UDC 541.791.02.238

PERSPECTIVES OF SIBERIAN CHEMICAL ENTERPRISE IN INCREASING VOLUMES OF URANIUM CONCENTRATES RECYCLING

V.V. Lazarchuk, T.G. Shikerun, A.S. Ryabov, V.I. Shamin, A.N. Zhiganov*

Federal Unitary Enterprise of Siberian Group of Chemical Enterprises, Seversk (FUE SGCE)
*Seversk State Technological Academy (SSTA), Seversk
E-mail: shk@seversk.tomsknet.ru
*E-mail: nmd@ssti.ru

The purification technology of uranium concentrate of natural isotopic composition developed at Siberian chemical enterprise is basically universal, allows recycling uranium concentrates with different content of impurities and obtaining uranium nitrate solutions corresponding by quality to the international standards requirements to uranium hexafluoride preparation for isotopes ASTM C 787-03 separation and to ceramic fuel ASTM C 788-02 preparation. Uranium reserves in Russia and abroad were appraised.

Global changes in international politics occurred for the last 10–15 years required radical restructuring of atomic energy industrial complex and atomic arms complex in Russia.

Siberian Group of Chemical Enterprise (SGCE) initially founded for solving the tasks of nuclear deterrence includes a number of plants which should be applied in the new political balance. The peculiarity of SGCE is the presence of commercial production capacity equally with productions solving defence tasks in its structure.

Realization of the perspective of enterprise civil part liquidation occurred after approval of the first intergovernmental Agreement of Russia and the USA in 1994 about the shutdown of reactors turning out plutonium in 2000. Logically, after reactor shutdown, the radiochemical plant and a number of factories should be withdrawn from production string supporting secondary use of uranium from irradiated fuel. In the next years both sides suggested to postpone time-limits but did not change the substance of the approved agreement.

After approving the Agreement the complex multi-aspect task of carrying out research works on development and adoption of conversion technologies being able to compensate in full the intended shutdown was set for the scientists of the enterprise and Seversk State Technological Academy (SSTA).

The most successful conversion trend for the enterprise is to develop technologies close in their content to the shutdown productions. This approach supports application of the effective enterprise infrastructure, significant part of equipment and scientific-engineering potential of highly skilled personnel.

At the beginning of the first decade of the XXI c. it became obvious that the deficiency of energy consumption, environment contamination, threat of general warming at the present stage of mankind development may be compensated by atomic energy: this power supply can fully satisfy energy demands supporting technical and environmental safety. Besides, sharp price rise for traditional sources of energy supported competitiveness and demand for atomic energy.

At the present stage of development and in prospect of Russia it is necessary to increase multiply uranium production for realization of proper programs and fulfillment of obligations of international agreements. The possibility of uranium production at new Russian deposits as well as supporting cooperation and access to uranium raw material of Kazakhstan, Uzbekistan, Ukraine and Canada, Australia, South Africa in perspective are considered [1].

Therefore, the developed technology of nuclear quality uranium production should be universal, solve the tasks of cleaning raw materials of any origin, support a good position of Siberian Group of Chemical Enterprises in further development of atomic energy industrial complex of Russia.

The perspectives of increasing the scales of uranium material processing at Siberian Group of Chemical Enterprises are determined in whole both by uranium production in Russia and Rosatom cooperation with uranium-mining foreign companies.

Uranium production and consumption in Russia

Russian «nuclear renaissance» is formalized by the Federal task program «Development of nuclear energy-industrial complex of Russia for 2007–2010 and in perspective up to 2015» approved on July 15 2006 with amount of financing of 1471,4 bn rubbles including 674,8 bn rubbles of the budget. Task minimum is to retain a part of atomic power engineering in global energy balance of the country (15...16 %). According to a basic script the part of atomic power engineering in global energy balance should amount to 18,6 % up to 2015 and it may amount to 30 % up to 2025 as a result of the program realization.

The published data on uranium production state, perspective proven territories and availability of stock resources (by the estimation of IAEA Russia has 200...250 thousand tons of uranium in stocks [2]) show that in Russia there is enough uranium for successful development of atomic power engineering for many decades. However, the accelerating paces of development of atomic power engineering services consumption, stimulation of price rise decreasing stock resources, long-term commissioning of new mines are already the basis for expanding new powers at uranium production. Thus, today uranium requirement for NPP located in Russia and constructed abroad by soviet projects amounts to 6,5...8,0 thousand tons [2] at uranium production rather more than 3 thousand tons.

It should be mentioned that all deposits in the world are divided into groups according to the level of uranium production cost. The threshold values for the groups of cost are presented in the review report [3], Table.

Table. *Categories of cost of uranium production at the deposits*

Cost category	US $/ kg U	US $/pound U_3O_8
Low	<34	≤13
Average of the 1group	34...52	13...20
Average of the 2group	52...78	20...30
High	78...130	30...50
Very high	>130	>50

Raw materials base of all foreign manufacturers excels qualitatively the domestic one. Thus, in Canada, Australia, Namibia, Niger uranium is mainly produced by pit-run technique (in Russia – chiefly by the shaft one). Uranium content in Canada deposits is more than 1 %, in Australia it is 0,3...0,4 % and in Russia it is 0,1...0,2 %. All reserves in the country may become payable owing to ores average quality at uranium price exceeding 80 $/kg.

Forthcoming depletion of stock resources, declaration of the representative of «Tekhsnabeksport»in June 2006 that Russia is not going to extend the Agreement HEU – LEU after 2013 [4] and breaks off natural uranium export abroad starting with 2007 [5] and finally world «uranium renaissance» resulted in world price rise to the mark of 114 $/kg of uranium in the form of U_3O_8 in September 2006 [6].

Thus, average Russian ores became needed and perspective for being involved in industrial uranium production.

Expected uranium resources approved by the Department of the Interior of the Russian Federation in 1999 as of 01.01.1998 amount to 600 thousand tons at the cost not higher than 80 $/kg.

In the territory of Russia in Chitinskaya region (Streltsovskiy uranium-ore region) the most large-scale enterprise in uranium production – Priargunskoe mining and chemical corporation (PC «PPMCC») functions. In recent years supplementary exploration was carried out here and 170 thousand tons of uranium by the cost category of 34...52 US$ per 1 kg of uranium was set for balance [3].

Besides, three more large uranium ore regions suitable for processing by the technique of underground leaching (UL) – Zauralskiy, West-Siberian and Vitimskiy were detected.

Zauralskiy uranium ore region (Kurgan region) dislocation CC «Dalur» – expected uranium resources in the region are estimated at 115 thousand tons.

West-Siberian uranium ore region (between cities Novosibirk and Kemerovo, deposit Malinovskoye) – expected uranium resources are 40 thousand tons with real backgrounds to several times increasing in the region of sheeted oxidation on Kulundinskaya area.
Vitimskiy uranium ore region is in the north-east part of Buryat Republic upriver Vitim. Place of uranium production is PC «Khiagda». Expected resources are 123 thousand tons of uranium [7].

Except the uranium ore regions described above in the territory of Russia a number of regions and areas with uranium deposits suitable for UL is known.

Charskiy region (further north-east than Vitimskiy region) – expected resources and reserves are estimated at 200 thousand tons.

Elkonskiy region in Sakha Republic (Yakutia) – uranium reserves at the price of 80 $/kg of uranium exceeds 200 thousand tons [7].

Subject to gradual failure from using stock resources it is intended to increase annual uranium production in Russia from 3,3...3,5 up to 4,9 thousand tons in 2010 and up to 18 thousand tons in 2020 [8].

The increase of uranium production is planned both at operating enterprises (PC «PPMCC», CC «Dalur» and PC «Khiagda») and at new mines founded on the basis of standby deposits. Total annular production at three operating enterprises amounts to 8, 0 thousand tons by 2015 (PC «PPMCC» – 5 thousand tons, CC «Dalur» – 1 thousand tons, PC «Khiagda» – 2 thousand tons). Uranium production at standby deposits placed in Transbaikalia and South Yakutia (Elkonskiy region) should be started in 2010 and reach 7 thousand tons by 2020 [8].

Except proper deposits development the agreement about establishment of joint venture in the territory of Kazakhstan with production of 5...6 thousand tons per year was reached. In conjunction with the program on uranium exploring and production in Russia developed by the Department of the Interior the question about supporting the program of atomic power engineering development in Russia with uranium is closed [9].

Thus, the Russian Federation disposes of uranium reserves in sufficient amount for supporting proper NPP as well as those constructed and serviced by Russia abroad. Economic situation and prices of the world market caused the necessity of multiple increase of new deposits development and creation of processing powers for rising volume of natural uranium not for military programs but for civil use.

Uranium production and use in countries of CIS

Uranium production in countries of CIS is based on the capacities of former Ministry of medium machine building in the USSR. In those republics where deposits with significant uranium content are explored and prepared for engineering the production is successfully carried on.

In Kirgizia and Tajikistan in the middle of 80-s all deposits were exhausted or production was stopped because of evident unprofitability. Hypothetically up to 2010 the production is not resumed here.

In Ukraine the Eastern ore-dressing and processing enterprise which mines 3 deposits by the shaft technique is functioning, ores are poor with uranium content 0,1 % and less. Uranium production amounted to 600 tons in 2000 and constant decrease of production is observed. Uranium cost conforms to the average 2[d] group – 52...78 $ per 1 kg. By 2010 total cease of proper uranium production is possible [3].

Uzbekistan possesses significant uranium deposits. Total resources are estimated at 185 thousand tons, 117,3 thousand tons of which are suitable for underground leaching. Besides, there are about 240 thousand tons of unexplored resources. The whole produced uranium is exported. In 2000 production volume amounted to 2200 tons by low cost – 34 $ per 1 kg. In 2010 uranium production does not exceed 2300 tons [10].

After withdrawal from the USSR uranium production in Kazakhstan was developed best of all. In 80-s the republic produced 4,5...5,0 thousand tons of natural uranium per year. Uranium resources approximately amount to 900 thousand tons, the 600 thousand tons of which is suitable for production by the technique of underground leaching by the low price category – lower than 34 $ per 1 kg. In the first half year of 2006 2 thousand 336, 7 tons of uranium was produced in Kazakhstan; production increased in comparison with the same period of 2005 amounted to 11, 7 % [11].

By 2010 Kazakhstan intends to control 30 % of uranium world market. However, there are fears in Kazakhstan to have strong opponents as nuclear powers represent leading players on the market and they do not need additional key player [10].

In May 2006 «Kazatomprom» increased predictions at uranium production in 2010 by 17 % (up to 17,5 thousand tons). By this time Kazakhstan intends to become the major uranium producer in the world [11].

Natural uranium production in the countries of the world and the perspectives of its expansion

Uranium world resources are estimated in the report «Uranium 2005: Resources, production and needs» [12] prepared by IAEA and the Organization of Economic Co-operation and Development. It is reported in it that the total volume of the found uranium resources amounts to ~4,7 million tons. Expenses for its production do not exceed 130 $ per 1 kg. These resources are enough for 85 years of world NPP operation (hypothetically the total world reserve is higher and amounts to ~35 million tons). From 2001 the increase of expenses for uranium production is noticed in the world: in 2004 they amounted to 130 bn $ that is higher than in 2002.

World uranium consumption for supporting NPP functioning constantly increases and approximately amounts to 67 thousand tons by 01.01.2003. And at the same time, uranium production remains almost at the level of 32...35 thousand tons due to its production from the depths. Uranium production deficiency during 10...15 years is mainly compensated owing to stock resources and export from the countries of CIS and first of all from Russia [7].

By the data of the USA Department of Energy there are uranium deposits in 43 countries of the world. The largest resources are in Australia (about 27 % of the world resources and there is no NPP in Australia), Kazakhstan (17 %), Canada (15 %), South Africa (11 %), Namibia (8 %), Brazil (7 %), Russia (5 %), the USA and Uzbekistan (4 % each) [12].

According to the data of the World Nuclear Association the maximum quantity of uranium in 2004 was produced by Canada (29 % of the worldwide production), Australia (21 %), Kazakhstan, Niger, Russia, Namibia, Uzbekistan, the USA, Ukraine and South Africa.

Canada is the main uranium producer in the world for many years. Canada possesses the unique deposits of the type «unconformities» distinguishing by high grade and compact ores with uranium content 18...23 %; the price for 1 ton of such ore achieves 3 thousand dollars. Annular volumes may achieve 16100 tons of uranium of low cost category (about 34 dollar per 1 kg) up to 2010 [2]. Canada exports 80 % of uranium (the buyers are the USA, France, Japan) [13].

In 70–80-s of XX c. the USA were the major uranium producer being worse only to USSR. Uranium production amounted to 9...10 thousand tons. At the beginning of 90-s many projects were wound up, many deposits were exhausted and uranium production decreased to 770 tons in 1993. Annular volumes of uranium production in the USA may achieve 2000 tons at the average 1[st] cost category (34...52 dollars per 1 kg) up to 2010 [3].

Australia takes one of the leading places in the world in uranium resources. In recent years Australia produces about 8 thousand tons of uranium and takes the second place in the world [2]. Uranium is exported to the USA, Japan, South Korea and other countries [13].

The largest uranium resources in Africa are concentrated in Niger, Namibia and South Africa. In Niger about 2000 thousand tons of uranium was produced in 1999. Ores with average uranium content are developed in a pit-run mode and somewhere by underground leaching, average cost of uranium concentrates is 32...50 dollars per 1 kg. In Namibia uranium is produced in the pit-run mode in the volume of 2500 tons per year, this level is possible to be retained till 2010. Production cost of 1kg of uranium is of the average 1st category. In South Africa uranium is simultaneously produced at gold deposits. In 80-s obtaining 700 tons of gold up to 6, 0 thousand tons of uranium per year was produced. Cost of 1 kg of uranium from the mines with the depth up to 3 km is average of the 1st category (34...52 US dollars). In 2000 uranium production was decreased to 1 thousand tons due to considerable reduction of the price for gold. It is supposed to produce 1000 tons at low cost group and 5500 tons at average 1st cost group at the African continent in 2010 [3].

Countries realizing insignificant uranium programs: Argentina, Brazil, Czech Republic, France, India, Romania and Spain, will produce 250...300 tons of uranium in 2010.

China where uranium production volumes are 400...600 tons but nuclear power engineering is intensively developed is detached in this row. In the near future China becomes active importer of natural uranium. Cost category of Chinese uranium is the average of the 1st group. Chine produces uranium practically for home consumption [13]. The expected uranium production in the mentioned countries is 600 tons at average 1st cost group and 300 tons at the 2d group [3].

Uranium resources in India are estimated at 78000 tons. The powers in uranium production which the country possesses now are not reported [14].

Over the last three years costs for uranium have increased almost four times. At the same time countries of the world start thinking about nuclear power engineering more favourably. The policy change is promoted by the increased costs for coal, natural gas and oil as well as the necessity to decrease the release of greenhouse gases which are charged with climate global warming [7]. As of the 1st of September, 2006 spot (for the produced uranium) market price for uranium increased to the mark 52 dollars (114 dollars per 1 kg) per a pound of uranium oxide U_3O_8.

By 2010 about 38300 tons of natural uranium will be produced in the whole world. Subject to the fact that new projects and increase of production volumes require time the uranium production may compensate not more than 60 % of the world need till 2010. Up to 2010 stock resources should be decreased by 210 thousand tons (the whole program HEU – LEU can give maximally 70 thousand tons during this period) [3].

Considerable reserves of ^{235}U are in «residue» – in depleted uranium being enriched with ^{235}U but owing to the defect of the used technique ^{235}U remained in the depleted uranium to 0,4 %. At uranium enrichment plants at the present time in the world there are about 1,5 million tons of depleted uranium [16]. Russia possesses the technologies allowing working in decreasing uranium-235 till 0,1 % [17].

Hydrometallurgical and refining preparation of uranium concentrates for conversion into UHF at Siberian Group of Chemical Enterprises

The peculiarity of refining uranium solutions obtained from natural uranium concentrate is their sharp difference form the solutions obtained at radiochemical processing of irradiated standard uranium slugs in composition and impurity concentration [18]. Except natural uranium concentrates proper including impurity elements of ore body secondary and technological uranium concentrates are also proposed for processing. Quantity and kind of impurities in such concentrates are determined by the type of production where these concentrates (may be in the form of wastes) were obtained or prepared for special purposes and contain alloy additions of various types and concentrations. Uranium and impurities content in chemical concentrate of natural uranium is normalized by international standard ASTM C967-02 which is followed by the producers. When processing technological concentrates there may be any impurities content.

The developed technique should be universal and include the processing regimes for any concentrates.

Laboratory experiments and checking up in production quantity at real uranium concentrates showed that dissolution (leaching) of uranium in nitric acid occurs rather satisfactorily with the formation of significant quantity of nonsettling, aggregatively stable fine suspensions. Further refining work is not possible without their separation. Experiments allowed planning further research issues from which the sequence of technological operations is made up: uranium leaching from uranium concentrates of natural isotopic composition with nitric acid solutions; purification of uranium nitrate solution (NS) from insoluble impurities; extraction purification of NS from soluble impurities; localization of solid radioactive waste (insoluble residues); localization of liquid radioactive solutions.

Searching for problem solution on each issue stipulate the cycle of investigations which should support optimal technology and process instrument execution.

So, by the present time, the dissolution technique of uranium concentrates in the form of powders, metal ingots, cuttings etc. obtaining NS with maximal uranium concentration supporting minimization of obtaining liquid radioactive solutions. By the results of investigations the sites of solution of powdery and compact uranium concentrates are created.

To purify NS from suspended solids the automatic centrifuges of settling type with separation factor from 2500 to 3200 were purchased. Trail starts of centrifuges showed that purification is not rather efficient, the increased amount of solid particles pass to postfiltration. The solution of the problem is coagulant application. The carried out investigations in wide range of coagulants and flocculants coming in the market allowed choosing the optimal reagent, industrial approbation is planned.

The technology of NS purification from soluble impurity elements was developed. Full-scale experiments were carried out at functional equipment of radiochemical and sublimate plants. The results confirmed that the designed technology allows obtaining nuclear-pure NS. The solutions correspond by quality to the International standards requirements for uranium hexafluoride preparation for separation NS isotopes ASTM C 787-03 and for preparation of ceramic fuel ASTM C 788-02. On the basis of carried out investigations the design of a site of extraction purification of NS with the change of pulsation columns for centrifugal extractor is finished.

Laboratory experiments on insoluble residues cementation were carried out, the satisfactory results were obtained. The method is known but for each enterprise it is necessary to certify the compaction technologies and the compacts themselves, including insoluble residues.

The technology of localization of liquid radioactive solutions is under development with the involvement of leading research institute of RAS IPC, Moscow. Problem solution will be probably traditional for the functional technology of radiochemical plant SGCHE.

Conclusion

The situation at the market of natural uranium and profitable geographic position of SGCHE including the perspective of capacity release at shutdown of reactors, turning out plutonium, open the possibility of involvement of uranium from new deposits in the east of the country to the enterprise.

The technology of purification of uranium concentrates with natural isotopic composition developed at SGCHE is universal and allows obtaining solutions of nitrate uranium salts corresponding by quality to the requirements of International standards for preparing uranium hexafluoride for separation of isotopes ASTM C 787-03 and for preparing of ceramic fuel ASTM C 788-02.

REFERENCES

1. TENEX ensures production. Electronic access mode: www.PRoAtom.ru. – Heading from the screen. – 11.07.2006.
2. Kotenko E. Fuel of the third millennium // Metally Evrasii. – 2001. – № 6. – P. 3–4.
3. Anderhill D.H. Analysis of world uranium supply up to 2050 // Uranium at the turn of the century: natural resources, production, consumption: Works of International symposium on uranium geology, Moscow, November 29 – December 1 2000 – Moscow: VIMS, MPR Press, 2002. – 317 p.
4. Russia does not intend to extend the Agreement HEU – LEU for the period after 2013. Russian nuclear site. Electronic access mode: www.Nuclear.Ru. – 24.07.2006
5. Dereshov V.A. Russia needs uranium // Zabaikalskiy Rabochiy. – 2005. – № 220 (23987) – P. 3.
6. «Trade Tech»: Spot price for uranium reached a record mark at 52 $ per pound U_3O_8. Russian nuclear site. Electronic access mode: www.Nuclear.Ru. – 06.09.2006.
7. Vorobyev E.A., Mashkoviets G.A., Naumov S.S., Ten V.V. Concept of uranium exploration work development in the territory of the RF for the period of 2000-2010 // Radioactivity and radioactive elements in human environment: Materials of the II International Conference. – Tomsk, 2004. – P. 125–129.
8. Zhivolov V.L., Servetnik V.A., Golovinskiy S.A. Supply of atomic branch consumers with raw materials // Actual problems of uranium industry: Theses of the report at the IV International theoretical and practical conference. – Alma Ata, 2006. – P. 5.
9. Agreement with Kazakhstan – step to reconstruction of technological complex of Sredmash. Russian nuclear site. Electronic access mode: www.Nuclear.Ru. – 26.07.2006.
10. Uranium is our everything. Site of Federal Agency on atomic power engineering. Electronic access mode: www.minatom.ru. – 23.05.2006.
11. Japanese companies call D. Koidzumi to consolidate their rights for uranium production in Kazakhstan. Russian nuclear site. Electronic access mode: www.Nuclear.Ru. – Digest (august 11–24 2006).
12. Uranium is enough for everybody. Electronic access mode: www.washprofile.org. -28.07.2006.
13. Tarkhanov A.V., Shatalov V.V. Uranium – 2005 (resources, production, needs) // Minerals. Economic-geological series. – Moscow: VIMS Press, 2006. – № 20. – 58 p.
14. India plans to increase twice its uranium potential. Russian nuclear site. Electronic access mode: www.Nuclear.Ru. Digest (July 26–31 2006).
15. Australian uranium: CPP after IPO? Russian nuclear site. Electronic access mode: www.Nuclear.Ru. – 31.05.2006.
16. Russian specialists work on technological solution of tail problem. Russian nuclear site. Electronic access mode: www.Nuclear.Ru. – 31.07.2006.
17. Lebedev V.M., Davydenko N.N., Arkhangelskaya A.I. Closed fuel cycle of Russia NPP. Problems and perspectives // Nuclear power engineering. – Obninsk. – 1999. – № 2. – P. 96–102.
18. Solonin M.I. State and development perspectives of nuclear fuel cycle (NFC) of the world and Russian nuclear power engineering // Fuel cycle of nuclear power engineering in Russia. Scientific problems and perspectives: Report of scientific and technical seminar. – Agoy, Krasnodar Territory, May 11–12, 2004. – Moscow: FUE VNIINM, 2006. – P. 38–57.
19. Shidlovskiy V.V., Lazarchuk V.V., Shamin V.I. et al. Use of extraction technology of radiochemical plant for supporting production of natural uranium hexafluoride according to the requirements of ASTM C 787-03 at Sublimate plant // Nuclear power engineering and fuel cycles: Works of International scientific and technical conference of AEHS-1.- Moscow-Dmitrovgrad. – Moscow, 2003. – P. 84–87.

Received on 07.12.2006