uranium													
Capacity factor													

Notes to Table 2.2:

1. Installed capacity distribution by the types of the technologies employed (2008):

- ADU-technology – 690 tons of uranium per year (37%);
- Gas-flame technology – 800 tons of uranium per year (42%);
- Reductive pyrohydrolysis ("dry conversion" or RPH) – 400 tons of uranium per year (21%).

The actual output of uranium dioxide powder by the types of technologies employed (2008):

- ADU-technology – 447 tons of uranium per year (30%);
- Gas-flame technology – 670 tons of uranium per year (45%);
- Reductive pyrohydrolysis ("dry conversion") – 373 tons of uranium per year (25%).

2. Plans of commissioning new capacities to be engaged in uranium dioxide powder production:

- 2008-2010 – commissioning of uranium dioxide powder production process based on ADU-technology at MBP, its capacity 400 tons of uranium per year;
- 2008-2010 – commissioning of RPH facility, its capacity 400 tons of uranium per year;
- 2011-2016 - commissioning of RPH facility, its capacity 400 tons of uranium per year;
- 2011-2016 – upgrading of two "Saturn" facilities, their total capacity 400 tons of uranium per year;
- 2017-2020 – upgrading of two "Saturn" facilities, their total capacity 400 tons of uranium per year.

Table 2.3

JSC "TVEL" plans for developing the capacities to be engaged in fuel pellets fabrication and demand for fuel pellets fabrication in the period of 2008-2020 predicted by JSC "TVEL", tons of uranium per year

Parameter	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Installed capacity, tons of uranium													
Demand, tons of uranium													
Capacity factor													

Notes to Table 2.3:

1. Plans of commissioning new capacities to be engaged in fuel pellets fabrication:

- 2008-2011 – commissioning of two complexes using "dry" technology, their capacity 800 tons of uranium per year;
- 2012-2017– commissioning of two complexes using "dry" technology, their capacity 800 tons of uranium per year.

Table 2.4

JSC "TVEL" plans for developing the capacities to be engaged in Zr components production and demand for Zr components production in the period of 2008-2020 predicted by JSC "TVEL", tons of zirconium rolled product per year

Parameter	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Installed capacity, tons													
Demand, tons													
Capacity factor													

Notes to Table 2.4:

1. Plans of commissioning new capacities to be engaged in Zr components production:

- 2010-2012 – commissioning of two KPW rolling mills, their capacity 50 tons of Zr rolled materials per year;
- 2013-2019 – annual commissioning of two KPW rolling mills, their capacity 50 tons of Zr rolled materials per year.

Table 2.5

JSC "TVEL" plans for developing the capacities to be engaged in fabrication of FA for the VVER-1000/VVER-1200/VVER-1200M reactors and demand for FA fabrication for the VVER-1000/VVER-1200/VVER-1200M reactors in the period of 2008-2020 predicted by JSC "TVEL", pieces

Parameter	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Installed, FA pieces													
Demand, FA pieces													
Capacity factor													

Notes to Table 2.5:

1. The plans for upgrading the operating and commissioning of new fuel elements production lines:

- 2008-2011 – upgrading of the fuel elements production lines and increase in their output up to 240,000 thousand pieces of fuel elements per year;
- 2012-2017 – commissioning of new fuel elements production lines, their total output 240,000 thousand pieces of fuel elements per year.

Таблица 2.6

JSC “TVEL” plans for FA fabrication for the VVER-440, VVER-1000, VVER-1200, BN-600, BN-800, RBMK-1000, RBMK-1500, EGP-6, VBER-300, PWR (AREVA NP GmbH) reactors in the period of 2008-2023, pieces

Reactor or FA type	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
VVER-440																
RBMK-1000																
VVER-1500																
BN-600 (enriched)																
BN-600 (depleted)																
BN-800 (enriched)																
BN-800 (depleted)																
EGP-6																
VBER-300																
PWR (AREVA NP GmbH)																

CHAPTER 4

THE RUSSIAN PRESENT-DAY AND FUTURE FA DESIGN CHARACTERISTICS

4.1 FA for the VVER-440 reactors

As of late 2009 24 VVER-440 type nuclear reactors are operated in the world, specifically:

- In Russia – 6 units;
- In Ukraine – 2 units;
- In Armenia – 1 unit;
- In Finland – 2 units;
- In Slovakia – 5 units;
- In Czechia – 4 units;
- In Hungary – 4 units.

The VVER-440 reactor operation experience is over 800 reactor-years.

The achieved fuel burnup of the fuel assembly is:

- Average fuel burnup – 46.8 MW·day/kgU;
- Maximum fuel burnup – 51.1 MW·day/kgU.

Average indices of fuel rod cladding failure in the period of 2003-2007 amounted to $9.7 \cdot 10^{-7}$ 1/year, the same indices for NPP in Czechia, Slovakia, Hungary, and Finland - $3.2 \cdot 10^{-7}$ 1/year.

Table 4.1 shows the development stage of the operating fuel assemblies (FA)[2] for the VVER-440 reactor.

[2] In the VVER-440 reactors shroud-type operating FA and ARK fuel assemblies are used. ARK fuel elements in the VVER-440 reactor perform the functions of: emergency protection (A); control (R); compensation for slow change in reactivity (K).

Table 4.1

VVER-440 FA development stages

FA implementation date, year	Before 1997	1998-2002	2003-2008	2010-2011
FA type	First generation standard shroud-type FA,	First generation standard shroud-type FA	Second generation shroud-type FA	Third generation shroudless FA
Fuel rod bundle type	Unshaped (nonprofiled)	Shaped (profiled)	Shaped (profiled)	Shaped (profiled)
Fuel	UO_2	UO_2	UO_2 / UO_2-Gd_2O_3	UO_2 / UO_2-Gd_2O_3
Makeup average enrichment, % in ^{235}U	3.60	3.82	4.25/4.38	Up to 4.87
Number of makeup FA, pcs.	105	84	66	60
Fuel burnup, MW·day/kgU	36	45	57	65
Fuel cycle	3-year	4-year	5-year	6-year
Natural uranium consumption, kg/MW·day	0.256	0.209	0.184	0.180

Table 4.2 provides key parameters of the VVER-440 reactor second generation fuel assembly (FA) basic design.

Table 4.2

Key parameters of the VVER-440 second generation FA basic design

Parameter	Value
Thermal power, MW, maximum permissible	5.3
Fuel	UO_2[3] (UO_2-Gd_2O_3)[4]
Fuel weight per FA, kg, nominal	136.0
Maximum permissible FA burnup, MW×day/kg U	44.3[5] (53.0)[6]
FA "turnkey" size, mm	144
Number of fuel rods per FA	126
FA length, mm	3217
Shroud material	Zr-2.5%Nb
Fuel rod length, mm	2550
Fuel rod cladding	Zr-1%Nb
Fuel rod outer diameter, mm	9.15
Fuel rod pitch in a FA, mm	12.2
Spacer grid: • Material; • Number; • Rim height, mm; • Cell height, mm • FA pitch through the height, mm.	 Zr-1%Nb 10 11 10 240

Development of detail design of the third generation fuel assemblies (FA) for the VVER-440 reactor is aimed at improvement of economic indices and consumer properties of the fuel used with retaining its safe operation, therefore, the following design approaches are made use of as compared to the second generation fuel assemblies:

- Increase in the fuel rod pitch within a bundle;
- Shroudless design with a frame made up by 6 angle pieces and 3 bearing tubes;
- Increase in internal diameter of the fuel rod cladding and fuel pellet diameter;
- No central hole in the fuel rod pellets;
- Optimized arrangement and number of spacer grids (SG);
- Employment of higher arch-type SG;
- Introduction of a new shape "daisy" type coolant circulating channels in the support lattice;
- Increased travel of spring-loaded head thimbles.

The third generation VVER-440 operating fuel assemblies were developed based on experience and results gained during the development of the second generation VVER-440 fuel assemblies, as well as TVSA and TVS-2 for the VVER-1000. It proved possible to improve water-uranium ratio in the design of the third generation FA due to employment of angle pieces in the frame, water channels and increase in fuel rod arrangement pitch within a bundle up to 12.6 mm. The fuel cycle is a 6-year one. It is anticipated that implementation of the 3rd generation FA will result in fuel efficiency improvement by approximately 10%. The 3rd generation FA detail design was approved in 2007. Supply of a pilot batch of the 3rd generation FA for pilot-industrial operation is planned in 2010.

Figure 4.1 depicts schematic diagram of the 3rd generation operating fuel assemblies (FA) for the VVER-440 reactor.

[3] For a 4-year FA fuel cycle.
[4] For a 5-year FA fuel cycle.
[5] For a 4-year FA fuel cycle.
[6] For a 5-year FA fuel cycle.

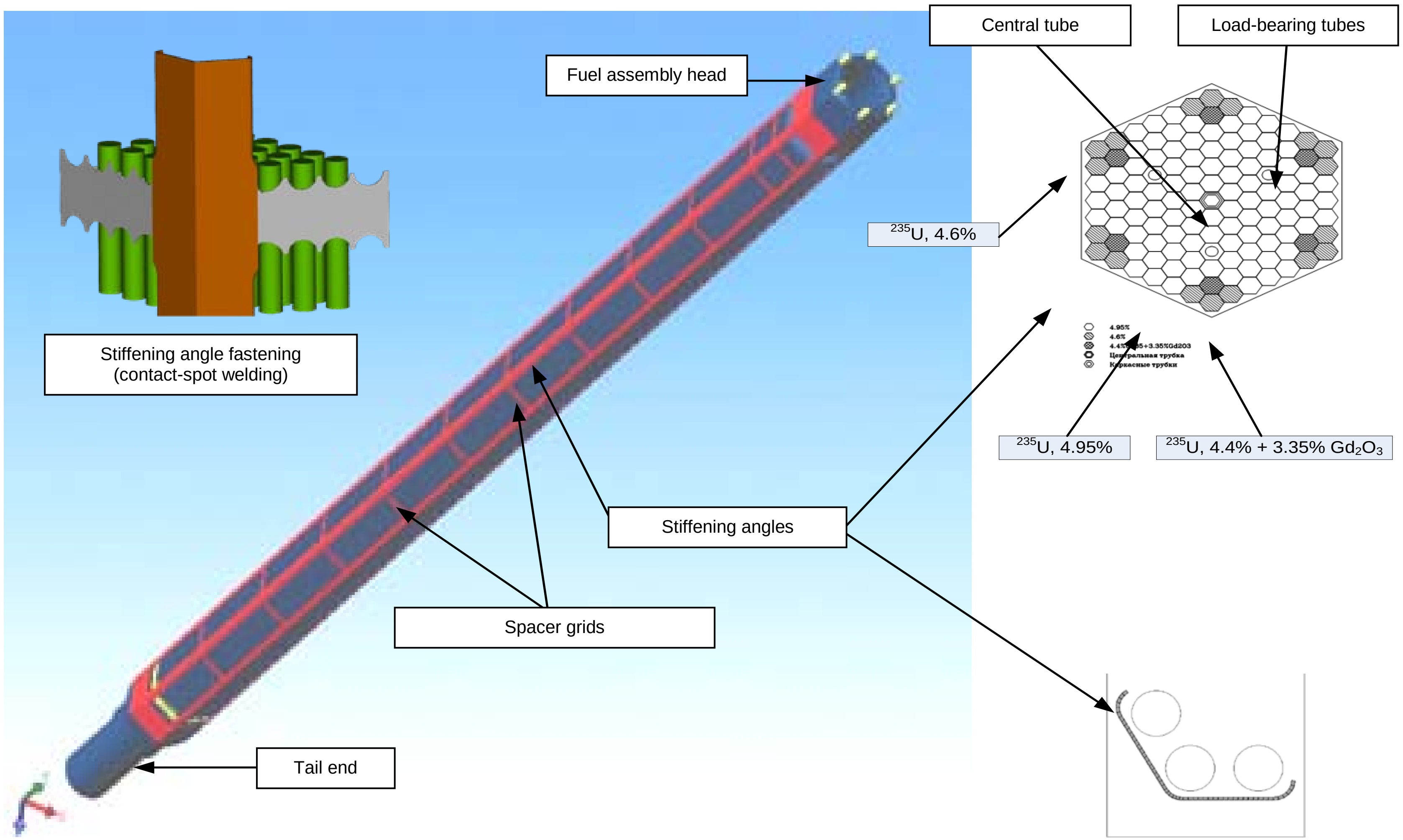

Figure 4.1

Schematic arrangement of the VVER-440 third generation FA

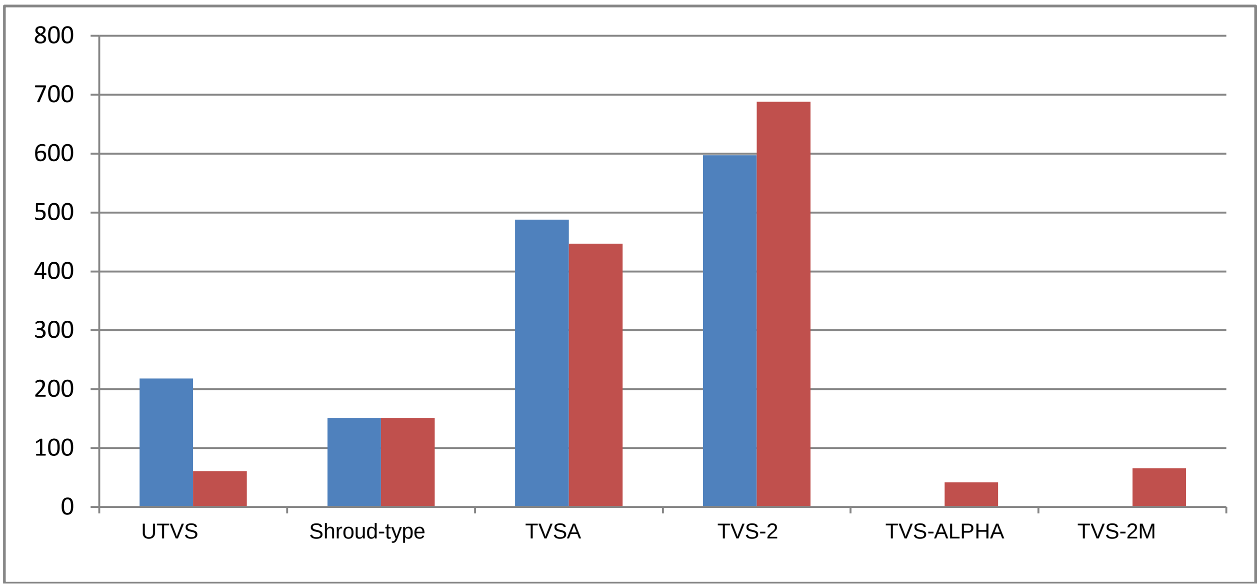

Figure 4.2

Number and types of the FA in JSC "Rosenergoatom" VVER-1000 reactor cores after refueling completion in 2006 (blue) and in 2008 (red), pieces

The history of the VVER-1000 fuel assembly development goes back to 1969. For the Novovoronezh NPP, unit 5, a shroud-type fuel assembly was developed, its concept devised by the reactor designers. In 1977 the Russian design bureaus proceeded with development of fuel assemblies for a commercial reactor. As the developers had no experience in using zirconium materials, stainless steel was used in the design of the first FA. A FA for a two-year fuel cycle was developed, being later modified for a three-year cycle. In 1986 the project aimed at developing a fuel assembly from zirconium-niobium alloys, such as E-110 alloy, was started.

Early in the 90s of the last century the Russian NPP confronted with problems – there were cases, when CPS rods failed to be fully inserted into the reactor core. It was explained by the fact that the FA could not properly withstand mechanical loads, axial ones, above all. It resulted in FA bowing or warping and, accordingly, in CPS rods failure to be completely inserted into the core.

For the purpose of:

- FA operation reliability improvement;
- FA service life extension;
- Fabrication of dismountable (maintainable) FA;
- Implementation of safe and economically efficient fuel cycles, including:
    - Increase in FA burnup;
    - Increase in the unit thermal power;
    - Implementation of longer fuel cycles;
    - Reduction of neutron load on the reactor vessel,

the Russian enterprises, i.e. Experimental Design Bureau "Hydropress" (conjointly with JSC "Novosibirsk Chemical Concentrates Plant") and Experimental Machine Building Bureau in Nizhny Novgorod (conjointly with JSC "Machine Building Plant") have developed two types of new generation FA – TVSA and TVS-2. Different approaches to coping with the problem of providing the FA rigidity and FA geometry retention were used in the TVSA and TVS-2. In the TVS-2 rigidity is attained at the expense of the fuel assembly bunch as such, and in the TVSA it is provided by a frame of angle pieces and grids. In the period from middle 90s of the last century and up to year 2010 several modifications of the TVSA and TVS-2 FA were developed. The process of the TVSA and TVS-2 FA improvement is still continued.
Table 4.4 shows design differences between the TVSA and TVS-2.

Figure 4.5 presents schematic drawings of the TVS-2, TVS-2M and TVS AES-2006.

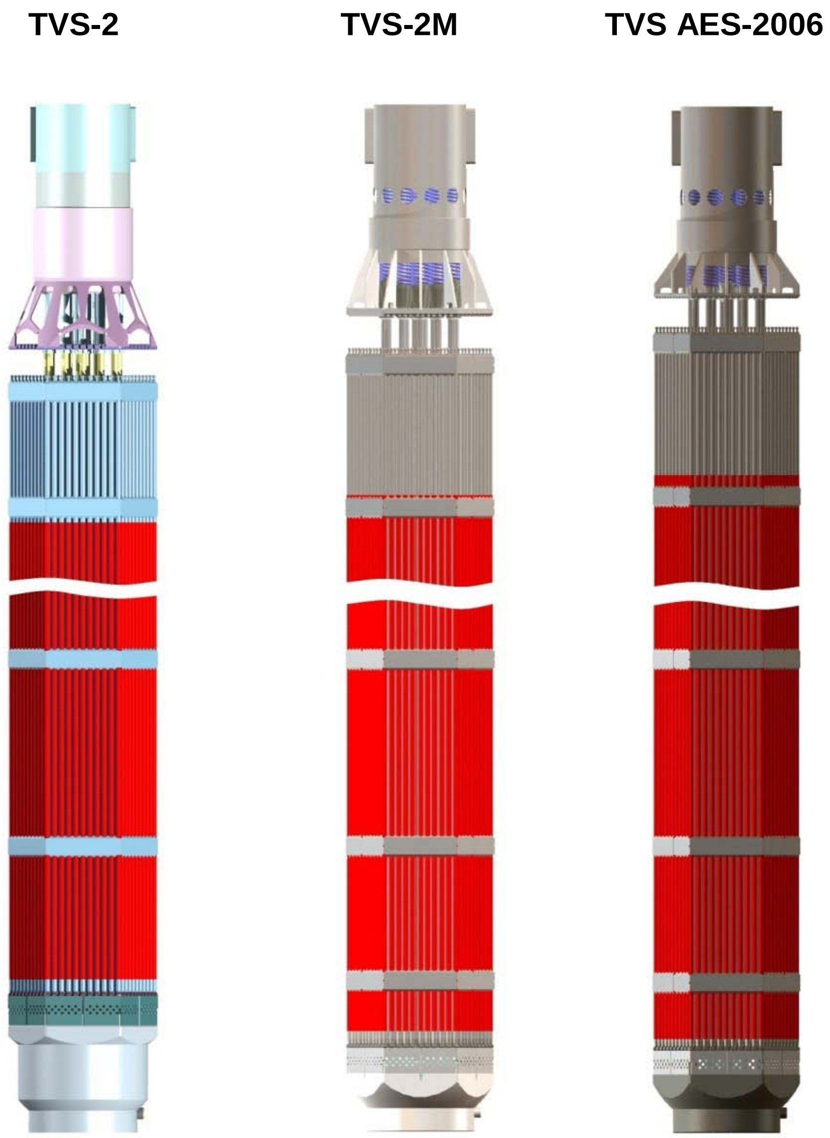

Figure 4.5

TVS-2, TVS-2M, and TVS AES-2006 schematic drawings

Table 4.7 provides basic characteristics of the AES-2006 FA.

CHAPTER 5

COMMERCIAL AND ECONOMIC INDICES OF THE RUSSIAN FA FABRICATION INDUSTRY

5.1 Data on FA and fuel pellets fabrication and supplies

Table 5.1 provides data pertinent to actual output of FA in Russia in the period of 2006-2008.

Table 5.1

Data on actual FA fabrication in Russia in 2006-2008, pcs.

FA fabrication and supplies	Pcs./year		
	2006	2007	2008
VVER-1000, incl.:			
• for Russian NPP;			
• for foreign NPP			
VVER-440			
• for Russian NPP;			
• for foreign NPP			
RBMK-1000, -1500			
• for Russian NPP;			
• for foreign NPP			
BN-600			
EGP-6			
Square-lattice FA (for AREVA NP GmbH)			
FA for research reactors			
Total:			

Table 5.2 presents data on the actual output of fuel pellets in Russia and the relevant supplies to customers in the period of 2006-2008.

Table 5.2

Data on actual fuel pellet fabrication in Russia and supplies to the customers in 2006-2008, ton U/year

Fuel pellet supply routes	Ton U/year		
	2006	2007	2008
Production and supplies of fuel pellets made from reprocessed uranium for AREVA NP GmbH			
Production and supplies of fuel pellets for Nuclear Fuel Complex (India)			

Table 5.3 shows integral data concerning nuclear fuel fabrication volume as FA and fuel pellets in the period of 2006-2008.

Table 5.3

Integral data on nuclear fuel production as FA and fuel pellets in 2006-2008, ton U/year

FA and fuel pellet fabrication and supplies	Ton U/year		
	2006	2007	2008
VVER-1000, incl.:			
• for Russian NPP;			
• for foreign NPP			
VVER-440			
• for Russian NPP;			
• for foreign NPP			
RBMK-1000, -1500			
• for Russian NPP;			
• for foreign NPP			
BN-600			
EGP-6			
FA + fuel pellets (for AREVA NP GmbH)			
Fuel pellets for Nuclear Fuel Complex (India)			
FA for research reactors			
Total:			

5.2 Data on commercial and economic aspects of FA fabrication

FA average fabrication price = FA fabrication net cost + Enterprise commercial expenses cost per one FA + Enterprise managerial cost per one FA + Enterprise profit (loss) per one FA.

Specific FA average fabrication price = [FA fabrication price under contracts with JSC “TVEL” for domestic market x number of the FA fabricated for domestic market + FA fabrication price under contracts with JSC “TVEL” for foreign market x number of the FA fabricated for foreign market] / Number of specific FA fabricated for domestic and foreign markets.

The specific FA fabrication price reimbursed to the enterprises (MBP and NCCP) under contracts with JSC “TVEL” differs for domestic and foreign markets. The VVER-440 FA price for foreign market is ~ 10 thous. RUR higher than the one for domestic market. The VVER-1000 FA cost for foreign market is ~ 100 thous. RUR higher than the one for domestic market.

Table 5.4 indicates data on fabrication prices and average fabrication prices for different types of FA at JSC “Machine Building Plant”. The cost (prices) of nuclear materials and FA components is not included into the price and average fabrication cost, unless otherwise specified.

Table 5.4

Data on the net cost and fabrication prices of different FA at JSC Machine Building Plant in 2008

FA type	FA fabrication net cost in 2008, VAT exclusive, RUR/FA	FA average fabrication prices in 2008, VAT exclusive, RUR/FA
VVER-440 FA[7]		
VVER-1000 FA[8]		
RBMK-1000 FA[9]		
RBMK-1000 FA[10]		
RBMK-1500 FA[11]		
BN-600 FA[12]		
EGP-6 FA[13]		

Table 5.5 provides comparison of average prices for fabrication of the VVER-440 and VVER-1000 FA at JSC "Machine Building Plant" in 2008 and 2009.

Table 5.5

Comparison of average prices for fabrication of the VVER-440 and VVER-1000 FA at JSC "Machine Building Plant" in 2008 and 2009

FA type	FA average fabrication price in 2008, VAT exclusive, RUR/FA	FA average fabrication price in 2009, VAT exclusive, RUR/FA
VVER-440 FA[14]		
VVER-1000 FA[15]		

The reduction in the average FA fabrication price in 2009 versus 2008 was made based on the relevant directive by JSC "TVEL". The price reduction in 2009 was dictated by increase in the receipts (proceeds) of JSC "Machine Building Plant" under direct contracts with AREVA NP GmbH.

Table 5.6 shows data on fabrication net cost and average fabrication price of different FA at JSC "Novosibirsk Chemical Concentrates Plant". The cost (price) of nuclear materials and FA components is not included into the net cost and average fabrication price.

Table 5.6

Data on the net cost and fabrication price for different FA at JSC "Novosibirsk Chemical Concentrates Plant" in 2008

FA type	FA fabrication net cost in 2008, VAT exclusive, RUR/FA	FA average fabrication price in 2008, VAT exclusive, RUR/FA
VVER-440 FA[16]		
VVER-1000 FA[17]		

[7] For FA with uranium weight 120 kg.
[8] For FA with uranium weight 435 kg.
[9] For FA with uranium weight 112.8 kg.
[10] For FA with uranium weight 112.8 kg and recycled fuel (uranium dioxide scrap processing).
[11] For FA with uranium weight 112.8 kg.
[12] The BN-600 FA components price is included into the fabrication price. The BN-600 FA and components for the BN-600 FA are manufactured at JSC Machine Building Plant.
[13] The EGP-6 FA components price is included into the fabrication price. The EGP-6 FA and components for the EGP-6 FA are manufactured at JSC Machine Building Plant.
[14] For FA with uranium weight 120 kg.
[15] For FA with uranium weight 435 kg.
[16] For FA with uranium weight 120 kg.
[17] For FA with uranium weight 435 kg.

Table 5.7

Data on the net cost of certain process stages at JSC "Machine Building Plant" during FA fabrication per kg of nuclear fuel (uranium dioxide), RUR/kg of uranium dioxide

FA type	VAT exclusive net cost of fuel pellet fabrication, RUR/kg (in the 2008 prices)	VAT exclusive net cost of FA fabrication (starting from fuel pellets), RUR/kg (in the 2008 prices)	VAT exclusive net cost of FA fabrication, RUR/kg (in the 2008 prices)
VVER-440 FA			
VVER-1000 FA			
RBMK-1000/1500 FA			
RBMK-1000/1500 FA			

Table 5.8

Data on the net cost of certain process stages at JSC "Machine Building Plant" during FA fabrication per kg of uranium, RUR/kg of uranium dioxide

FA type	VAT exclusive net cost of fuel pellet fabrication, RUR/kg (in the 2008 prices)	VAT exclusive net cost of FA fabrication (starting from fuel pellets), RUR/kg (in the 2008 prices)	VAT exclusive net cost of FA fabrication, RUR/kg (in the 2008 prices)
VVER-440 FA			
VVER-1000 FA			
RBMK-1000/1500 FA			
RBMK-1000/1500 FA			

India

There are two Russian-design VVER-1000 reactors in India. Fuel supplies are made based on the contract valid up to the end of the power units' life. In 2008 supplies were made for initial loading of the reactor core and for the first refueling of both reactors.

In 2009 a contract was signed with Nuclear Fuel Complex (India) envisaging supply of natural uranium fuel pellets for Indian heavy-water reactors. The contract period is 10 years. The volume of supplies within 10 years will reach 2000 tons of U. 120 tons of the fuel is planned to be supplied in 2009.

Iran

The first power unit of Bushehr NPP with the VVER-1000 reactor will be made operational in Iran in 2010. The contract on 10 refueling operations was signed. In 2008 the initial core load for Bushehr-1 was supplied.

Fuel for research reactors

Cooperation with all consumers in the market of research reactors was continued in 2008. Supplies of nuclear fuel for research reactors "Maria" (Poland), VVR-M (Ukraine) were made in 2008. Contracts were signed for nuclear fuel supplies to Bulgaria, IRT-2000, and Czech, LWR-15, in 2009.

5.4 Financial and economic results of the Russian nuclear fuel (pellets and FA) fabrication industry in 2008

Table 5.9 provides data on regional structure of nuclear product sales by JSC "TVEL" and its subsidiaries[18].

Table 5.9

Regional structure of nuclear product sale in 2006-2008, $ mln.

Region/direction	Revenues, $ mln.		
	2006	2007	2008
CIS			
Central / Eastern Europe			
Western Europe			
Asia			
Research reactors			
Total:			

Table 5.10 presents data on regional structure of nuclear product sales by JSC "TVEL" (exclusive of direct sales by JSC "Machine Building Plant") in 2008.

[18] JSC TVEL + JSC Machine Building Plant (direct contracts with AREVA NP GmbH).

Table 5.10

Regional structure of JSC TVEL nuclear product sales (exclusive of direct sales by JSC Machine Building Plant) in 2008, RUR thousand

Region/direction	Revenues, RUR thous.	%
Russian NPP		
Ukrainian and Armenian NPP		
East European and Lithuanian NPP		
Chinese NPP		
Iranian NPP		
Indian NPP		
Total:		

Table 5.11 shows data on JSC "TVEL" revenues pattern by trends of activities in 2008.

Table 5.11

JSC TVEL revenues structure for various activities in 2008

No.	Activity	Revenues, RUR thous.	%
1	Nuclear fuel fabrication		
2	Fuel fabrication for commercial reactors		
3	Production of superconductor pilot batches		
4	Uranium hexafluoride production		
5	Leasing activity		
6	Trading operations		
7	Agent's operations		
8	Other operations		
	Total:		

Table 5.12 and Figure 5.1 provide comparison of JSC "TVEL" financial activity indices in 2006-2008.

Table 5.12

Comparison of JSC TVEL financial activities in 2006-2008

Index	RUR mln.		
	2006	2007	2008
Sales proceeds			
Net profit			
Net assets			

CHAPTER 6

STATUS AND DEVELOPMENT OUTLOOKS FOR THE FA AND FA COMPONENTS FABRICATION INDUSTRY IN UKRAINE

The State Targeted Economic Program "Ukrainian Nuclear Fuel" has been approved by Ukrainian Cabinet Council Regulation No. 1004 dated September 23, 2009. The Program objective is providing for development of uranium and zirconium production, as well as capacities for nuclear fuel and its components production in Ukraine. The document admits that the following option for Ukraine is the most preferable one:

- Ukraine sets up its own nuclear fuel production based on implementation of the relevant fabrication technologies of components, fuel pellets and fuel assemblies purchased from foreign companies;
- Services in uranium conversion and enrichment for the Ukrainian nuclear fuel production will be purchased in the foreign market.

The Program envisages that the objective will be attained by:

- Increase in natural uranium concentrate annual production up to 1,880 tons;
- Providing of a complete zirconium production cycle, rolled zirconium product annual output up to 170 tons;
- Setup of manufacture process for fuel assembly components, its annual output 620 complete assemblies;
- Setup of nuclear fuel production (ranging from uranium reprocessing to fuel assembly fabrication) and construction of the first phase of fuel assembly fabrication plant (from furnishing the fuel rods to fabrication of the fuel assemblies), its annual capacity 220 tons of enriched uranium.

The Program will be implemented in 2009-2013.

It is contemplated in the Program that the first phase of the FA fabrication plant, its capacity 220 tons of enriched uranium, will be completed and the plants will be made operational in 2013.

For arrangement of nuclear fuel production and construction of the first phase of the nuclear fuel fabrication plant the Program envisages:

- Identification of a potential partner, owner of the manufacture technology for the VVER type reactors, and concurrence of the terms for the technology transfer to Ukraine (from uranium hexafluoride conversion into uranium dioxide powder to fabrication of fuel assemblies);
- Purchase of the technology and equipment for fabrication of fuel rods and fuel assemblies;
- Development of regulatory documentation concerning nuclear and radiation safety assurance issues during nuclear fuel production;
- Provisions for training highly qualified specialists in nuclear fuel production;
- Construction of the first phase of the fuel assembly fabrication plant, its location to be identified within the relevant feasibility study.

For coping with the task of securing rolled zirconium production the Program provides for:

- Purchase of the technology and equipment for zirconium alloy and tube shells production;
- Improvement of cold working technology and purchase of equipment for rolled zirconium production;
- Upgrading and technical re-equipment of:
    - ✓ State Research and Production Enterprise "Zirconium" for arranging zirconium dioxide production and putting into operation of zirconium alloy and tube shell production lines;
    - ✓ "Zaporozhye Metallurgical Pilot-Industrial Works under State Titanium Research and Design Institute" for construction of zirconium sponge production line and making its operational;

CHAPTER 7

STATUS AND DEVELOPMENT OUTLOOKS FOR THE FA AND FA COMPONENTS FABRICATION INDUSTRY IN KAZAKHSTAN

7.1 Major provisions of draft State Program of the Nuclear Sector Development in Republic of Kazakhstan in 2010-2020

A draft State Program of the Nuclear Sector Development in Republic of Kazakhstan in 2010-2020 was developed by the Ministry of Energy and Mineral Resources of Kazakhstan by October, 2009. Approval of the Program by the RK Government before the end of 2009 was contemplated. However, unsolved fundamental issues in the trends of national Kazakhstan nuclear power and industry development (the terms of developing the cooperation with Russia, in the VBER-300 reactor specifically) in all probability will hinder the formal approval of the Program and, possibly, will entail its essential revision[19]. Admittedly, possible amendments of the draft Program and putting off its approval date, nonetheless, will not affect essentially Kazakhstan's plans as regards the development of its national nuclear fuel production (uranium oxide powder and fuel pellets) and FA fabrication industry. The Republican Budgetary funds and extra budgetary sources can be mentioned among the State Program sources of financing.

The Program provides for:

- Development of nuclear fuel production in Kazakhstan (uranium dioxide powder and fuel pellets);
- Setup of the fuel rods and FA assembling lines.

An agreement with AREVA on construction of a fuel assembly fabrication plant[20] at "Ulba Metallurgical Plant" industrial site for setting up FA fabrication and advance of nuclear fuel components and FA to the market was signed in 2008. It is planned that the plant will fabricate fuel assemblies both for French-design nuclear reactors (at the initial phase) and for reactors of other designs mainly intended for the South-East Asia markets and for meeting the fuel demand of Republic of Kazakhstan own nuclear power sector. The estimated project costs are 21.4 bln. tenge or $142 mln. Fabrication of the first pilot batch of product is planned in 2013.

JSC NAC "Kazatomprom" has become a shareholder of Westinghouse Electric Co., one of world leaders in nuclear sector, for advancing Kazakhstan's fuel to the market. As a result of the transaction Kazakhstan now is capable of mastering the promising fuel production technologies (fuel pellets and FA fabrication) for the Westinghouse-design nuclear facilities.

It is planned that implementation of the above-mentioned projects will increase uranium product output at JSC "Ulba Metallurgical Plant", including incremental production of uranium powder and enriched uranium hexafluoride fuel pellets.

The Program envisages that design capacity of the FA fabrication plant will make up annually 1,200 tons U. Increase in uranium product output at JSC "Ulba Metallurgical Plant" is planned, uranium oxide powder and fuel pellets inclusive:

- In 2010 – up to 70 tons U annually to the sum of 3 bln. tenge;
- In 2015 – up to 504 tons U annually to the sum of 6.7 bln. tenge;
- In 2020 – up to 955 tons U annually to the sum of 15.4 bln. tenge.

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[19] In 2009 the Russian nuclear sector top management returned to the idea of integrating the nuclear complexes of Russia and Kazakhstan based on exchange of shareholding in the management companies. The probability of integration of the Russian and Kazakhstan nuclear complexes in 2010-2011 based on exchange of shares or on any other terms is estimated by IBR™ specialists as 15% at most. In that instance, the Program will be revised radically enough. The problem of integration stems from the fact that JSC NAC "Kazatomprom" can claim for a very insignificant shareholding of JSC "Atomenergoprom", while SC "Rosatom" may claim no less than 50% in JSC NAC "Kazatomprom". Under the circumstances SC "Rosatom" will dictate its policies to the Kazakhstan nuclear power complex.

[20] In conformity with the enterprise concept the FA components should be supplied by AREVA.

Table 7.1

JSC “NAC “Kazatomprom” plans and IBR™ forecast of the nuclear fuel and FA fabrication development in Kazakhstan

Year	Uranium oxide powder and fuel pellets, tons U per year		FA, tons U per year	
	JSC “NAC “Kazatomprom” plan	IBR™ forecast	JSC “NAC “Kazatomprom” plan	IBR™ forecast
2010				
2015				
2020				

Supplement 1

Russian export of FA: 2006 (QI) – 2009 (QII)

Table S.1.1

Russian export of FA: 2006 (QI) – 2009 (QII)

Customer / Reactor	Manufacture	Qv. of FA, pics.	Weigh of LEU, kg	Average enrichment, %	Declared price of one FA, $
Russian export of fuel assemblies in the second quarter of 2009					
KernKraftWerke NO (Switzerland)/ Beznau NPP (via AREVA NP GmbH)					
Bogunice NPP (Slovakia)/VVER-440					
Zaparogskaya NPP (Ukraine)/VVER-1000					
Uzhnoukrainskaya (South Ukrainian) NPP/VVER-1000					
Paks NPP (Hungary)/VVER-440					
Dukovany NPP (Czech Republic) /VVER-440					
Dukovany NPP (Czech Republic) /VVER-440					
Zaparogskaya NPP (Ukraine)/VVER-1000					
KernKraftWerke NO (Switzerland)/ Beznau NPP (via AREVA NP GmbH)					
Loviissa NPP(Finland) / VVER-440					
Bogunice NPP (Slovakia)/VVER-440					
KernKraftWerke NO (Switzerland)/ Beznau NPP (via AREVA NP GmbH)					
Russian export of fuel assemblies in the first quarter of 2009					
Mohovice NPP (Slovakia) / VVER-440					
Tyanvan NPP (China) / VVER-1000					
Ignalina NPP (Lithuania)/ RBMK-1500					
Russian export of fuel assemblies in the fourth quarter of 2008					
Rovno NPP (Ukraine) / VVER-1000					
KernKraftWerke NO (Switzerland)/ Beznau NPP (via AREVA NP GmbH)					
Rovno NPP (Ukraine) / VVER-440					
Loviissa NPP(Finland) / VVER-440					
Paks NPP (Hungary)/VVER-440					
Loviissa NPP(Finland) / VVER-440					

Supplement 2

The "State Corporation "Rosatom" plan of measures concerning Ukraine to be put in action after July 15, 2009, if Ukraine fails to sign a long-term document on fuel supply after year 2010"

Открытое акционерное общество
Атомный энергопромышленный
комплекс»

(ОАО «Атомэнергопром»)

ул.Б.Ордынка, 24/26, г. Москва, 119017

[illegible] № [illegible]

на ________ от ________

Заместителю
Генерального директора
Госкорпорации «Росатом»

А.М.Локшину

О плане мероприятий по Украине

Уважаемый Александр Маркович,

По поручению Директора ОАО «Атомэнергопром» В.В. Травина, направляю на утверждение проект «Плана мероприятий Госкорпорации «Росатом» по действиям в отношении Украины после 15 июля 2009 года при неподписании долгосрочного документа на поставку топлива после 2010 г.».

Приложение: упомянутое, на 9 л.

С уважением,

Заместитель Директора В.И. Корогодин

Open Joint Stock Company
"Atomic Power and Industrial Complex"
JSC "Atomenergoprom"
B. Ordynka st., 24/26, Moscow, 119017

Deputy Director General,
State Corporation "Rosatom"

A.M. Lokshin

04.07.2009 No. ….

On planned measures concerning Ukraine

Dear Alexander Markovich,

Here is a draft of the "State Corporation "Rosatom" plan of measures concerning Ukraine to be put in action after July 15, 2009, if Ukraine fails to sign a long-term document on fuel supply after year 2010", which is submitted for approval by order of JSC "Atomenergoprom" Director, V.V. Travin.

Attachment: the aforesaid on 9 sheets.

Best regards,

Deputy Director V.I. Korogodin

Concurred by
Director of JSC "Atomenergoprom"
______________ V.V. Travin

Approved by
Deputy Director General,
State Corporation "Rosatom"
_____________A.M. Lokshin
"___"___________2009

Plan of measures
by State Corporation "Rosatom" concerning Ukraine
to be put in action after July 15, 2009,
if Ukraine fails to sign the long-term contract on fuel supply after year 2010

Politicization of the issue of Ukrainian NPP provision with nuclear fuel and US interference into internal affairs of Ukraine in all probability will result in another failure as regards the date of signing the long-term contract on nuclear fuel supply for Ukrainian power plants after year 2010.

Transfer of the issue of nuclear fuel supply from the level of economic entity to the level of Ukraine National Security and Defense Council, Presidential Administration and Cabinet Council prevented final concurrence of the long-term contract commercial terms and its official signing.

President of Ukraine V.A. Yushchenko continuously insists on diversification of nuclear fuel supplies and demands that measures are taken aimed at breaking up the monopoly of the Russian suppliers on the Ukrainian market. It has come to the point, where the Russian partner was even accused of attempts to capture the Ukrainian uranium enrichment market, despite the fact that Ukrainian Premier Yu.V. Timoshenko affixed her signature to the Protocol of the fourth meeting of Committee for economic cooperation issues within the Russian-Ukrainian Intergovernmental Commission.

Top management of SE National Atomic Energy Generating Company (SE NAEC) "Energoatom" privately warns that the long-term contract will not be signed before this July and no directives for signing the document will be given before completion of the electioneering campaign in Ukraine on January 17, 2010, while the war of words after the election may entail its further updating. It is unlikely that the efforts aimed at signing the contract will yield results before May-June of the next year.

In spite of the situation in Ukraine, State Corporation "Rosatom" exerted utmost effort for transferring the negotiations into economic domain and for the document concurrence on time. After April 29, this year, six meetings of the task group were arranged on the initiative of the Russian partners. In May a plan of State Corporation "Rosatom" actions aimed at concluding the long-term contract within the specified period was developed. Proposals for settlement of all the discordant issues based on trade-off approaches were advanced. Earnestness of the intentions to take part in the fuel fabrication plant construction project in Ukraine were made clear by developing the project investments substantiation, as well as by offer to arrange a joint Russian-Ukrainian venture in Ukraine to be engaged in compliance with commitments of the parties. State Corporation "Rosatom" has concurred the Ukrainian formulation of the subject of the long-term contract, which, in the opinion of the Ukrainian partner, was the main obstacle to final concurrence of the contract within the period specified by Premiers of Russia and Ukraine.

In the framework of many rounds of negotiations the Russian partner proposed different options of tradeoff decisions for final concurrence of the long-term contract commercial terms. Specifically, speeded up construction of the nuclear fuel production plant in Ukraine was guaranteed on condition of long-term purchase of the Russian fuel assemblies for all fifteen operating Ukrainian power units. JSC "TVEL" did not oppose the localization of fuel powder and pellets production in Ukraine before 2020, if the US fuel supplies are replaced with fuel assemblies fabricated by the plant. The Russian partner was ready to support compliance with commitments pertinent to the plant construction in Ukraine, providing the Russian Federation government guarantees in exchange for Ukrainian commitments to make long-term purchases of the Russian uranium enrichment services.

Instead of addressing the tradeoff proposals, the Ukrainian partner continued enhancing the requirements in reference to JSC "TVEL" commitments within the long-term contract, sometimes upsetting the agreement reached by Premiers of Russian and Ukraine. Having concurred the Ukrainian formulation of the subject of the contract, SE NAEC "Energoatom" still refuses to complete the negotiating process and to sign the contract on time.

Supplement 3

Average exchange rate $/RUR & EUR/RUR in 2003 – 2008

Table S.3.1

Average exchange rate $/RUR & EUR/RUR in 2003 – 2008

Year	2003	2004	2005	2006	2007	2008
Exchange rate $/RUR	30.713	28.831	28.262	27.235	25.584	24.874
Exchange rate EUR/RUR	34.682	35.817	35.260	34.057	34.961	36.446