Up front in the CIS

A snapshot of the supply side of CIS front-end fuel cycle capabilities as it exists today.

by CAROLE A GREY

Prior to the break-up of the former Soviet Union, all uranium mined in Kazakhstan, Russia, Ukraine and Uzbekistan was sent to one of two conversion plants, and then to one of four enrichment plants, all of which are located in Russia. Now, of course, the republics are not bound to send their uranium only to Russia, but can also sell it on the world market. However, CIS reactors continue to be supplied with conversion and enrichment services, and fuel assemblies solely by Russia. Although Kazakhstan has a sizeable facility to reconvert enriched UF_6 and pelletise UO_2, the manufacture of the final fuel assembly product is done in Russia.

Currently, most industries within the CIS are in a state of turmoil as attempts are made to cope with hyper-inflation and massive debt. Specifically, the conditions under which the uranium mines, mills, conversion plants, enrichment plants and fuel fabrication plants operate are extremely difficult as they all suffer from severe payment delays and are trapped in a labyrinth of debt. Suppliers on every level, from the electricity distributor down to the uranium miner, are not being paid by their consumers.

Given the current economic climate, the aim of this article is not to forecast CIS front-end fuel cycle production capacities, which would be a difficult task under the circumstances, but to provide a snapshot of the supply side of the front end as it exists today. It must be noted that in Russia, different enterprises operate each nuclear facility and are under the control of the Russian Federation Ministry of Atomic Energy (Minatom).

However, only one company, Techsnabexport (Tenex), markets the products. Thus, for simplicity, the Russian supplier of natural uranium, conversion, enrichment and fabricated fuel will be referred to here as Tenex. Similarly, Kazakhstan has a variety of enterprises operating mines and a fuel pelletising plant, but the Kazakh State Atomic Power Engineering and Industry Corporation (Katep) is the parent company and sole Kazakh marketer.

In 1993, uranium was extracted in four CIS republics, Kazakhstan, Russia, Ukraine and Uzbekistan; but was processed in six, Kazakhstan, Kyrghystan, Russia, Tadjikistan, Ukraine and Uzbekistan.

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MINING AND MILLING

The map below shows the location of the various uranium mines and mills in the CIS, while the table opposite lists the operators, mining and milling methods used, production capacities, and actual uranium production since 1991.

Uranium production from the CIS as a whole has been steadily decreasing since 1988, as can be seen in the graph below. However, the production in individual republics has been declining at different rates, primarily due to increasing costs of production, as each republic moves to a free market economy, and also to restricted market access imposed by the US anti-dumping suspension agreements and the Euratom Supply Agency's restrictive import policy. The piechart below shows that Kazakhstan, Russia and Uzbekistan have continued to be significant world producers of uranium, with each republic holding close to 8% of world production, or less than 3000 tU each. To put this in perspective, the largest uranium producing country in the world, Canada, accounted for 26% of world production in 1993, followed by Niger, with just over 8%.

Kaskor, a Kazakhstan uranium producer and subsidiary of Katep, announced in early 1994 the suspension of uranium production at one of its mills, namely Aktau[1]. The mill had been producing uranium since 1964 as a co-product of phosphate fertiliser and rare earths taken from deposits of phosphatised fish skeletons. Aktau's production had been steadily declining from its capacity of 1000 tU[1]. In Kyrghystan, slurries from Kazakhstan are processed at the mill at Kara

CIS uranium mines and mills

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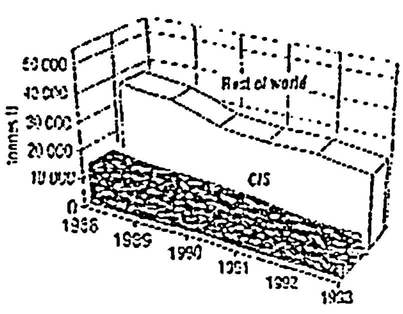
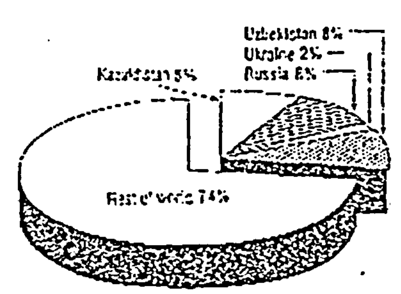
▲ Key to map: • Ore processing centre. 1 Kaskor Mining's mines. 2 Tselinny Mining's mines. 3 Stepnoye Mining's mines. 4 Central Mining's mines. 5 Ore Company No 6 mines. 6 Priargunsky mine. 7 Vatutinskii mine. 8 Uchkuduk mine. 9 Zarafshan mine. 10 Vostok mine. 11 Zafarabad mine. 12 Nurabad mine.

CIS & Western World uranium output



World uranium production 1993



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CIS uranium production from 1991 to 1993

Country	Mine	Mill	Operator	Mining method	Milling method	Production 1991 (tU)	Production 1992 (tU)	Production 1993 (tU)	Mill capacity 1993 (tU)
Kazakhstan	Grachevskoye + Vostok	Stepnogorsk	Tselinny MCC	UG	A/IX	Combined	Combined		Combined
	Kamyshevoye + Shokpak	Stepnogorsk	Tselinny MCC	UG	A/IX	total	total		total
	Zvezdnoye	Stepnogorsk	Tselinny MCC	UG	A/IX	of	of		of
	Zaozernoye	Stepnogorsk	Tselinny MCC	UG	A/IX	1200	800		3000
	Melovoye + Tomak	Aktau	Koshkar MCC	OP/BP	P_2O_5	800	400		1000
	Kanzhugan + Moynkum	Kara Balta	Central MC	ISL	ISL/IX	600	500		
	Uvanas + Mynkuduk	Kara Balta	Stepnoye MC	ISL	ISL/IX	800	600		
	North Karamurun	Chkalovsk	Ore Company #6 (Chiili)	ISL	ISL/IX	400	400		
Total						3800	2700	2700*	4000
Kyrghystan	No mines		Kara Balta	Kara Balta MCC		ISL/IX	1200	1100	1100	2000
Russia	Krasnokamensk	Krasnokamensk	Priargunsky MCC	UG/HL	K/P/IX	3300	2640	2400	4000
Tadjikistan	No mines	Chkalovsk	Vostokredmet MMC		ISL/IX	1350	1200	0	0
Ukraine	Vatutinskii	Zholtye Vody	Eastern MCW	UG	A/SX	800	600	500	2000
	Ingulskii	Dnieprodzerzhinsk	Dniepr Basin CW	UG	A/SX	0	0	0	0
Total						800	600	500*	2000
Uzbekistan	Uchkuduk	Navoi	Navoi MMC	OP	A/IX	560	520		Combined
	Uchkuduk	Navoi	Navoi MMC	ISL	ISL/A/IX	400	380		total
	Nurabad	Navoi	Navoi MMC	ISL	ISL	850	760		of
	Zarafshan/Vostok	Navoi	Navoi MMC	UG	A/SX	290	190		4000
	Zafarabad	Chkalovsk	Navoi MMC	ISL	ISL	830	830		
Total						2930	2680	2600	4000
GRAND TOTAL**								8200	11000

*Uranium mined in Russia in 1993 was 2691t. The 1993 Russian production figure is for milled material. *UI estimate*
*** Excludes Kyrghystan & Tadjikistan mill production as it is mined in other countries*
Mining: UG, underground; OP, open pit; BP, bi-product; ISL, in situ leach; HL, heap leach

Balta (outside the capital city of Bishkek), as Kyrghystan has no operating uranium mines. This processing will stop soon, however, as Katep has stated it plans to reduce the amount of material milled at Kara Balta to zero over the next three years. The closure of the Kara Balta mill should not affect the amount of uranium produced by Kazakhstan, as it has sufficient ore processing capacity of its own. The large Priargunsky complex in Russia processes uranium ore extracted from surrounding underground mines and heap leaching operations, and also from a nearby Mongolian mine. Production has decreased in recent years from Russia, as all of the underground mines were closed. Tadjikistan also processed ore from both Kazakhstan and Uzbekistan, but stopped in 1993 as the mill was converted to a lead/zinc concentrator earlier that year. Production in Ukraine has decreased substantially since one of two underground mines was shut in 1991. Uzbekistan, like Kazakhstan and Russia, has, in the past few years, been increasing the proportion of uranium mined using the *in situ* leaching technology. However, the net result has been a gradual reduction in the total quantity of uranium produced. In 1993, the Uzbekistan government announced that, as reserves were almost depleted, the country's open pit and underground mines would close soon.

EL CYCLE

Conversion

The conversion of U_3O_8 to UF_6 for the four Russian enrichment plants currently takes place at the Angarsk conversion facility, 30 km northwest of Irkutsk in Russia (see map below). The majority of the plant's production ultimately goes to Eastern European and CIS reactors, as fuel. The safe and sustainable operating levels, over an extended period, typically fall between 80% and 90% of nameplate capacity. The table on page 18 estimates the effective capacity of Angarsk at 18 700 tU (ie 85% of the plant's nameplate capacity of 22 000 tU). Actual production in 1993 is estimated to have been 10 800 tU. By way of comparison, the 1993 reactor requirements for Eastern Europe and CIS were almost 4000 tU less than was converted at Angarsk, or approximately 7000 tU.

A second conversion facility exists in Siberia, namely Tomsk-7. This plant, however, ceased to convert natural uranium in 1991 because there was more than enough conversion capacity to meet demand at Angarsk. At that time, the plant was dedicated to the re-conversion (and also re-enrichment) of reprocessed uranium, and continues with this practice today. While it is theoretically possible for Tomsk-7 to be used for extra conversion capacity if ultimately needed, this is unlikely as the plant

CIS fuel cycle facilities

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CIS fuel cycle facilities

Country	Site	Location	Operator	Technology	Product	Nominal capacity 1993	Actual production 1993
CONVERSION							
Russia	Angarsk	30 km NW Irkutsk	Electrolysing Chemical Combine	UF_4 fluorination	Natural U_3O_8 to UF_6	18700 tU	105[illegible]
	Tomsk-7	Tomsk	Siberian Chemical Combine	UO_2 fluorination	RepU to UF_6	na	na
ENRICHMENT							
Russia	Ekaterinburg	Near Ekaterinburg	Electrochemistry Combine	Gas centrifuge	LEU & previously HEU	7 MSWU	A
	Tomsk-7	Tomsk	Siberian Chemical Combine	Gas centrifuge	Enriched RepU & previously HEU from RepU	4 MSWU	combined total
	Krasnoyarsk-45	90 km E Krasnoyarsk	Electrochemistry Plant	Gas centrifuge	LEU	2 MSWU	of
	Angarsk	30 km NW Irkutsk	Electrolysing Chemical Combine	Gas centrifuge	LEU	1 MSWU	6 MSW[illegible]
RE-CONVERSION							
Kazakhstan	Ust Kamenogorsk	East Kazakhstan	Ulbinski	ADU*	Natural & RepU UF_6 to UO_2	1256 tU	624 t
Russia	Elektrostal	54 km from Moscow	Minatom	Dry-flame spraying	UF_6 to UO_2 powder for VVER-440 fuel	700 tU	230 t
PELLETISING							
Kazakhstan	Ust Kamenogorsk	East Kazakhstan	Ulbinski	Conventional	VVER-440 RepU to RBMK-1000 pellets	A combined	A total
				Conventional	VVER-440 RepU to RBMK-1500 pellets	total of	of 570 t
				Conventional	VVER-1000 pellets	2650 tU	220 t
Russia	Elektrostal	54 km from Moscow	Minatom	Conventional	VVER-440 pellets	700 tU	230 t
FUEL FABRICATION							
Russia	Elektrostal	54 km from Moscow	Minatom	Conventional	RBMK-1000 fuel elements & assemblies	A total	A total
				Conventional	RBMK-1500 fuel elements & assemblies	of 570 tU	of 570 t
				Conventional	VVER-440 fuel elements & assemblies	700 tU	230 t
	Novosibirsk	Siberia	Minatom	Conventional	VVER-1000 fuel elements & assemblies	1000 tU	210 t
ZIRCONIUM PRODUCTION							
Russia	Glazov	Udmurtia	Minatom	Conventional	RBMK zirco-alloy tubing	6000 km	200[illegible]
				Conventional	VVER zirco-alloy tubing	2000 km	na

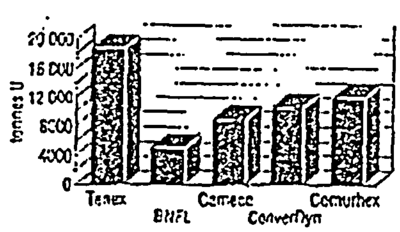
*Conventional, ammonium diuranate

has been contaminated with U-232 and U-234 from the reprocessed uranium.

In 1993, worldwide effective conversion supply capacity (calculated at 85% of nameplate capacity) was 55 300 tU and the worldwide demand was 52 000 tU. About 90% of this demand was met by existing contracts with the five primary suppliers: ConverDyn of the USA; Cameco of Canada; Comurhex of France; BNFL of Britain; and Tenex of Russia[2]. A further 4% of the requirements was met by supply from LEU, and 6% from spot purchases which reflect inventory drawdowns. The histogram (right) compares the effective conversion capacities of the five primary suppliers; it shows Russia having the largest capacity in the world at 34% of the total.

Russia is very likely to retain its current market share in Eastern Europe and the CIS, due to its available surplus production capacity, surplus LEU and, potentially, HEU. However, it is questionable whether much Russian conversion will be sold to Western markets in any other form except as a component of LEU. The main reasons are that the conversion facilities in Russia are integrated with enrichment facilities – an arrangement which is not practical for toll conversion – the fact that the transport of concentrates for toll conversion over long distances from West to East would be costly, and the risks due to the unstable political environment.

Primary suppliers' effective conversion capacities 1993



As mentioned, additional sources of conversion supply in the CIS are LEU and HEU. LEU from the former Soviet Union has been coming into Western markets since 1973, with initial shipments being made to West European utilities. The USA began importing Soviet LEU in the late 1980s and Asian utilities purchased small quantities in 1990 and 1991. However, continued entry into Western markets has been restricted, in the USA by the Department of Commerce pursuant to anti-dumping suspension agreements, and in Europe, by the Euratom Supply Agency restricting imports to 20% from any one supplier. The Russian HEU stockpile represents potentially the largest source of secondary conversion supply, at the equivalent of 150 000 tU or 92 000 tSWU.

Enrichment

All four gas centrifuge enrichment pl[illegible] the CIS (Ekaterinburg, Tomsk, Krasn[illegible] and Angarsk) are located in Russia ([illegible] map on page 17). The oldest and lar[illegible] Ekaterinburg, formerly Sverdlosk-44, [illegible]ed near the city of Ekaterinburg. It [illegible]menced operation in 1949 using ga[illegible] diffusion enrichment technology. T[illegible] newest and smallest plant is An[illegible]. Between 1966 and 1992, the gaseous [illegible]sion technology previously employed [illegible] of the enrichment plants was comp[illegible] replaced with the more efficient centr[illegible] technology. In 1993, Minatom intimate[illegible] the total Russian enrichment capacit[illegible] about 14 million SWU per year an[illegible] Ekaterinburg was the largest of th[illegible] plants. Minatom also stated that the se[illegible]tion capacities of the plants, as a perce[illegible] of the total, were as follows: 4[illegible] Ekaterinburg, 29% at Krasnoyarsk, 1[illegible] Tomsk and 8% at Angarsk[3]. Based o[illegible] distribution, the capacities are estim[illegible] the table. Currently, Ekaterinburg i[illegible] primarily for providing enrichment s[illegible] for export, whereas the Tomsk-7 pl[illegible] dedicated to re-enriching reprocesse[illegible]nium as noted above. Both these [illegible] were HEU production facilities, bu[illegible] Tomsk-7 used reprocessed uranium t[illegible]duce the HEU. As is the case with th[illegible]

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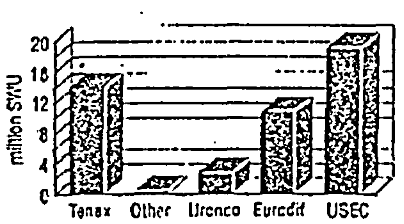
grated conversion plant at Tomsk-7, the enrichment plant has also been contaminated with U-232 and U-234 from the reprocessed uranium.

In 1993, worldwide enrichment supply capacity was 47 million SWU, compared with demand of only 32 million SWU. There were four primary suppliers of enrichment services: US Enrichment Corporation with production in the USA; Eurodif with production in France; Urenco with production in Britain, the Netherlands and Germany; and Tenex with production in Russia. These primary suppliers collectively supplied 96% of the demand. The 1993 Russian enrichment production, or commitment, as estimated by The Uranium Institute was about 6 million SWU, or 40% of their capacity. This estimation is based on the assumed Eastern European and CIS reactor demand of 4 million SWU, plus the export to the West of 2 million SWU (or 6% of the Western market), as stated by Mr Evgenij Mikerin of Minatom at the USCEA Enrichment Conference held in Washington DC in June 1993. Thus, the Russian enrichment production, as a proportion of worldwide demand, was almost 19% in 1993. The histogram below compares the worldwide enrichment supply capacities held by each of the four primary suppliers.

Fuel fabrication

After enrichment, the fabrication of VVER fuel involves the re-conversion of UF_6 to UO_2, pelletising, zirconium tube installation and fuel bundle assembly. The raw material for RBMK fuel is reprocessed uranium originating from spent VVER fuel separated at the Mayak plant in Chelyabinsk, which is also pelletised, installed in zirconium tubes and assembled in fuel bundles.

Primary suppliers' enrichment capacities 1993



The fabrication of fuel pellets is presently done at the Elektrostal plant in Russia and the Ust-Kamenogorsk plant in Kazakhstan. The next step – fuel element and fuel assembly fabrication for Eastern European and CIS reactors – takes place only at the two sites in Russia: Elektrostal and Novosibirsk. The Glazov plant in Udmurtia, Russia, produces zirconium and the zirconium-based alloy tubing for VVER and RBMK fuel elements.

Re-conversion for VVER-400 fuel is done at Elektrostal, which employs the flame spraying process, one of the gaseous or "dry" methods[4]. Consequently, the resultant UO_2 powder is not sufficiently free-flowing and so undergoes further treatment to produce a "press-powder", from which the VVER-440 pellets are pressed. The VVER-440 fuel pellets are then produced into fuel elements and fuel assemblies on site. Elektrostal also receives already-fabricated RBMK-1000 and RBMK-1500 fuel pellets from Ust-Kamenogorsk, with which it manufactures the fuel elements and assemblies. Fast reactor fuel and breeding blankets are all fabricated at Elektrostal.

The bulk of fuel pellet fabrication in the CIS is done at Ust-Kamenogorsk in North East Kazakhstan. As mentioned above, this plant produces RBMK-1000 and RBMK-1500 pellets from reprocessed VVER spent fuel and sends them to Elektrostal for final fabrication. It also produces VVER-1000 fuel pellets, but sends these to Novosibirsk for final fabrication. Ust-Kamenogorsk is an integral part of the fuel fabrication process, and unless the Elektrostal pelletising plant is expanded, it is likely to remain so. It also produces the rare metals tantalum and scandium, as well as having one of the largest beryllium refineries in the world.

The fuel fabrication capacity of the CIS is limited not by the capacity of the pelletising plants but by the capacities at Elektrostal and Novosibirsk, as these plants put the final assemblies together. As shown by the table on page 18, Elektrostal produced at 63% of its capacity, while Novosibirsk operated at only 21% of capacity. These production rates are likely to be reversed as the fuel requirements for RBMKs decrease (when they reach the end of their lifetimes), and requirements for the planned VVER-1000s increase (when they begin operation). In 1993, there were over 20 fuel fabrication plants around the world. The total LWR fuel fabrication capacity was about 11 000 tU and annual demand was 6000 tU. The piechart (right) shows Russia's share of the world's LWR fuel fabrication capacity at slightly less than 16% (not including any RBMK fuel fabrication capacity). However, in 1993, Russia supplied only 7% of the world's LWR fuel fabrication demand, with virtually all of its supply going to Eastern Europe and the CIS.

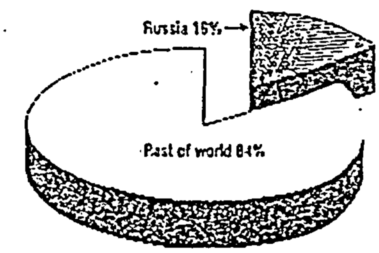
Since the world fuel fabrication industry is oversupplied, competition in the West as well as in the East is likely to become even more intense. Before the break-up of the Soviet Union, Russia was the sole supplier of fuel to domestic reactors and all foreign reactors of Soviet origin. Since the break-up, Western fabricators have begun moving into Eastern Europe, where they have seen a new market opportunity to supply the Soviet-designed reactors. For instance, in October 1992, Westinghouse edged out a competitive bid by the Russian fabricator and won a contract to design a new core and provide fuel for the Czech Republic's two 1000 MWe VVER reactors at Temelin. More recently, Westinghouse, Framatome and the Russian fabricator have been short-listed by the Czech and Slovak Republics to supply fuel for ten VVER-440 reactors, at Dukovany, [illegible] and Mochovce. Negotiations are [illegible] with the bidders before a decision [illegible] to which fabricator has won the [illegible] supply contract.

STILL A LEADING PLAYER

Since production data have [illegible] from the CIS, it can be seen that [illegible] production, like that from the West, has been steadily declining. Since the break-up of the former Soviet Union local costs of production have begun to reflect market [illegible] with the result that some uneconomic [illegible] have been closed, and attempts [illegible] Western markets on a large scale [illegible] triggered government limitations [illegible]. Nevertheless, three republics [illegible] CIS, namely Kazakhstan, Russia and [illegible], remain in the top five uranium [illegible] in the world, in terms of actual [illegible]. In the future, CIS uranium [illegible] likely to continue to play a very sign[illegible] in world supply.

Changes within the CIS and [illegible] the global fuel cycle market have not been limited to the uranium production in[illegible]. Until recently, Russia was the sole supp[illegible] fabricated fuel to all of the Eastern E[illegible] and CIS reactors; Western fuel fab[illegible] have reduced Russia's supplies to Eastern Europe, and could perhaps do the same [illegible]. As for conversion and enrichment [illegible] it is unlikely that the West would have [illegible] in either Eastern Europe of the CIS [illegible] displace Russia's dominance until [illegible] have been used. On the other hand, [illegible] has been supplying increasing [illegible] of converted or enriched uranium [illegible] and consequently government [illegible] been taken to restrict market access [illegible] natural uranium. Nevertheless, in [illegible] held about [illegible] of the world's conversion market and close to 19% of the world's [illegible] market.

Russian LWR fuel fabrication capacity 1993



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4 Y Ziojlashvii and F G Reshetnikov [illegible] nuclear fuel cycle: An industrial perspe[illegible] *Bulletin* March 1995.

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