The Achinsk nepheline based alumina plant was put into operation in 1970. It was the first full scale plant in the world to use this process, which gives cement, soda and potash as by products.

COMMODITY REPORT

The Soviet aluminium industry

By Theodore Shabad

The Soviet Union, usually regarded as virtually self-sufficient in most industrial raw materials, has a poor resource base for the production of aluminium, but possesses a large hydro-electric power potential needed for aluminium smelting. After some experimentation with domestic resources of nonbauxitic raw materials, Soviet economic planners have shown increasing preference for imports of high-grade bauxite and alumina. In 1980, as much as 50 per cent of Soviet aluminium production may have been derived from imported raw materials, and this level is expected to be maintained. In view of the world energy shortage, the Soviet hydro-electric potential might be utilized increasingly in the future, the world political situation permitting, to convert imported raw materials into aluminium for re-export to the rest of the world.

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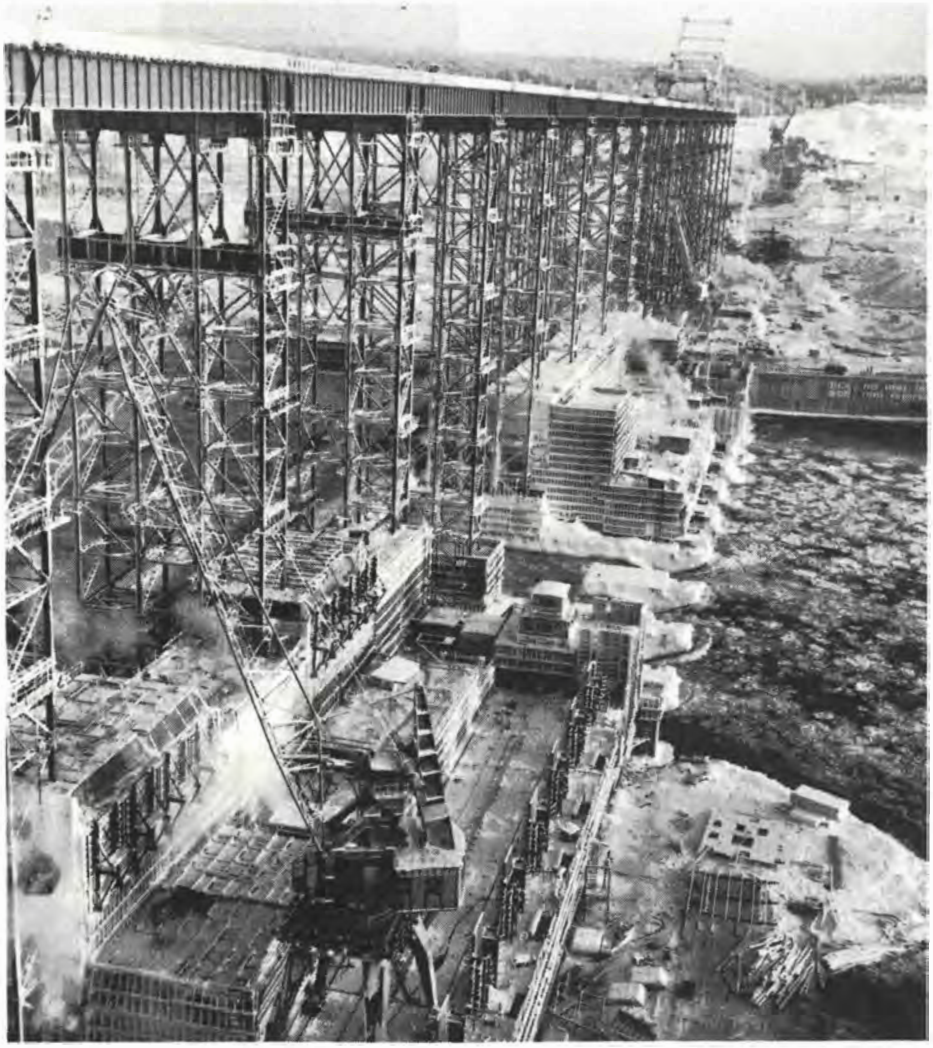
The Soviet Union, which is generally viewed as one of the major potential suppliers of mineral raw materials to the world economy[1], is poorly endowed with a resource base for the production of aluminium, one of the principal sectors of modern industrial economies. Despite years of geological prospecting, only limited resources of high-grade bauxite have been identified, and the domestic mineral base for aluminium remains limited to low-grade bauxite and nonbauxitic ores such as nepheline and alunite. At the same time the Soviet Union possesses and has been increasingly developing a large hydro-electric power potential that provides attractive sites for aluminium smelters because of the large electricity requirements of the conventional electrolytic process of aluminium reduction. In seeking to reconcile the poor raw material base, on the one hand, and the hydro-electric potential, on the other hand, Soviet aluminium planners opted in the late 1960s for increasing dependence on raw material imports and, on that basis, have developed the world's second largest aluminium industry, after the United States. In 1981, the primary aluminium production of the Soviet Union was 2.475 Mt (compared with 4.489 Mt in the United States)[2], and about 50 per cent of Soviet aluminium production was derived from imported raw materials. (Dependence on imported materials was 12 per cent in 1965, 38 per cent in 1970 and 45 per cent in 1975.[3])

The potential of Soviet hydro-electric power for aluminium smelting is not always considered in long term projections of the world aluminium industry. A projection of electricity supplies for aluminium smelting, published in 1980, found that the availability of hydro-electric power for that purpose would be limited over the long term and that most additional world aluminium capacity to be installed by the year 2000 would have to rely on higher-cost thermally generated power (coal-based and nuclear), thus causing a rise in the price of aluminium.[4] The study examined the potential of the industrial and less developed countries, but did not consider the possibility of locating more of the world's aluminium capacity in southern Siberia, one of the world's regions with a concentrated hydro-electric potential.

The dynamics of the Siberian aluminium industry

At the end of 1980, the Siberian electric power system had an installed hydro-electric generating capacity of 18 700 MW, mainly on the Yenisei River and its principal right tributary, the Angara. The Siberian hydro-electric capacity represented 36 per cent of the total hydro capacity of the Soviet Union. The Siberian system was also the only Soviet power system in which installed hydro capacity exceeded thermal power capacity. Two of the world's largest aluminium smelters, Bratsk and Krasnoyarsk, with capacities of 300 kt to 400 kt each, have been built next to major hydro-electric stations – Bratsk, with 4 500 MW generating capacity, and Krasnoyarsk, with 6 000 MW. A third aluminium plant is under construction at Sayanogorsk, near the hydro station with a designed capacity of 7 500 MW. The Sayanogorsk aluminium smelter is expected to raise Soviet production to more than 3 Mt by 1990, and Siberia would then account for some 60 per cent of the country's production of aluminium. Additional hydro-electric dams are planned, with work already under way at the site of the Boguchany dam (4 000 MW) on the Angara River, and surveys starting at the projected Middle Yenisei dam (7 500 MW) on the Yenisei, just below the mouth of the Angara. Plans for the construction of an aluminium smelter at the Boguchany hydro-electric station have been announced, and work may begin in the late 1980s.



Building of the third dam of the Angara cascade, which gives 4 300 MW, in 1972. The severe Siberian climate poses special problems.

The raw material base of the Soviet aluminium industry

Table 1 attempts to develop a raw material balance of the Soviet aluminium industry over the last two decades and to project it at least to the end of the current 11th Five-Year Plan period (1981–1985). The construction of such a balance is made difficult by the fact that the Soviet Union does not publish systematic statistics on the production of aluminium ores, alumina and aluminium. Like other nonferrous metals production, the output of aluminium is a government secret. In addition, official Soviet data on foreign trade in aluminium and its raw materials have been suppressed since the middle 1970s. Soviet statistics for exports of aluminium and imports of alumina were last published for 1975, and imports of bauxite were last reported for 1976. However, Western estimates are being made for aluminium production, and those published by the US Central Intelligence Agency appear to be most reliable.[5] They are being revised (most recently in 1980) in light of new information, and seem to conform best with scattered information found in Soviet sources.

The table shows that Soviet aluminium production began to rise particularly rapidly in the 1960s, with the startup of the new hydro-based Siberian aluminium plants: the Irkutsk plant at Shelekhov, which started up in 1962, the Krasnoyarsk plant in 1964, and the Bratsk plant in 1966. These plants contributed to a quadrupling of Soviet production, from 620 kt in 1960 to 2 460 kt in 1980. Since the middle 1970s, the rate of growth has slowed. It was 15 per cent/year during the 10th Five-Year Plan period (1976–1980), and the planned annual increase during the present plan period is 14.3 per cent.[6] The increase is to be achieved through completion of additional capacity at the Krasnoyarsk plant the startup of the Sayanogorsk plant, now scheduled for 1984 after long delays, and the completion of additional capacity in the Tadzhik plant at Tursunzade in Central Asia, which started up in 1975 and has reached half of its designed capacity of some 400 kt. The Tadzhik plant, with an associated prebaked anode manufacturing plant and large electrolytic reduction cells using a current of 160 to 175 kA, is the most modern in the Soviet Union.

Alumina

The requirements of alumina, the intermediate aluminium oxide Al_2O_3 which is derived from bauxite and is then reduced to the metal in aluminium smelters, can be calculated on the basis of two tons of alumina required for one ton of aluminium metal. Until 1966, the Soviet industry had kept domestic capacities for alumina and aluminium production in rough balance so that all the alumina requirements could be met from domestic production. However, the rapid surge of aluminium capacity in Siberia then outdistanced alumina production, and the practice of importing alumina began. Within a decade, by 1975 (the last year of official import statistics), the Soviet Union was obtaining as much as one million tons of alumina from abroad. Some 40 per cent of the alumina came from Hungary, which received an equivalent amount of aluminium in return, but alumina suppliers also included the United States, Jamaica, Guyana and other countries. Soviet alumina imports appear to have reached a peak around 1980, when a large alumina plant began operation at Nikolayev on the Black Sea. The Nikolayev plant, built in four stages of 250 kt alumina capacity each, was completed in August 1982,[7] and was scheduled to break in its full capacity of one million tons of alumina during the 11th Five-Year Plan, by 1985. With this additional domestic supply of alumina, imports are likely to decline again to some one million tons, or about 18 per cent of Soviet alumina requirements (Table 1).

Bauxite, nepheline and alunite

Soviet alumina plants derive their aluminium raw materials from two basic types of sources: high-grade bauxite, both im-

Table 1

Raw Material Balance of the Soviet Aluminium Industry (kt)

	1960	1965	1970	1975	1980	1985 (projected)
1. Primary aluminium production	620	970	1 490	2 130	2 460	2 800
2. Estimated alumina requirements (2a+2b)	1 240	1 940	2 980	4 260	4 920	5 600
2a. Imported alumina	–	–	518	1 029	1 300	1 000
2b. Domestic alumina production (3+4)	1 240	1 940	2 462	3 231	3 600	4 600
3. Domestic alumina from high-grade bauxite	992	1 436	1 379	1 700	1 800	2 800
a. Ore equivalent	2 480	3 590	3 448	4 300	4 600	7 000
b. Imported high-grade bauxite	429	605	1 548	3 477	3 500	5 000
c. Domestic high-grade bauxite	1 500	2 000	2 500	3 000	3 500	3 500
4. Domestic alumina from low-grade bauxite and nonbauxitic materials	148	504	1 083	1 500	1 750	1 850
Ore equivalent	600	2 200	4 700	7 300	7 800	8 300
4a. Domestic alumina from low-grade bauxite	100	150	630	650	650	650
Ore equivalent	400	600	2 500	2 600	2 600	2 600
4b. Domestic alumina from nepheline	50	350	400	900	1 000	1 100
Ore equivalent	200	1 600	1 800	4 000	4 500	5 000
4c. Domestic alumina from alunite	–	–	50	100	100	100
Ore equivalent	–	–	350	700	700	700
5. Domestic aluminium ore production (3c+4)	2 100	4 200	7 200	10 300	11 300	11 800
High-grade bauxite	1 500	2 000	2 500	3 000	3 500	3 500
Low-grade bauxite	400	600	2 500	2 600	2 600	2 600
Total domestic bauxite	1 900	2 600	5 000	5 600	6 100	6 100
Nepheline concentrate	200	1 600	1 800	4 000	4 500	5 000
Alunite	–	–	350	700	700	700

Explanations of Table 1.

1. From Central Intelligence Agency, *Handbook of Economic Statistics, 1982* (CPAS 82–10006), September 1982, p. 143.

2. Estimated on basis of two tons of alumina for one ton of aluminium.

2a. 1960–1975 from: *Vneshnyaya torgovlya SSSR* (Foreign Trade of USSR) statistical yearbook, various years; 1980 and 1985 estimated.

2b. By subtraction.

3. 1960–70 shares of high-grade bauxite in Soviet alumina from: N.S. Malts and M.I. Zaitsev, *Povysheniye effektivnosti polucheniya glinozema iz boksitov* (Increasing the Effectiveness of Obtaining Alumina From Bauxites). Moscow: Metallurgiya, 1978, p. 7 for 1980, the same source says 50 per cent of the alumina was obtained by the Bayer process, which is used for high-grade bauxite; other years estimated.

3a. Estimated on the basis of 2.5 t of high-grade bauxite to one ton of alumina.

3b. 1960–75 from *Vneshnyaya torgovlya SSSR*, op. cit.; 1980 and 1985 estimated.

3c. Domestic high-grade bauxite production, almost all from the northern Urals, estimated by author. In some years total bauxite supplies seem short of requirements, and in other years in excess of requirements. Part of the explanation may lie in the use of stockpiles or in the accumulation of stockpiles.

4. 1960–70 shares of low-grade bauxite and nonbauxitic materials in Soviet alumina production from Malts and Zaitsev (op. cit.), which also says that 50 per cent of the alumina in 1980 was obtained by processes other than the Bayer process; other years estimated.

4a. Estimated by author; ore equivalent of low-grade bauxite is calculated at 4 t of bauxite to one ton of alumina.

4b. Estimated by author; ore equivalent of nepheline is calculated at about 4.5 t of nepheline concentrate to one ton of alumina.

4c. Estimated by author; ore equivalent is calculated at 7 t of alunite ore to one ton of alumina.

5. By addition of previous data.

Storage of aluminium ingots at the Bratsk plant. Photo from 1976.

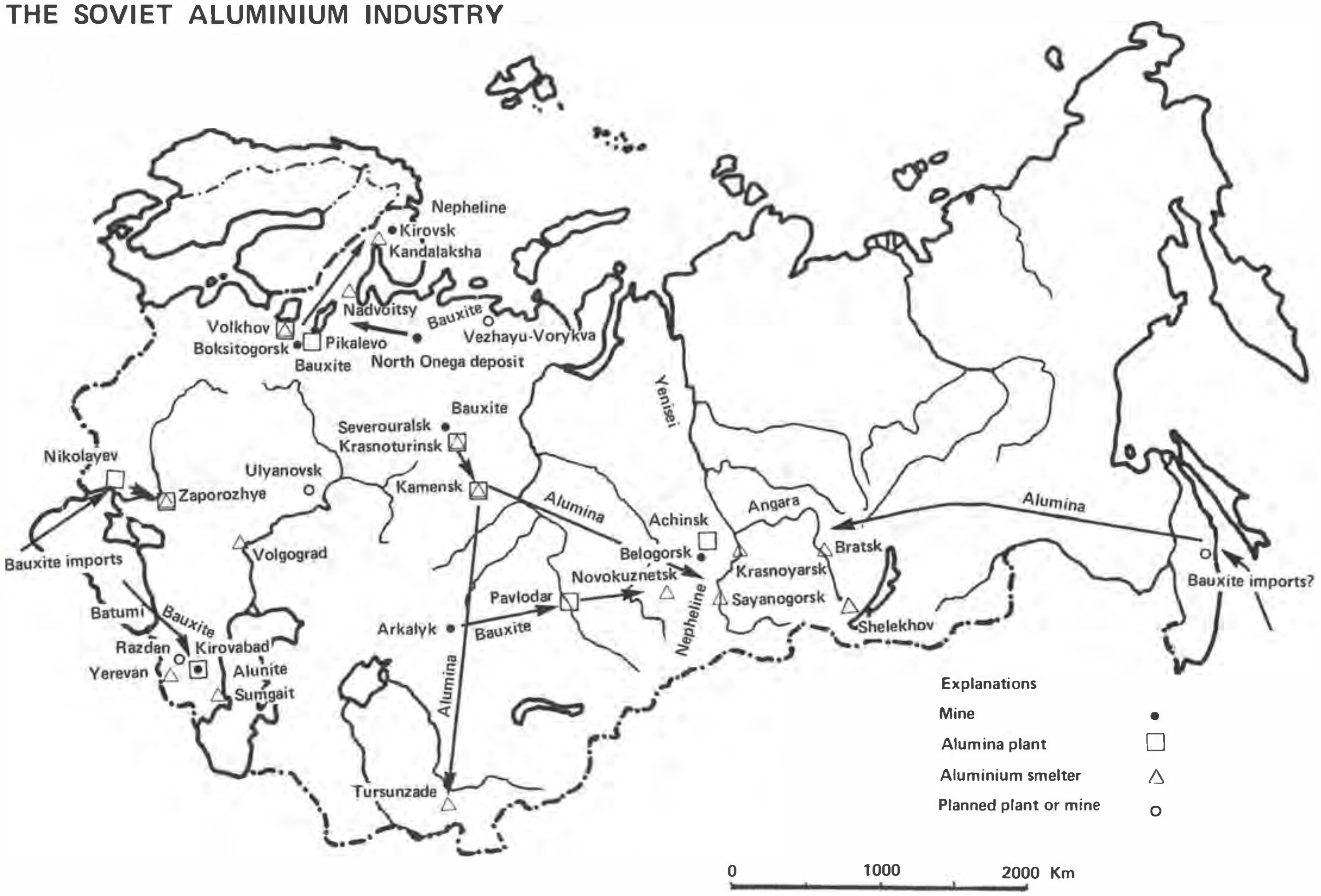
ported and domestic, and low-grade bauxite and nonbauxite ores (nepheline and alunite, all domestically mined). In the 1960s, when bauxite imports were still relatively small and the Soviet Union was still eager to develop its domestic raw material base, even if of low-grade, the ratio of high-grade bauxite to low-grade materials changed dramatically in Soviet alumina plants. In 1960, these plants used 80 per cent high-grade bauxite and 20 per cent low-grade materials; in 1970, the ratio was 56 per cent and 44 per cent respectively.[8] Accordingly, the use of the so-called Bayer process, common throughout the world for producing alumina from high-grade bauxite, also declined in the Soviet Union as it was forced to turn to more complex and costly techniques to process lower-grade domestic materials. The share of alumina produced by the Bayer process in the Soviet Union declined from 83 per cent in 1960, to 61 per cent in 1970 and only 50 per cent in 1980.[9] This trend is now being reversed during the first half of the 1980s because of the completion of the new Nikolayev plant, which uses the Bayer process for high-grade bauxite from Guinea and other foreign sources. By 1985, Bayer-process alumina may again be up to some 60 per cent, 2.8 Mt out of a projected 4.6 Mt. (Table1.)

Associated with this trend is a sharp increase in the use of imported bauxite. As the curtain of secrecy descended in 1976 on Soviet official statistics of bauxite imports, as much as 3.5 Mt a year was already being received, although much of these imports had to be stockpiled because of the absence of adequate alumina-production capacity. The biggest supplier of bauxite was Guinea, which was shipping some 2.5 Mt a year from a bauxite mine at Debele (near Kindia), developed with Soviet assistance. Other bauxite suppliers were Yugoslavia and Greece. But by 1985, according to the projection in Table 1, as much as 5 Mt of imported bauxite may be required. Preparations to receive such large amounts were started in the 1970s, when a huge bauxite terminal went into operation on the Black Sea next to the Nikolayev alumina plant. The first stage of the terminal can accommodate 3.8 Mt of bauxite a year; it is to be expanded to a capacity of 6 Mt,[10] which would be sufficient to handle the projected import needs by 1985. Imports accounted for some 60 per cent of Soviet use of high-grade bauxite in 1980 and were expected to rise further during the 1980s.

This trend was further confirmed in December 1982 by the announcement of a Soviet-Jamaican trade accord under which the Russians undertook to import one million tons of Jamaican bauxite a year over the seven-year period 1984-1990.

The Soviet Union has only one known bauxite deposit that is at all comparable in quality to the ores of the world's great bauxite suppliers such as Australia, Guinea, Jamaica, Brazil, Suriname and Guyana. However, unlike most world bauxite, which is mined in open pits, this Soviet deposit, in the northern Ural Mountains at Severouralsk, is mined mainly underground. Moreover, the deposit, which was originally developed in the mid-1930s, has largely depleted the near-surface reserves and, in the early 1970s, began excavating to depths of 1 200 meters. By the late 1970s, the production of the northern Urals bauxite district was estimated at 3.5 Mt,[11] and this level of output, is not expected to undergo any major change.

Before the opening of the new Nikolayev alumina plant of the Black Sea, the Soviet Union's high-grade bauxite (both domestic and imported) was converted into alumina at four locations: Krasnoturinsk and Kamensk in the Urals, Zaporozhye in the Ukraine, and Kirovabad in Azerbaijan. The two Urals alumina plants, using mainly northern Urals bauxite, but also some imported bauxite, yielded



roughly 1.5 Mt of alumina, of which one-third was converted into aluminium at the same two locations and two-thirds was shipped eastward to the Siberian aluminium plants.[12] The two Urals alumina-aluminium plants date from the World War II period and have been expanded repeatedly since then. Further expansion is planned at Krasnoturinsk during the current Five-Year Plan (1981–1985). The Zaporozhye alumina plant, also associated with local aluminium production, was rebuilt in 1956 from World War II destruction to handle imports of Greek bauxite, which were then beginning. The Zaporozhye alumina plant is estimated to have a capacity of 200 kt of alumina. The Kirovabad alumina plant using high-grade imported bauxite is of particular interest because it was opened in 1977 as an expansion of a previous alunite-based alumina plant (see below). After Soviet planners had become disillusioned by the performance of the alunite operation, they decided to expand alumina production at Kirovabad on the basis of imported bauxite. In 1980, the Kirovabad alumina plant yielded about 250 kt of alumina, divided about evenly between alunite-based and bauxite-based alumina. The section that processes imported bauxite is to be expanded, and an output goal of some 350 kt of alumina has been set for 1985.[13] Soviet intentions for Kirovabad development are suggested by the bauxite storage capacity associated with the new alumina plant; it is 2 Mt of bauxite, or the equivalent of some 800 kt of alumina. The bauxite for Kirovabad is being unloaded at the Black Sea port of Batumi, and Kirovabad alumina is used mainly in the new Central Asian aluminium plant of Tursunzade.[14]

The use of low-grade domestic ores

The low-grade domestic aluminium ores of the Soviet Union have originated in five mining areas:

- the old Boksitogorsk low-grade bauxite deposit, which has been exploited since before World War II and became exhausted in the 1970s;
- the Arkalyk low-grade bauxite deposit in northwest Kazakhstan, which began production in 1964 with a designed capacity of 3 Mt of bauxite;
- nepheline concentrate, which is a by-product of the mining of apatite, a phosphatic ore, in the Kola Peninsula;
- nepheline-syenite of southern Siberia;
- the alunite of Kirovabad. A sixth nonbauxite deposit, at Razdan in Soviet Armenia, also envisaging the use of nepheline–syenite, was abandoned in 1977 after 20 years of research and development.[15]

Each of these low-grade bauxite and nonbauxitic ore sources has been beset with problems, and it is these problems that account for continuing Soviet interest in the use of imported high-grade bauxite.

The Boksitogorsk alumina plant, following the depletion of the local ore base, was supposed to be converted to the use of another low-grade bauxite from the North Onega deposit, which was being developed near Plesetsk in the late 1960s and early 1970s. Although the North Onega deposit finally yielded its first bauxite from an open pit in 1977,[16] it turned out to be so difficult to process that it has not been further developed.[17] Although plans for the conversion of the Boksitogorsk alumina plant to the use of North Onega bauxite were announced for the 10th Five-Year Plan (1976–1980)[18] and again for the current, 11th plan period 1981–85)[19] the entire project remains in doubt.

The use of the low-grade bauxite of Arkalyk in northwest Kazakhstan, which now yields some 600 kt of alumina at the Pavlodar alumina plant, has also proved to be uneconomical and technologically difficult. It is the first time in the world that a modern aluminium industry tries to process such low-grade material, which elsewhere in the world would be characterized as lateritic clays rather than as bauxite. The use of Arkalyk bauxite required the development of a special technology, and it is only the byproduct recovery of valuable gallium (since 1978) and of vanadium (since 1980) that helps to improve the economics of the Pavlodar alumina operation. Despite the presence of cheap local power sources (from pit-mined subbituminous coal at Ekibastuz), no effort has been made to construct a projected aluminium plant at Pavlodar. In the meantime, the quality of the already low-grade bauxite at Arkalyk is declining further, and any additional bauxite deposits that might be developed in this region would be of even poorer quality. Still, the Pavlodar alumina plant yielded as much as 20 per cent of Soviet alumina (before the construction of the Nikolayev plant) and supplies a substantial portion of the needs of the Siberian aluminium plants, notably Novokuznetsk, Krasnoyarsk and Bratsk.

The nepheline controversy

The importance of nepheline concentrate as a source of alumina has long been a matter of controversy in the Soviet Union. After the development of the nepheline technology and its experimental use in the small alumina-aluminium plant of Volkhov, near Leningrad, a 300 kt alumina plant using the nepheline process was put in operation in 1959 at Pikalevo, near Boksitogorsk. The Pikalevo plant supplies alumina to a group of small aluminium plants in northwest European Russia, including Volkhov, Nadvoitsy (opened in 1954) and Kandalaksha (opened in 1951). Despite the large amount of raw material needed (at least 4 tons of nepheline concentrate to one ton of alumina), the process was thought to be economical because it yields large amounts of cement as well as soda ash and potash as byproducts. Plans were announced in 1967 for the expansion of capacity at Pikalevo and the construction of two additional nepheline-alumina plants in the Volga region, near Ulyanovsk and Volgograd.

However, these plans broke down in bureaucratic controversy. The Ministry of Nonferrous Metals, in charge of the aluminium industry, has shown a lack of interest in the nepheline route, partly because it does not wish to be concerned with the marketing of cement or chemical byproducts. Instead it has shown preference in the importation of high-grade bauxite. The Ministry of the Chemical Industry (since 1980, the Ministry of the Fertilizer Industry); by contrast, is charged with the operation of the apatite mines and wishes to find a market for the byproduct nepheline, but with no success. As a result, only about 1.6 Mt of Kola nepheline concentrate is now being used for alumina production, and about seven times that amount, or 11 Mt, goes unused into mill tailings.

The wave of interest in the nepheline process in the 1950s led to the design of a large nepheline-based Siberian plant to supply alumina to the Krasnoyarsk aluminum plant nearby. It took 18 years, including the abandonment of one mine and the development of another deposit, for the construction of the Achinsk plant and for its technology to be developed. Even after production finally started in 1970, the Achinsk plant did not perform efficiently, and after a decade of operation, in 1980, it was still producing at only 73 per cent of capacity, or 584 kt of the designed capacity of 800 kt.[20] Full production is now scheduled to be achieved in the current Five-Year Plan.[21] One problem has been that the Achinsk nepheline operation generates far too much byproduct material for cement production than can be used in the surrounding marketing region within an economical transport distance. In 1980, only 46 per cent of the potential cement output of 4.5 Mt was actually being used. The lag in alumina production at Achinsk has been partly responsible for the slow pace of capacity installation in the Krasnoyarsk aluminium plant. Although the first aluminium reduction section opened in 1964, the Krasnoyarsk plant is working at only 75 per cent of designed capacity, and is now scheduled to be completed during the current Five-Year Plan.

As indicated earlier, little has come of the use of alunite in the Kirovabad alumina plant of Azerbaijan, which was originally envisaged as supplying alumina to two small Transcaucasian aluminium plants, at Sumgait, also in Azerbaijan, and at Yerevan in Armenia. The alunite process was inaugurated in the mid-1960s, but it continued to be plagued by techno-

Breaking the oxide crust on the electrolytic cells at the Krasnoyarsk plant. Left.

Svetlana Kotjkareva is working in the control room at the Volchov aluminium plant. Right.

logical problems. By the time it was decided to base further expansion on imported bauxite, the Kirovabad plant was producing only about 100 kt of alunite-based alumina, or half of the original design.

Summary

In short, virtually all the Soviet attempts to make use of domestic resources for alumina and aluminium production have encountered problems, and there are no indications that any significant expansion of the existing capacity is contemplated. In 1980, these inferior domestic raw materials contributed to 35 per cent of Soviet alumina needs, with about the same amount being derived from domestic and imported high-grade bauxite, and close to 30 per cent consisting of alumina imports.

For the foreseeable future, the Soviet Union will depend increasingly on imported bauxite and imported alumina, with the proportion of the two materials depending on the construction of alumina capacity in the Soviet Union. There has already been a proposal for the building of a large alumina plant on the Pacific coast,[22] possibly using bauxite from Australia if the proper commercial arrangements can be made. The alumina from such a Pacific seaboard plant could be transported to the Siberian aluminium plants over the Baikal-Amur Mainline, the new Siberian railroad scheduled to go into operation in the mid-1980s.

In the meantime, the development of the hydro-electric potential of southern Siberia and associated aluminium smelting capacity is likely to proceed. The rate of development will probably depend on Soviet growth of consumption and the prospects of aluminium exports, but the southern Siberian potential might well be considered in any long-term projections of the world's aluminium production, especially in light of energy shortages. Even in the Soviet Union, there have been suggestions that aluminium production might ultimately be based on nuclear power sites.[23] One such proposal envisages northern European Russia as such a nuclear-based aluminium complex based on domestic raw materials. The advocates of such a development point to the presence of the North Onega bauxite (assuming that the proper technology can be developed) and to another low-grade bauxite deposit, the prospective Vezhayu-Vorykva site, in the middle Timan Mountains of the Komi Republic of northern Russia. Other raw material sources that are being proposed in connection with the use of nuclear power in northern Russia are expanded use of Kola Peninsula nepheline and yet another potential aluminium ore, the kyanite of the Keiv uplands in the center of the Kola Peninsula. However, the realization of such plans appears to be for the more distant future, and the immediate outlook is for a Soviet aluminium industry to grow on the basis of imported raw materials and the use of Siberian hydro-electric power.

Notes:

1 Jensen, Robert G.; Theodore Shabad and Arthur W. Wright, editors, *Soviet Natural Resources in the World Economy*. The University of Chicago Press, 1983 (in press).

2 Aluminium production is an official state secret in the Soviet Union. The most reliable Western estimates appear in: US Central Intelligence Agency, *Handbook of Economic Statistics 1982* (CPAS 82–10006), September 1982, p. 143.

3 The present author's estimates of Soviet import reliance have been revised on the basis of later information. It was given as 40 per cent imported raw materials in: Theodore Shabad, "Raw Material Problems of the Soviet Aluminium Industry", *Resources Policy* (Guildford, England), December 1976, pp. 222–234. For earlier accounts of the Soviet aluminium industry, see: Theodore Shabad, *The Soviet Aluminium Industry*. New York: American Metal Market, 1958, 25 pp., and a supplement, *Soviet Aluminium Developments in 1959*. New York: American Metal Market, 1960, 22 pp. For developments during the 1960s, see Theodore Shabad, *Basic Industrial Resources of the USSR*. New York: Columbia University Press, 1969, pp. 58–63, and under particular projects. For developments since 1970, see the regular News Notes section in *Soviet Geography*.

4 J. Skea, "Electricity Supplies for the Primary Aluminium Industry", *Resources Policy*, March 1980, pp. 60–70.

5 CIA op. cit.

6 *Tsvetnye Metally* (Soviet nonferrous metals journal), 1982, No. 4, p. 15.

7 *Stroitelnaya Gazeta* (Soviet construction industry newspaper), 1982-08-11.

8 N. S. Malts and M. I. Zaitsev, *Povysheniye effektivnosti polucheniya glinozema iz boksitov* (Increasing the Effectiveness of Obtaining Alumina From Bauxites). Moscow: Metallurgiya, 1978, p. 7.

9 *Ibid.*

10 *Vodny Transport* (Soviet water transport newspaper), 1979-11-17.

11 *Sovetskaya Rossiya*, 1977-05-04, says current northern Urals bauxite production was 25 times the 1940 level, which was about 150 kt.

12 *Izvestiya*, 1981-01-29, says that one-one-third of Urals alumina is used for aluminium reduction in the Urals and two-thirds is transported to Siberian aluminium plants.

13 *Bakinski Rabochi* (Baku), 1981-04-24, in an apparent lapse of censorship, reported that alumina production at Kirovabad in the first three months of 1981 was 67.6 kt, or an annual rate of about 250 kt.

14 *Soviet Geograhpy*, November 1977, p. 705, and December 1978, pp. 742–743.

15 *Soviet Geography*, March 1978, pp. 218–219.

16 *Soviet Geography*, May 1977, p. 347.

17 *Sotsialisticheskaya Industriya*, 1980-02-20.

18 *Malts and Zaitsev* ibid, pp. 11–12.

19 *Tsvetnye Metally*, 1982, No. 4.

20 *Ibid*, 1980, No. 7.

21 *Ibid*, 1982, No. 4.

22 *Ekonomicheskaya Gazeta*, 1975, No. 5, p. 13.

23 *Tsvetnye Metally*, 1982, No. 1. ■