VVER NUCLEAR FUEL
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TVEL FUEL COMPANY OF ROSATOM STATE CORPORATION

For more details please visit the company website:
www.tvel.ru
TVEL FUEL COMPANY, NUCLEAR FUEL DEVELOPER, PRODUCER AND SUPPLIER

TVEL Fuel Company is a fuel division of Rosatom State Corporation. The development, production and sale of nuclear fuel, as well as associated nuclear and non-nuclear products both in Russia and abroad are the core activities of the Company. Currently, TVEL Fuel Company runs fuel fabrication assets, a separation-sublimation complex, as well as gas centrifuges manufacturing facilities and a R&D Unit. TVEL focuses on fulfilling the strategic mission of Rosatom State Corporation, which is to fuel the growth of nuclear technology exports.

TVEL’s strategy aims at expansion of its share on traditional and new markets, including Western-designed reactors market.

Today TVEL Fuel Company fully meets the needs of power reactors in 14 countries (16 % of the global market), and supplies fuel to Russian- and Western-designed experimental reactors. Every 6th power reactor is powered by fuel produced by TVEL Fuel Company.

The advantages of TVEL are based on the scope of supply, along with high quality and competitive price resulting from large-scale production and technological know-how in the field of nuclear fuel production.
TVEL FC develops, manufactures and supplies nuclear fuel that meets the highest international reliability standards for Russian and foreign nuclear power plants with VVER-440, VVER-1000, VVER-1200, BN-600, BN-800, RBMK-1000, EGP-6 reactors, for experimental reactor facilities and marine nuclear steam power plants. The Company also developed fuel for PWR 17х17 reactors.

TVEL FC offers consumers modern nuclear fuel while considering how to increase the capacity of power units, introduce new fuel cycles with improved technical and economic characteristics and the innovative projects of NPP 2006 and a floating NPP.

In cooperation with APEVR NP, TVEL FC manufactures and supplies fuel for West European PWR and BWR reactors.

— TVSA-12 and TVS-2M modern fuels for VVER-1000 reactors allow consumers to increase the technical and economic characteristics of nuclear power plants by increasing the campaign duration and introducing extended fuel cycles.

— Second and third-generation nuclear fuels for VVER-440 reactors are characterized by increased technical and economic performance and allow 5 to 6-year fuel cycles to be introduced at nuclear power plants with an increase in heat output.

— Fuels for floating NPPs with KLT-40 C reactors have been developed based on the technology of marine nuclear steam power plants, which meet the requirements for non-proliferation of nuclear weapons and use of uranium with enrichment not more than 20%.

— Fuels for NPP 2006 with VVER-1200 reactors ensure higher power unit thermal capacity, and operation in flexible fuel cycles of various duration with an option of diurnal maneuvering.
TVEL ON THE GLOBAL MARKET

**YEAR 2017**

- **72** power-producing reactors in 14 countries
- **448** number of nuclear power units used worldwide, as of the end of 2017
- **57** number of nuclear power units under construction worldwide, as of the end of 2017
- **>350** deliveries of nuclear fuel and its components annually
- **EVERY 6TH POWER REACTOR IN THE WORLD USES FUEL PRODUCED BY TVEL**
- **16%** of the global nuclear fuel market
- **6%** of the nuclear fuel supplies for Russian- and Western-design research reactors

**% OF NPP CAPACITIES PROVIDED WITH FUEL PRODUCED IN RUSSIA**

- Russia 100%
- Hungary 100%
- Slovakia 100%
- Czech Republic 100%
- Bulgaria 100%
- Iran 100%
- Armenia 100%
- Ukraine 57%
- Finland 36%
- India 30%
- China 6%

**Russia**
- Balakovo
- Bilibino
- Vilyuchinsk
- Volgodonsk
- Gatchina
- Desnogorsk
- Dimitrovgrad
- Zarechny
- Kursk
- Murmansk
- Novovoronezh
- Obninsk
- Polyarnye Zori
- Sosnovy Bor
- Tomsk
- Udomlya

**Nuclear Fuel Supplies for Russian- and Western-Design Research Reactors**

- TVEL on the global market
- Supplies in cooperation with Framatome

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* перевозки осуществляются всеми видами транспорта: автомобильным, железнодорожным, авиационным и водным
INTERNATIONAL QUALITY, SUSTAINABILITY, OPERATIONAL HEALTH AND SAFETY, ENERGY MANAGEMENT STANDARDS


The system covers the full cycle involving design, development, production, storage, supplies and theoretical/technical support for handling fuel assemblies and reactor core elements, as well as respective materials and components.

THE MAIN GOAL TVEL PURSUES IN TERMS OF QUALITY MANAGEMENT IS THE CONTINUOUS IMPROVEMENT OF PRODUCT QUALITY AIMED AT MAXIMUM CUSTOMER SATISFACTION, ALLOWING FOR MARKET EXPANSION, ENSURING SUSTAINABLE DEVELOPMENT OF SUBSIDIARIES AND PROMOTING THE COMPANY TOWARDS GLOBAL LEADERSHIP

TVEL understands that product quality influences the safety and efficiency of facilities using the product.

ZERO FAILURE PROJECT

Stage I of the Current Status Evaluation has been completed. The design, production and operation processes for the TVEL nuclear fuel used with VVER-1000 reactors at Russian, Czech, Ukrainian and Bulgarian NPPs have been analyzed.

Currently, the Company is developing an organizational and technical action plan to be introduced at design offices, nuclear fuel plants and NPPs to minimize or eliminate fuel failures.

TVEL FUEL COMPANY HOLDS ANNUAL SATISFACTION SURVEYS FOR ITS MAIN CUSTOMERS IN ACCORDANCE WITH THE CUSTOMER SATISFACTION SURVEY PROCEDURE BASED ON ISO 9001:2008
Currently, more than 200 PWR reactors are in operation worldwide, located in North America, Europe and Asia.

Having reached such a high level of nuclear fuel research and technology and quality of nuclear fuel production, TVEL managed to develop fuel for PWR 17x17 reactors. The solution incorporated proven Russian technologies, materials and know-how.

The resulting fuel assembly for PWR core TVS-KVADRAT meets every modern economic and performance requirement.

Accidents at nuclear power plants have shown a particular danger of the steam-zirconium reaction that occurs when the temperature of the fuel element cladding rises after the loss of coolant and outsurge of reactivity. The Accident Tolerant Fuel (ATF) could become the solution. It can operate both in normal conditions and in case of coolant loss. TVEL Fuel Company sees the ways of solving this global problem in modifying zirconium fuel element cladding surface, using steel fuel element cladding and creating new fuel compositions with high thermal conductivity. Russian company has already been developing ATF.
## Basic Nuclear Fuel Types

### VVER-440

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Hexagonal</th>
<th>3rd generation fuel assembly</th>
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<tbody>
<tr>
<td>Geometry</td>
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<tr>
<td>Number of fuel rods per assembly fuelled</td>
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<td>Number of fuel rods per assembly unfuelled</td>
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<td>Overall length, mm</td>
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<td>Pellet length, mm</td>
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<tr>
<td>Pellet outside diameter, mm</td>
<td>760</td>
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<tr>
<td>Pellet density, g/cm³</td>
<td>10.4-10.7</td>
<td>10.4-10.7</td>
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<tr>
<td>Peak linear fuel rating, kW/m</td>
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<tr>
<td>Cladding material</td>
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<td>Zr-1%Nb</td>
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<tr>
<td>Maximum cladding temperature, °C</td>
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<tr>
<td>Spacer grid material</td>
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<tr>
<td>Average discharge burnup, MWD/kgU</td>
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<tr>
<td>Maximum assembly burnup, MWD/kgU</td>
<td>57</td>
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### VVER-1000 TVS-2M

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<td>Number of fuel rods per assembly unfuelled</td>
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<tr>
<td>Overall length, mm</td>
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<td>Overall width, mm</td>
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<tr>
<td>Fuel rod length, mm</td>
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<td>Pellet outside diameter, mm</td>
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<tr>
<td>Pellet density, g/cm³</td>
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<tr>
<td>Spacer grid material</td>
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<tr>
<td>Average discharge burnup, MWD/kgU</td>
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<tr>
<td>Maximum assembly burnup, MWD/kgU</td>
<td>66</td>
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<tr>
<td>Fuel column height, mm</td>
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<td>UO₂ weight, kg</td>
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### VVER-1000 TVSA-12PLUS

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<tr>
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<tr>
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</table>
Designing fuel for new reactor systems

Fuels for floating NPPs with KLT-40C reactors have been developed based on the technology of marine nuclear steam power plants, which meet the requirements for non-proliferation of nuclear weapons and use of uranium with enrichment not more than 20%.

Fuel for VVER-1200 reactors that ensures operation in more severe conditions (temperature, pressure, steam content) against those of VVER-1000, and operation in flexible fuel cycles of various duration with an option of diurnal maneuvering within the range of 100-75-100% Nnom.

For the time being, TVEL is creating a demo experimental energy package with a BREST-OD-300 reactor and production facilities for the fabrication and processing of mixed uranium-plutonium nitride fuel at the site of JSC SGChE, and is also participating in the development of MOX fuel industrial production for a BN-800 reactor at FSUE GChC.


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