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EU Power Technologies

Russian Uranium Conversion Industry State & Prospects.

2023

IBR EU Power Technologies, LLC

Hungary 2023

About
IBR EU Power Technologies, LLC (IBR^{TM}, Hungary)

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- ***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.***

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1.2 Russian uranium conversion industry nominal capacity / actual capacity / load factor

The capacity of the Russian uranium conversion industry is determined by the capacity of technological equipment (and processes) having the minimum capacity. There are two types of technological equipment (processes) that can determine the capacity of Russian conversion industry:

- ✓ The capacity of equipment for molecular fluorine (F_2) production;
- ✓ The capacity of flame reactors for UF_6 production.

The capacity of the Russian uranium conversion industry until 2020 determined by the capacity of the equipment for the production of molecular fluorine (F_2). Because the volume of uranium hexafluoride (UF_6) that could be produced by using of available equipment (we consider that the resources of anhydrous hydrogen fluoride (UF) are unlimited) was less than equipment capacities for uranium hexafluoride production (the flame reactors), or less than the equipment capacities for intermediate product production (the high-temperature dry hydro fluorination reactors) and the other equipment capacities used in the technological lines for the production of uranium hexafluoride.

The only now existing Russian company for the production of uranium hexafluoride (SCC) has uses the following technological flow chart since 2012-2013:

- ✓ At the first stage - high-temperature dry hydro fluorination of uranium oxides with anhydrous hydrogen fluoride at the M-2463 installation to obtain an intermediate product in the form of uranium fluoroxides + uranium tetrafluoride;

- ✓ At the second stage, fluorination with molecular fluorine of a mixture of uranium fluoroxides + uranium tetrafluoride in a flame reactor, to obtain the final product in the form of uranium hexafluoride (UF_6).

The capacity of two A-202 flame reactors (2 reactors in operation and 2 reactors in standby / maintenance / repair / replacement mode) operating in two technological lines of SCC Sublimation (conversion) plant is:

- ✓ ~ 25,000 tU per year (UF_6) for fluorination of uranium tetrafluoride (UF_4);
- ✓ ~ 19,000 tU per year (UF_6) for fluorination of uranium fluoroxides + uranium tetrafluoride (UF_4);
- ✓ ~ 15,000 tU per year (UF_6) for fluorination of oxides.

As for the installation M-2463, intended for high-temperature dry hydro fluoridation of uranium oxides by anhydrous hydrogen fluoride and that is installed at the SCC Sublimation (conversion) plant, each of the four reactors (two at each technological lines) has a capacity of ~ 7,700 tU per year (installation M-2463 output product is a mixture of uranium fluoroxides + uranium tetrafluoride). The installations M-2463 are able to satisfy the maximum demands of two SCC flame reactors that are in the operation.

Table 1.1 presents the initial data and the results of the calculation of the Russian uranium conversion industry capacity dynamics in 1991-2022. The capacity of the Russian uranium conversion industry is calculated as minimum value of two values:

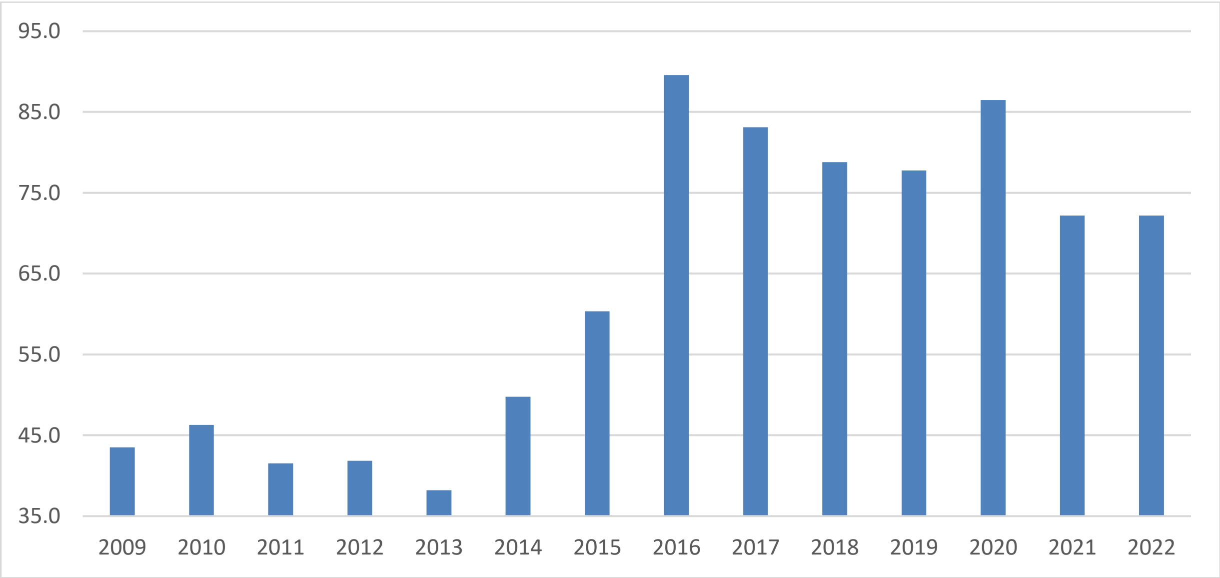
- ✓ The data of nominal capacity of electrolysis equipment used in the technological scheme for the production of uranium hexafluoride. It is suppose that all electrolyzers are under working condition. The electrolysis equipment capacity losses due to its major overhaul and correspondently underproduction of molecular fluorine (F_2) are not taken into account. The downtime of electrolysis equipment and correspondently underproduction of molecular fluorine (F_2) due to service maintenance is taken into account.

- ✓ The capacity of the flame reactors are in operation.

Remarks:

- ✓ *The Russian uranium conversion industry actual production values were calculated on the base of quantity of F contented in fluorspar and anhydrous hydrogen fluoride (HF) produced/purchased by JSC Siberian Chemical Combine and Angarsk Electrolysis and Chemical Combine.*
- ✓ *In 2019, CAMECO and ORANO delivered ~ 1,092 tU of natural quality in the form of UF_6 to the Ural Electrochemical Combine (UECC).*
- ✓ *Table 1.3 presents the actual production of UF_6 by the Russian uranium conversion industry in the period 2009-2022. Data were obtained by using the methodology presented in Appendix 3.*

Figure 1.4
The load factor of Russian conversion industry, %



Note. The value of load factor is in good agreement with the data of the former director of the Siberian Chemical Combine presented in 2017-2018 (Section 2).

Remarks to the Figure 2.1:

- ✓ *The first installation of uranium dioxide production (out of 3 necessary) was put into operation at the end of June 2020.*

- ✓ *After the commissioning of the first uranium dioxide production unit, as before, a significant part of U_3O_8 will be supplied to the high temperature dry uranium hydro fluorination units bypassing the conversion stage to UO_2.*

2.5 Russian uranium conversion industry development prospects

The main data used by IBR for
Russian uranium conversion industry development forecast

The Russian uranium conversion industry is very closely connected with Russian uranium enrichment industry. Actually, the Russian uranium enrichment industry defines the development of Russian conversion industry. The following five points are used by IBR for the design of Russian conversion industry development forecast through 2040.

A. **The concept of development of the Russian uranium conversion industry and the forecast of capacity utilization**

The conflict between Russia and Ukraine that began in 2022 obviously should have negative consequences for the export of Russian nuclear materials at a number of geographical segments of the market. Of course, it is clear to SC Rosatom / FC TVEL. Despite this, by the beginning of 2023, FC TVEL had not yet formulated a new strategy for its development, different from the Strategy of Fuel Company TVEL; approved by Rosatom's Strategic Council on December 9, 2014 (latest revision of the Strategy's quantitative target is dated by 2020). Accordingly, at the official level, the goal of the Strategy of SC Rosatom / FC TVEL remains the same, namely the occupation of 33.3% (FC TVEL + TENEX) of the world market of enriched uranium product.

According to the authors of the report, it is necessary to separate the strategy for the development of conversion capacities and the planned (projected) loading of conversion capacities. As for the development of the capacities of the Russian industry for the conversion of uranium, in the opinion of the authors of the report, all measures for the modernization of the conversion capacities will be carried out, because. these measures not only provide for an increase in the capacity of industry, but also pursue the task of increasing the efficiency of production. As for the SC Rosatom / FC TVEL predicted loading of conversion capacities, the authors of the report believe the plans of SC Rosatom / FC TVEL dated by 2020 are too high. The capacity utilization forecast will use IBR's own forecast based on Russian conversion capacity requirements for the Russian uranium enrichment industry and exports.

When forming a forecast for the development of the Russian conversion industry, the authors of the report were based on the following facts and assumptions:

- ✓ In 2022, the Russian export of nuclear materials and products actually turned out to be even higher than the export of 2021. This was due to the fact that a number of consumers of nuclear materials assumed the imposition of sanctions against Russian nuclear fuel cycle enterprises, and were making appropriate stocks. This suggests that for most companies, economic factors take precedence over political factors;
- ✓ The authors of the report do not predict imposition of sanctions against Russian enterprises of the nuclear fuel cycle in the short and medium term. Building replacement capacity in the West requires significant time and investment;
- ✓ However, in the medium and long term, Russian nuclear fuel cycle enterprises will lose some volume of orders in a number of geographical market segments, due to the self-limitation of some customers on the products of Russian nuclear fuel cycle enterprises. However, due to the predicted change in the political system of Russia in the short/medium term from totalitarian/authoritarian to hybrid/democratic system, political restrictions on cooperation with Russia will be gradually removed and by about 2030 the export of nuclear materials and products from Russia will recover even in those geographical segments where self-limitations were introduced;

- ✓ The concept and strategy for the development of Russian nuclear fuel cycle enterprises (the latest official version is dated 2020) does not envisage the use of foreign depleted uranium for re-enrichment and generation of natural-quality uranium in the future. In this regard, with the predicted dynamics of the Russian uranium enrichment industry development, the accumulated Russian "rich" depleted uranium will last until 2034-2036. Therefore, depleted uranium, starting from 2034-2036, can no longer serve as a source of natural uranium hexafluoride used in the enrichment industry. Starting from this period, only the Russian conversion industry will be the source of uranium hexafluoride for its subsequent enrichment;
- ✓ By the end of the 2030s, the question of decommissioning the existing conversion plant and the need to build a new plant will arise. It is predicted that the construction of the new plant will begin in the mid-1930s. The commissioning of the first stage of the new plant should be coordinated with the completion of the program for the re-enrichment of "rich" Russian depleted uranium, since with the completion of this program, a significant source of uranium hexafluoride will disappear.

B. The SCC general director data

Sergey Tochilin, former general director SCC, October 2017:

- ✓ "Now SCC is the only enterprise in the country that produces this product (UF_6 - note IBR) for enrichment. Our capacities are 12 thousand tons U per year; we cover the demand of Rosatom for Russian stations and for a significant quantity of stations abroad. The available capacities cover the need of the corporation in hexafluoride uranium for 9-10 years ahead";

- ✓ "There were prerequisites that it would be necessary to increase Russian capacities to 18 thousand tons. If we talk about this plant (a new plant - IBR note), even if there will be a need for its creation, it takes no more than two years to build it. We understand these processes, if necessary a corporation (SC Rosatom - IBR note) can easily solve the problem of increasing capacities for uranium hexafluoride production."

Sergey Tochilin, former general director SCC, August 2018[16]:

- ✓ At present time the SCC conversion plant load factor is ~ 80%;
- ✓ Over 9-10 years the SCC conversion plant load factor will reach 100%[17];
- ✓ The SCC conversion capacity will be increased at 20% minimum by 2025-2026.

The former SCC director's data are a little outdated, but overall they correctly reflect the capacity development strategy and workload of the Russian uranium enrichment industry.

C. Act of analysis of the reasons for non-compliance and development of measures to ensure the implementation of the conversion program

On May 20, 2019, an act was drawn up with an analysis of the reasons for non-compliance and development of measures to ensure the implementation of the conversion program at the Siberian Chemical Combine No. 4-51/214-PR-dsp.

On May 31, 2019, a roadmap was signed containing a list of activities aimed at implementing the Conversion Program at the Siberian Chemical Combine No. 11-60/01-08/42708-VK.

As of early 2023, a roadmap signed in May 31, 2019 and containing a list of activities aimed at implementing the Conversion Program at the Siberian Chemical Combine No. 11-60/01-08/42708-VK is mostly fulfilling, which contributes to the growth of installed capacity and increase of production efficiency.

[16] http://atomsib.ru/%D0%BF%D1%80%D0%BE%D0%B3%D1%80%D0%B0%D0%BC%D0%BC%D0%B0-%C2%AB%D1%81%D0%BE%D1%80%D0%BE%D0%BA%D0%BE%D0%B2%D0%BE%D1%87%D0%BA%D0%B0%C2%BB/6862-programma-sorokovochka-ot-09-08-18

[17] It should be noted that in 2018, FC TVEL’s forecast of global needs for Russian-made EUP (and, accordingly, the forecast of FC TVEL’s needs for conversion capacities) was higher than the forecast of 2022.

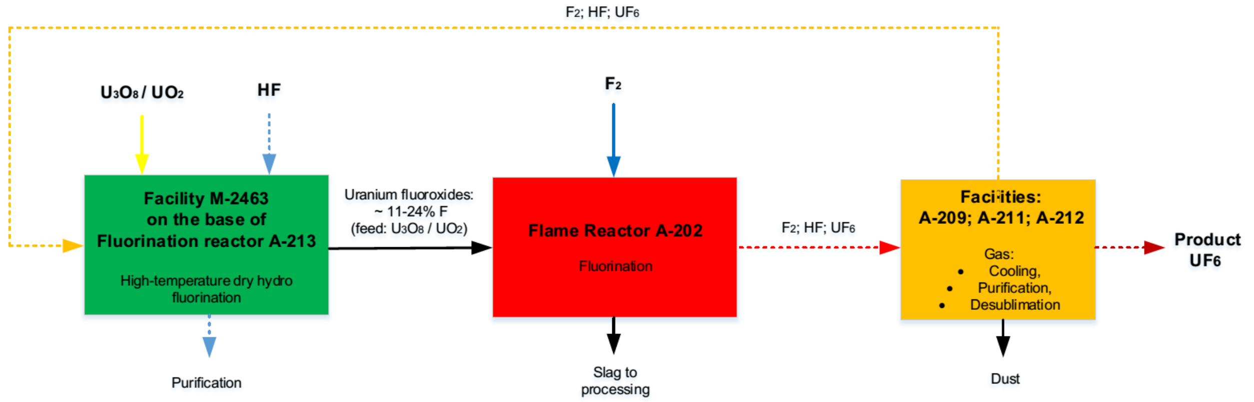


Figure 2.3
The SCC acting Conversion plant principle technological scheme

Table 2.4
Capacities of the main installations of the Conversion plant

Installation	Capacity of one installation, KgU/h
Flame reactor A-202	✓ ~ 1400 kgU/h as UF_6 (feeding mixture UO_2F_2 + UF_4, F ~ 17-24%) ✓ ~ 1140 kgU/h as UF_6 (feeding mixture UO_2F_2 + UF_4, F ~ 11-16%) ✓ ~ 880 kgU/h as UF_6 (feeding: UO_2 / UO_3 / U_3O_8)
High temperature dry hydro fluorination installation	✓ ~ 950 kgU/h as mixture UO_2F_2 + UF_4 (feeding: UO_2 / UO_3 / U_3O_8)

The SCC Conversion plant has two types of electrolysers for F_2 production:

- ✓ STE-10 (electric current – 9.8/13.5 kA), its nominal output is 49.6 tons of F_2 per year;
- ✓ STE-19 / STE-20U (electric current – 15.0/20.0 kA), its nominal output is 74.4 tons of F_2 per year.

As of beginning of 2023, the SCC Conversion plant had the following quantity of electrolisers in operation:

- ✓ Type STE-10 – 53 pieces;
- ✓ Type STE-19 / STE-20 – 48 pieces, including 32 pieces delivered from AECC and commissioned at SCC in the mid-2017.

Total number of electrolisers at SCC (in operation, in maintenance, in storage) was 152 pieces (STE-10 – 80 pieces; STE-19 / STE-20U – 72 pieces) as of the end of 2017[19].

In 2021, the project "Technical re-equipment of the M-1139 fluorine production unit" was launched. The goal of the project is to expand the capacity of the Siberian Chemical Combine to receive and use containers with hydrofluoric acid. The implementation of this project will allow SCC to reduce the volume of purchases of fluorspar for its own production of hydrofluoric acid and to switch to larger-scale purchases of hydrofluoric acid from suppliers.

The acting Siberian Chemical Combine uranium conversion plant was planned to operate until 2041.

The SCC and AECC Conversion plants have the similar design and equipment. The AECC Conversion plant is younger than SCC Conversion plant. The significant part of equipment from AECC can be delivered or already is delivered and commissioned at SCC Conversion plant for capacity extension or as spare parts for equipment maintenance / repair / replacement.

[19] TERMS OF REFERENCE for the overhaul of the electrical equipment of the subdivisions of SCC, 04/1798 dated December 22, 2017.

Chapter 3
Uranium Refining and Conversion Technologies Used in the Russian Uranium Conversion Industry[21]

General overview of the Russian uranium conversion technologies

The technological scheme for the production of uranium hexafluoride at the Siberian Chemical Combine (SCC) includes the following steps:

At the Radiochemical Plant:

- ✓ Chemical concentrates of natural uranium (TU95 1981-1989 standard grade; ASTM C967 standard grade, other standard grade) or reprocessed uranium (RT, FM) are refined. The process of refining includes an extraction refining scheme with obtaining of uranyl nitrate ($UO_2(NO_3)_2$) or ammonium polyuranate ($(NH_4)U_2O_7$) as the final products of refining, meeting to the STP 28.1 standard grade.

At the sublimation (conversion) plant:

- ✓ Uranyl nitrate or ammonium polyuranate are processed by calcinatiotion into UO[22]$_2$ / UO_3 / U_3O_8;
- ✓ Uranium oxides undergo a process of high temperature dry hydro fluorination by HF with the semi product at outlet $2UO_2F_2$ + UF_4 + Oxides;
- ✓ UF_6 meeting to the ASTM C787 standard grade is produced by direct fluorination the mixture of $2UO_2F_2$ + UF_4 + Oxides by F_2 in a flame reactor.

Uranium Refining Technology

At SCC Radiochemical Plant (RP), extraction-refining technology is used. The essence of the technology lies in the process of water-extraction dissolution of uranium and its subsequent purification. Extraction processing of solutions is based on the properties of certain organic substances (extractants) that do not mix with water and can selectively extract valuable components (uranium (U)). Upon contact of aqueous and organic solutions of uranium, impurities, fission products that are in solutions in various forms (salts, acids, cations, anions) are distributed between the aqueous and organic phases, depending on a number of conditions of the extraction process. These conditions can be selected in such a way as to quantitatively extract uranium, leaving impurities and fission products in the aqueous phase.

Uranium concentrate is dissolved in nitric acid heated to 80-90 0C. Insoluble particles are than precipitated from the solution with the help of flocculating agent FLOQULATTM FL 45 C. Clarified solution of uranium with concentration of uranium 250-350 g / l is sent to an extraction installation.

Until 2012, only the M-1345 uranium extraction purification installation operated at the SCC RP, which uses column-type pulsation apparatuses, and which includes four extraction plate-type pulsation columns; three buffer tanks; tank compilation; four receivers of compressed air; four remote centrifugal pumps. The aqueous phase leaving the re-extraction column is a solution of uranyl nitrate with a concentration of (110 ÷ 140) g / l. The resulting solution is sent to concentration and further processing. The organic phase undergoes a regeneration operation.

In 2012, a new refining production was commissioned at the SCC RP. The Central Design and Technological Institute (CDTI) developed the project; SMU-74 was the general contractor for construction and assembly work.

[21] The technologies and equipment of the Russian uranium conversion industry are described in detail in the report of Russian Uranium Conversion Industry, 2018. This report provides only a brief overview of the technologies and equipment.
[22] The first installation for the production of uranium dioxide by calcining UO3 / U3O8 in a hydrogen flow will be put into operation at the SCC Sublimation (conversion) plant in mid-2020.

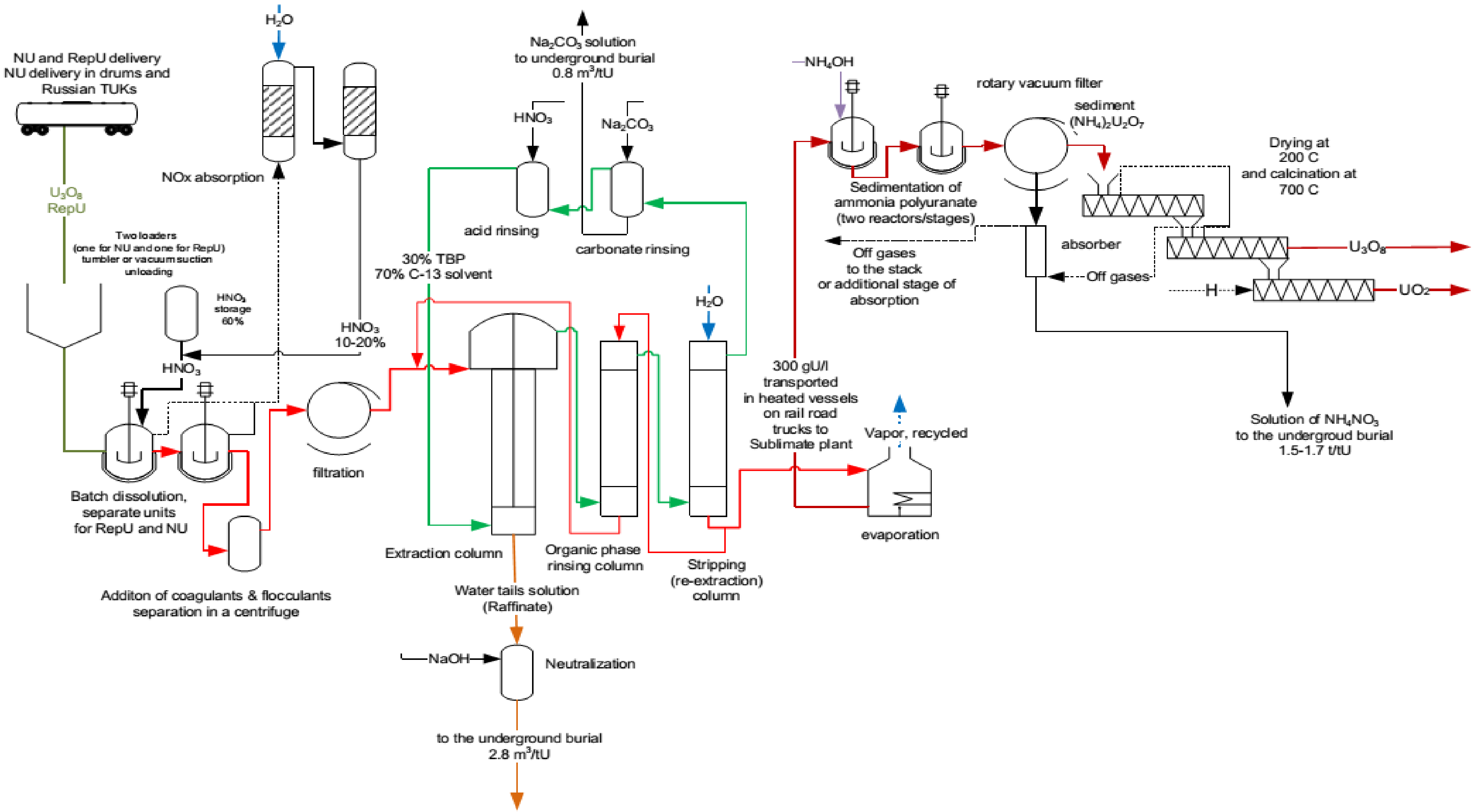


Figure 3.3

The technological scheme of the refining of uranium materials in the apparatus of the column type and the production of uranium oxides at SCC (RP / SP)

Using a methodology similar to that of calculating the specific price of uranium conversion, we calculate the cost of conversion at SCC. It should be borne in mind that the conversion is a service at SCC.

Table 4.3
Estimation of the SCC average specific conversion cost of natural and reprocessed uranium (2018 - 2022)[26]

No.	Item	Value (2018)	Value (2019)	Value (2020)	Value (2021)	Value (2022)
(1)	Expenses for the production of uranium conversion and enrichment products, million rubles	792	388	725	946	n.d.
(2)	Expenses for the production of uranium conversion and enrichment services, million rubles	5,349	5,912	6,315	5,949	n.d.
(3)	Total, million rubles, (1) + (2)	6,141	6,300	7,040	6,895	n.d.
(4)	SWU quantity produced at SCC, million SWU	3.794	3,100	2,922	2,922	2,880
(5)	SWU cost, rubles	600	700	750	790	810
(6)	Expenses for the production of uranium enrichment products and services, million rubles, (4) x (5)	2,276	2,170	2,192	2,308	n.d.
(7)	Expenses for the production of uranium conversion services, million rubles, (3) - (6)	3,865	4,130	4,848	4,587	n.d.
(8)	Produced (converted) uranium hexafluoride (UF_6), tU as UF_6	11,313	11,627	13,573	11,332	11,329
(9)	Average specific conversion cost, rubles / kgU	341	355	357	405	437
(10)	Average $/RUR exchange rate, $/RUR	62.5	64.7	71.9	73.7	68.3
(11)	Average specific conversion cost, $ / kgU	5.5	5.5	5.0	5.5	6.4

Table 4.2
Estimation of the SCC specific conversion cost of natural and reprocessed uranium (2018 - 2022)

No.	Item	Value (2018)	Value (2019)	Value (2020)	Value (2021)	Value (2022)
(1)	Specific conversion cost (purification + conversion) of natural uranium, $/kgU	5.0	5.0	4.5	5.0	5.3
(2)	Specific conversion cost (purification + conversion) of regenerated uranium, $/kgU	10.0	10.0	9.0	10.0	10.6

[26] Estimation of the SCC average specific conversion cost of natural and reprocessed uranium includes only “shop” costs and does not include enterprise’s commercial, management and some other general costs.

IBR considers that the decision made by SC Rosatom / FC TVEL on conversion concentration on the SCC single site is a correct solution of the problem of Russian conversion industry economy efficiency increasing. On the opinion of FC TVEL specialists, the conversion concentration on one site will permit reducing the conversion specific total net cost by a factor of 2.5-3.0.

According to the annual report of SCC for 2017, in 2017, projects aimed at reducing the cost of conversion and refining were successfully completed (project - “Concentration of refining production at the SCC site” and the project - “Concentration of conversion production at the SCC site”):

- ✓ The cost of refining is reduced by 24%;
- ✓ The cost of conversion is reduced by 23%[27].

[27] Apparently, 2013 is the base year when analyzing the improvement of economic indicators, i.e. by the year, when the cooperation on the production of uranium hexafluoride included 3 enterprises.

Appendix 1
Technical requirements to impurities content in the raw materials, intermediate and final products used in the Russian uranium conversion industry

Technical requirements to the content of limited impurities include the following:

- ✓ Requirements to the content of limited impurities in the raw materials in the form of uranium U_3O_8 – Russian TU95 1981-1989 standard and Western ASTM C967 standard;
- ✓ Requirements to the content of limited impurities in intermediate products – uranium tetrafluoride + fluoroxide for its subsequent conversion to uranium hexafluoride (grade A) and uranium tetrafluoride for production of standard uranium blocks (grade B), as well as to uranium monoxide-oxide resulting from refining at JSC "Siberian Chemical Combine" (STP 28.1);
- ✓ Requirements to the content of limited impurities in final product – uranium hexafluoride (UF_6) – ASTM C787 standard.

Table A1.1
Quantitative characteristics of the content of limited impurities in raw materials and finished products (percent in relation to uranium content)

<table>
<tr><th rowspan="3">Element</th><th colspan="3">Raw material (U_3O_8)</th><th colspan="3">Intermediate products (UF_4 / UO_2F_2 / UO_2 / UO_3 / U_3O_8)</th><th>Finished product (UF_6)</th></tr>
<tr><th rowspan="2">ASTM C967</th><th rowspan="2">TU95 1981-1989</th><th rowspan="2">U_3O_8 JSC UMP (Kazakhstan)</th><th colspan="2">UF_4 TU 1713-2005</th><th rowspan="2">U_3O_8 STP 28.1</th><th rowspan="2">ASTM C787</th></tr>
<tr><th>Grade A</th><th>Grade B</th></tr>
<tr><td>Antimony (Sb)</td><td></td><td></td><td></td><td>0.00010</td><td>-</td><td>0.00010</td><td>0.00010</td></tr>
<tr><td>Arsenic (As)</td><td>0.10</td><td></td><td>0.005</td><td>0.00030</td><td>-</td><td>0.00030</td><td>0.00030</td></tr>
<tr><td>Boron (B)</td><td>0.10</td><td>$2.5*10^{-5}$</td><td>0.005</td><td>0.00003</td><td>0.00003</td><td>0.00010</td><td>0.00010</td></tr>
<tr><td>Bromine (Br)</td><td></td><td></td><td>0.005</td><td>0.00050</td><td>-</td><td>-</td><td>0.00050</td></tr>
<tr><td>Chlorine (Cl)</td><td></td><td></td><td></td><td>0.01000</td><td>-</td><td>0.01000</td><td>0.01000</td></tr>
<tr><td>Iodine (I)</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Chromium (Cr)**</td><td></td><td></td><td></td><td>0.00100</td><td>0.00800</td><td>0.00100</td><td>0.00100</td></tr>
<tr><td>Molybdenum (Mo)*</td><td>0.30</td><td>0.0090</td><td>0.005</td><td>0.00014</td><td>0.00040</td><td>0.00014</td><td>0.00014</td></tr>
<tr><td>Niobium (Nb)</td><td></td><td></td><td></td><td>0.00010</td><td>-</td><td>0.00010</td><td>0.00010</td></tr>
<tr><td>Phosphorus (P)*</td><td>0.70</td><td>0.0080</td><td>0.050</td><td>0.00500</td><td>0.00800</td><td>0.00500</td><td>0.00500</td></tr>
<tr><td>Ruthenium (Ru)</td><td></td><td></td><td></td><td>0.00010</td><td>-</td><td>0.00010</td><td>0.00010</td></tr>
<tr><td>Silicon (Si)</td><td>2.50</td><td>0.0080</td><td>0.050</td><td>0.00500</td><td>0.00500</td><td>0.01000</td><td>0.01000</td></tr>
<tr><td>Tantalum (Ta)</td><td></td><td></td><td></td><td>0.00010</td><td>-</td><td>0.00010</td><td>0.00010</td></tr>
<tr><td>Titanium (Ti)</td><td>0.05</td><td></td><td>0.005</td><td>0.00010</td><td>-</td><td>0.00010</td><td>0.00010</td></tr>
<tr><td>Tungsten (W)*</td><td></td><td></td><td></td><td>0.00014</td><td>-</td><td>0.00014</td><td>0.00014</td></tr>
<tr><td>Vanadium (V)*</td><td>0.30</td><td>0.0100</td><td>0.010</td><td>0.00014</td><td>-</td><td>0.00014</td><td>0.00014</td></tr>
<tr><td>Carbonate (CO_3)</td><td>0.50</td><td></td><td>0.100</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Fluorine (F)</td><td>0.10</td><td></td><td>0.005</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Sulfur (S)</td><td>4.00</td><td></td><td>0.200</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Calcium (Ca)</td><td>1.00</td><td></td><td>0.020</td><td>0.10000</td><td>0.12000</td><td rowspan="11">0.03000</td><td rowspan="11">0.03000</td></tr>
<tr><td>Iron (Fe)</td><td>1.00</td><td>0.0300</td><td></td><td></td><td></td></tr>
<tr><td>Magnesium (Mg)</td><td>0.50</td><td></td><td>0.005</td><td></td><td></td></tr>
<tr><td>Potassium (K)</td><td>3.00</td><td rowspan="2">0.0100</td><td>0.005</td><td></td><td></td></tr>
<tr><td>Sodium (Na)</td><td>7.50</td><td>0.005</td><td></td><td></td></tr>
<tr><td>Thorium (Th)</td><td>2.50</td><td>0.0500</td><td>0.002</td><td></td><td></td></tr>
<tr><td>Zirconium (Zr)</td><td>0.10</td><td></td><td>0.005</td><td></td><td></td></tr>
<tr><td>Copper (Cu)</td><td></td><td>0.0003</td><td>0.010***</td><td></td><td></td></tr>
<tr><td>Aluminum (Al)</td><td></td><td>0.0100</td><td></td><td></td><td></td></tr>
<tr><td>Nickel (Ni)</td><td></td><td>0.0040</td><td></td><td></td><td></td></tr>
<tr><td>Manganese (Mn)</td><td></td><td>0.0040</td><td></td><td></td><td></td></tr>
</table>

Remarks:

** These impurities from volatile fluorides during fluorination process and consequently very prone to contaminate UF_6*
*** Concentration of Cr in UF_6 is less than 5 times lower than in the fluorinated raw material making Cr an important impurity*
**** Total content of (Cu+Pb+Bi+Sb)*