A case study of the Muruntau Gold Plant

ESTIMATING SOVIET GOLD PRODUCTION

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The USSR has long maintained a veil of strict, unbroken secrecy on domestic production of gold. The State Secrets Decree of 1947, amended in 1958, forbids disclosure of data on the quantity of gold produced, plan goals, production capacity of plants, and the size of gold deposits. To help ensure a reticent attitude among knowledgeable Soviet officials, the State Secrets Decree carries harsh criminal sanctions for violation of its provisions.

Since the early 1950s, intelligence analysts in the Office of Economic Research (OER) and its predecessor, the Office of Research and Reports, have tried to unravel the mystery of Soviet gold production. By effective use of all-source intelligence—and with expert assistance of other components of the intelligence community, non-USIB agencies, and sources in the business community—OER was able to penetrate much of the official blackout on gold production in the USSR and to develop estimates that are accepted as the official position of the United States government and by the intelligence services of allied nations as well.

Intelligence methods used to estimate gold production in the USSR are highlighted by a new methodology developed to estimate the capacity of the Muruntau Gold Plant, the largest gold plant in the world.*

The Basic Methodology

Gold is produced in the USSR by two methods: by mining placer and vein deposits, and by recovery as a by-product in the processing of other non-ferrous metals such as copper, leads, and zinc.

The Northeast Region, which consists of Magadanskaya Oblast and the Yakutskaya ASSR, is the country's largest gold-producing region. Open source Soviet literature revealed that the Northeast Region accounted for 60 to 65 percent of Soviet production of mined gold in the late 1950s. The rest was produced mainly in the Lena area of Irkutsk Oblast, the Transbaikal Region, the Kazakh SSR, and scattered locations in the Ural Mountains. Annual plan fulfillment data indicated that production of mined gold in other parts of the USSR was increasing about as rapidly as it was in the Northeast Region. Hence, the geographic distribution of mined gold production in the USSR was not changing much from year to year. Total Soviet production of mined gold thus could reasonably be estimated because two critical parts of the puzzle were known: a) the amount of gold produced in the Northeast Region, and b) this region's share of total Soviet production of mined gold.

Production of gold derived from by-product recovery was estimated using a weighted average recovery factor of 35 grams of gold (slightly more than 1 troy ounce) per ton of refined copper in conjunction with previously developed estimates of Soviet

*Many CIA personnel made valuable contributions to the original OER report on which this article is based, in particular John Keilty (OER); Mrs. Louise Noyes, John Jackson, and Richard Ordemann (IAS); Will Rogers (OCCR); and George Gilbert (DCD).

copper production. This average recovery factor was developed using information on average gold recovery at each copper refinery in the USSR. With these established tools, OER analysts developed estimates of annual Soviet gold production covering the period from 1957 through 1968. (See Table 1.)

Gradually, our confidence in the methodology increased, but we were aware of the fact that it hinged precariously on one key relationship: that gold production in the Northeast Region would remain a relatively constant share of total Soviet production of mined gold. In the late 1960s, evidence began to mount that this relationship of the Northeast to total production was about to change. The Soviets were building a huge gold processing plant outside the Northeast Region at Muruntau in the Uzbek SSR. The sheer size of the project suggested that the plant would produce large amounts of gold. New tools had to be developed to estimate the capacity of the Muruntau gold plant.

Muruntau

Muruntau—"Nose Mountain" for those not fluent in Uzbek—came to the attention of the intelligence community in 1964. In that year, the Soviet press began reporting that huge deposits of gold had been discovered at Muruntau in the Kyzyl-Kum desert of central Uzbekistan. The Soviet press first announced that Muruntau was the largest deposit of gold in the USSR. Later reports claimed that Muruntau was the largest gold deposit in the world.

Overhead photography of the Muruntau area in 1965 revealed evidence of large-scale geological prospecting, the possible beginning of an open pit mine, and a

Table 1

Gold Production in the USSR, 1957-68
(in Metric Tons)

	Mined Gold			
	Northeast Region	Other Areas	By-Product*	total
1957	48	32	14	94
1958	51	34	14	99
1959	55	35	15	105
1960	58	36	17	111
1961	62	38	18	118
1962	68	38	19	125
1963	71	42	21	134
1964	77	43	23	143
1965	86	44	24	154
1966	92	46	26	164
1967	96	48	28	172
1968	99	51	32	182

*By-product gold is obtained at the copper refineries located at Kyshtym, Norilsk, Pyshma (RSFSR); Balkhash, Dzhezkazgan, Irtysh (Kazakh SSR); Alaverdi (Armenian SSR); and Almalyk (Uzbek SSR).

considerable amount of unidentified construction. Except for general background purposes, however, OER analysts could do little with this photographic information. The June 1966 issue of *Soviet Life* suggested that the Muruntau deposit might be about the same size as the Kalgoorlie deposit in Western Australia, which produced about 20 tons of gold annually. Thus, until more information became available, OER tentatively estimated that upon completion Muruntau would produce about 20 tons of gold annually.

During 1971-73, however, as overhead photographic coverage of the Muruntau complex improved, it became evident that OER's estimate was inconsistent with the size of the project and its rate of construction. The observed scale of activity at Muruntau gave credibility to claims made in the Soviet press that Muruntau would be the largest gold plant in the USSR and stimulated a re-examination of the plant's production capacity. A systematic reassessment was started in 1972, which resulted in a revised estimate of Muruntau's production capacity that was almost seven times the original OER estimate and almost 25 times estimates made by other intelligence services.

Exploiting the Photography

At the outset, we decided to test the feasibility of developing a methodology based on high resolution overhead photography. Although OER had used satellite photography to estimate Soviet production of copper and aluminum, photography had never been used to estimate the production capacity of a Soviet gold plant. In the early stages of the research, no one knew if photography could be used for this purpose.

Our confidence in this attempt was increased by an idea an OER analyst received from a televised news account of the damage done to a sewage treatment plant by Hurricane Agnes. A plant engineer interviewed by TV reporters commented that there was a direct correlation between the size of the treatment tanks that had been damaged and the amount of sewage the plant could process. Photography of the Muruntau plant revealed circular tanks, similar to those at the sewage treatment plant (presumably processing different materials), and we reasoned that a correlation should also exist between the size and capacity of the tanks at Muruntau.

Experts at the U.S. Bureau of Mines confirmed this, stating that as a general rule, the processing of one ton of ore per day requires three to six square feet of surface area on thickening tanks with a depth of 20 feet, the depth indicated by photography of Muruntau. This correlation is a standard engineering yardstick used worldwide to rate the capacity of gold plants, with the exact amount of surface area required depending on the elevation of the plant, the type of ore being processed, and the metallurgical process used.

The Imagery Analysis Service and the Office of Geographic and Cartographic Research were asked to perform a detailed photographic and geographic analysis of the Muruntau complex. Meanwhile, efforts were started—with the assistance of the U.S. Bureau of Mines, the U.S. Geological Survey, the Colorado School of Mines, and two of the largest U.S. gold mining companies—to ascertain the geological composition of the Muruntau ore deposit and to identify the production process used at the Mauruntau plant.

The Results: Elevation

Experience of U.S. mining engineers indicated that elevation affects the correlation between the surface area of thickening tanks and tank capacity. As a general rule, more surface area is required as the elevation of the plant increases because of lower barometric air pressure. The Muruntau plant is 1300 feet above sea level and lies in a hilly, arid region, similar in climate and terrain to the high desert country of northern Nevada. Ascertaining the elevation of the Muruntau plant helped U.S. engineers to narrow the range of estimate of thickening tank surface required per ton of processing capability.

Support Facilities

Because of the relative isolation of Muruntau—roughly 250 nautical miles west of Tashkent, the nearest population center of any significance—the Soviets had to build extensive support facilities. These included 165 miles of rail line from the nearest terminal at Navoi, road links and powerlines, and a 155-mile water supply system from the Amu Darya river. Between 1966 and 1970 a new permanent settlement was built about 25 miles west of the plant to provide housing and day-to-day services for the Muruntau labor force. This settlement, called Zarafshan ("bearer of gold" in the Uzbek vernacular), eventually will grow to a population of 40,000.

In addition, there are three smaller housing components at the Muruntau site: housing for about 500 workers near the open pit mines; barracks for about 1,000 construction troops near the processing plant; and a prison compound for about 800 forced laborers also close to the processing plant. The prison labor is used in the dangerous task of building the underground mine.

The Ore Deposit

Intensive geological prospecting of the Kyzyl-Kum desert, involving some 3,000 people at its height, began in 1959 and continued at least through 1968. The decision to build the Muruntau plant apparently was based on estimates made during the early 1960s of gold in formations near the surface. This ore, which lies only six to ten feet beneath the surface in some areas, requires the removal of only light overburden and thus is suitable for cheap open-pit mining operations. Exploration from 1966 to 1968 revealed that vast reserves of gold also existed at depths as much as 7,000 feet below the surface. This ore apparently has a higher gold content than that near the surface. In 1969 the Soviets reported that the Muruntau deposit was twice as large as originally believed and that it was the world's largest proved gold deposit, with reserves that will last at least several decades.

At Muruntau the gold appears in quartz veins, similar to the Australian deposits at Ballarat and Castlemine and to formations of the Homestake gold deposit in South Dakota. According to the U.S. Geological Survey, the Muruntau deposit is described technically as a low-sulfide, quartz-pyrite-arsenopyrite formation.

The gold content of the Muruntau deposit could not be ascertained exactly. However, we had good reasons for believing that it was not less than 0.15 troy ounce of gold per ton of ore—about one-half the gold content of typical ores mined in the United States and South Africa. First, experts in the U.S. gold industry and U.S. Bureau of Mines estimated a probable gold content of at least 0.15 troy ounce per ton based on a study of the Muruntau deposit by the late Mr. Douglas Alverson of the U.S. Geological Survey. Mr. Alverson, a professional geologist and fluent Russian linguist, provided OER with a detailed study of the Muruntau deposit along with comparisons of this deposit with analogous ore bodies in non-Communist countries.

Second, published results of tests conducted by the Soviets in 1967 on ore samples from new quartz deposits in the USSR—almost certainly including Muruntau—showed an average gold content of 0.15 to 0.57 troy ounce per ton. These results were published in the Soviet *Journal of Nonferrous Metals*.

Third, the Soviets have compared the Muruntau deposit to the Kommunar deposit in the Altai Kray which, according to information published in Soviet technical journals, contains an "average industrial content" of gold. The system of mineral classification described in Soviet publications indicates that "average industrial content" means at least 5 grams (0.16 troy ounce) of gold per ton of ore. The second part of the puzzle had fallen into place.

The Central Processing Area

The processing plant is located on a plateau about 3 miles west of the open pit mining area and at an elevation of 800 feet relative to the mine. (See Figure 1.) It is connected to the mining area by a rail shuttle. The plant, which covers an area of 150 acres, is the largest gold plant in existence. It contains four major production facilities: a) a mill building 2,130 feet long; b) 18 circular thickening tanks, each 165 feet in diameter; c) two buildings housing cylindrical tanks (called Pachuca mixers) to extract gold from solution; and d) a refinery 435 feet long. Detailed photographic analysis of the thickening tanks yielded two vital pieces of information. First, we could measure the diameter of the tank, and hence calculate its surface area. Second, the tanks were constructed on exactly the same level, and there was no evidence of any internal piping between them; hence, each tank operated as an independent unit. In contrast, thickening tanks in U.S. gold plants are installed in a descending pattern, and the slurry is thickened sequentially, using gravity to move the slurry from one tank to the next. (Ground photography of typical thickening tanks and Pachuca mixers at Muruntau is shown in Figures 2 and 3.)

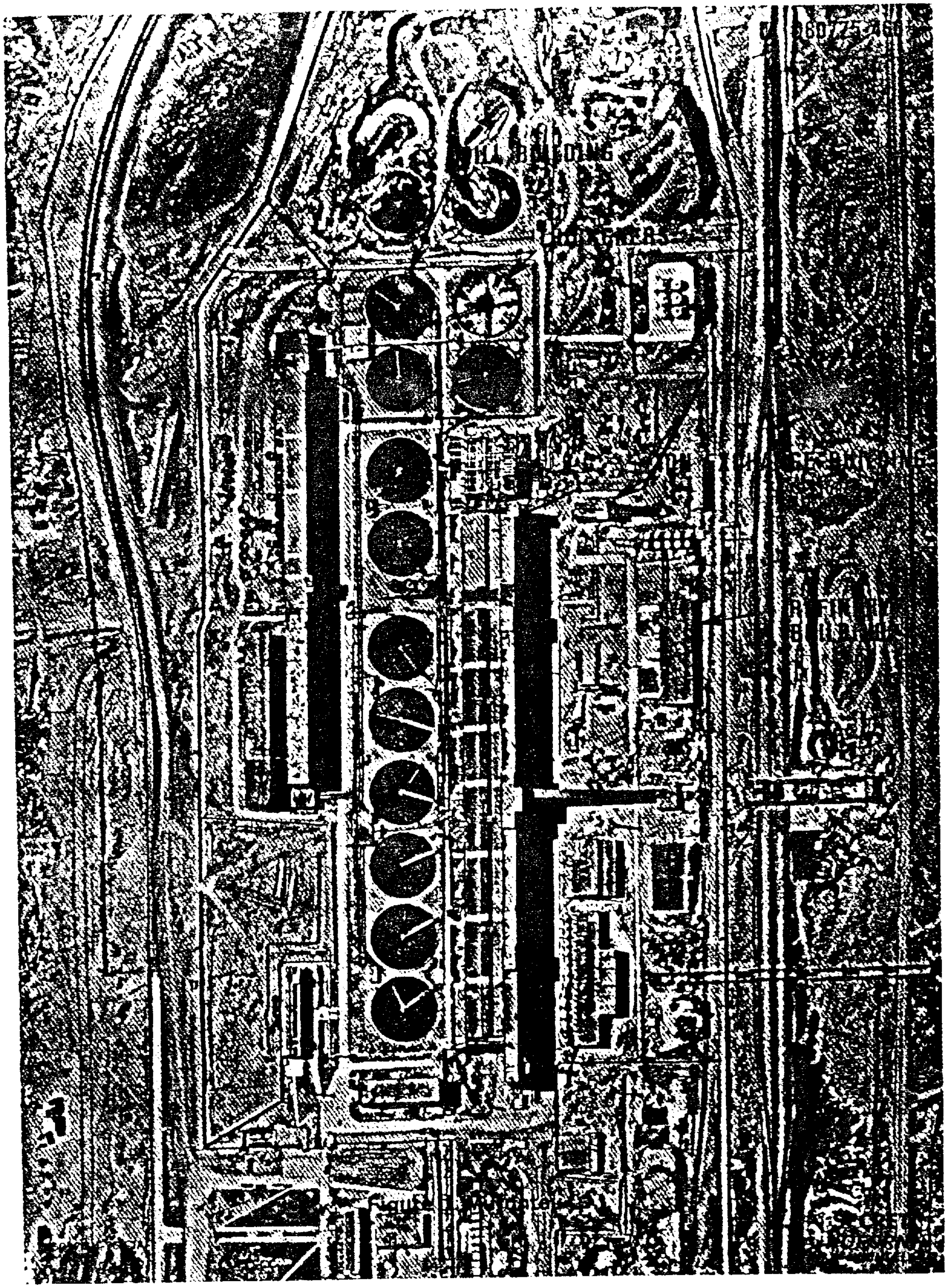
The Cost

Muruntau is the largest project ever carried out in the Soviet gold industry and is probably the most expensive undertaking by any gold industry in the world. On the basis of U.S. experience, we estimated that this project, including infrastructure, would cost $620 to $680 million (in 1974 dollars) if it were undertaken in the United States. The most expensive part of the project, the processing facility, probably would cost $375 million when outfitted with machinery and equipment. This is roughly six times the capital valuation of the largest gold plant in the United States and three times the average of South African plants.

The Production Process

The refining process at Muruntau is defined in metallurgical terms as an ion exchange in the pulp process. Although Muruntau is the only plant in the world that currently uses this technique to recover gold, the technology involved is well known and is used widely in uranium processing plants in the United States. The process involves five basic steps: crushing; grinding; thickening; extraction of gold with ion exchange resins; and final refining. (See Diagram, Figure 4.)

At Muruntau, the ore is transported to the plant from the mines by a standard-gauge rail line. Primary crushing of the ore occurs underground between the railcar unloading facility and the mill building. Secondary crushing and grinding of the ore



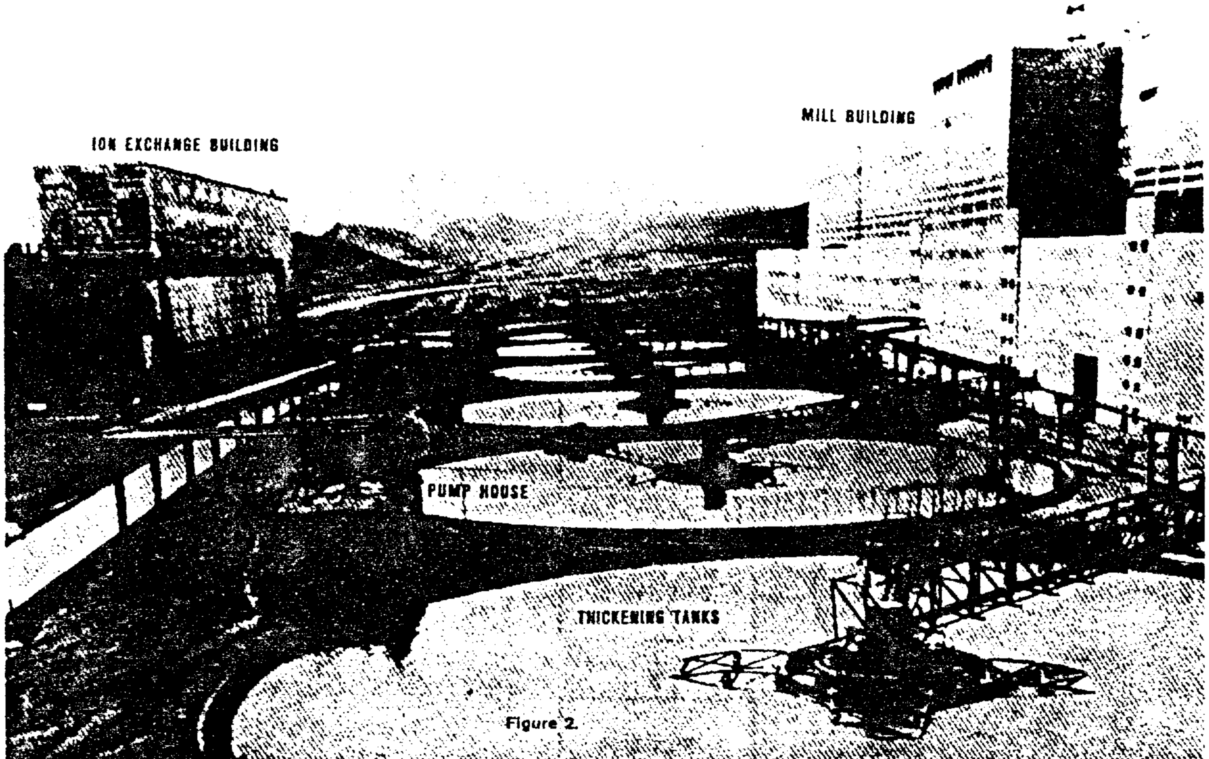


Figure 2.

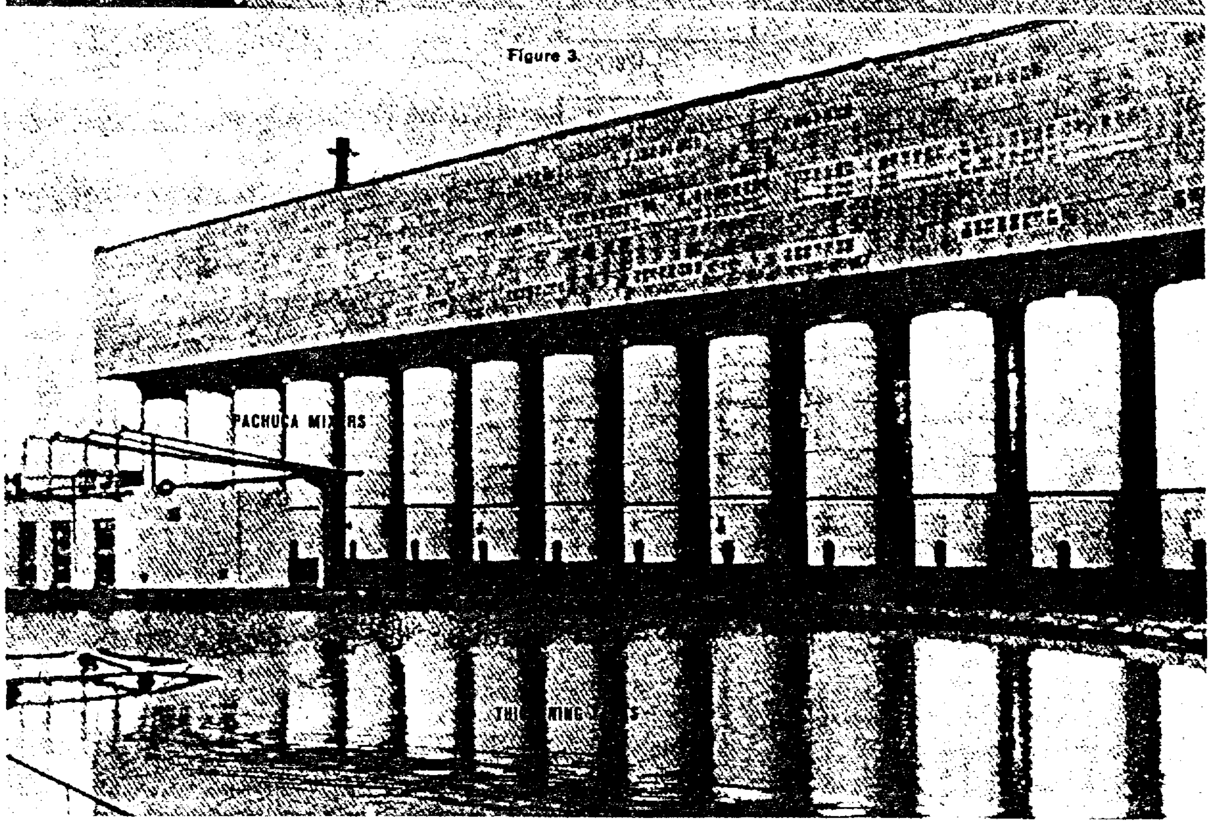


Figure 3.

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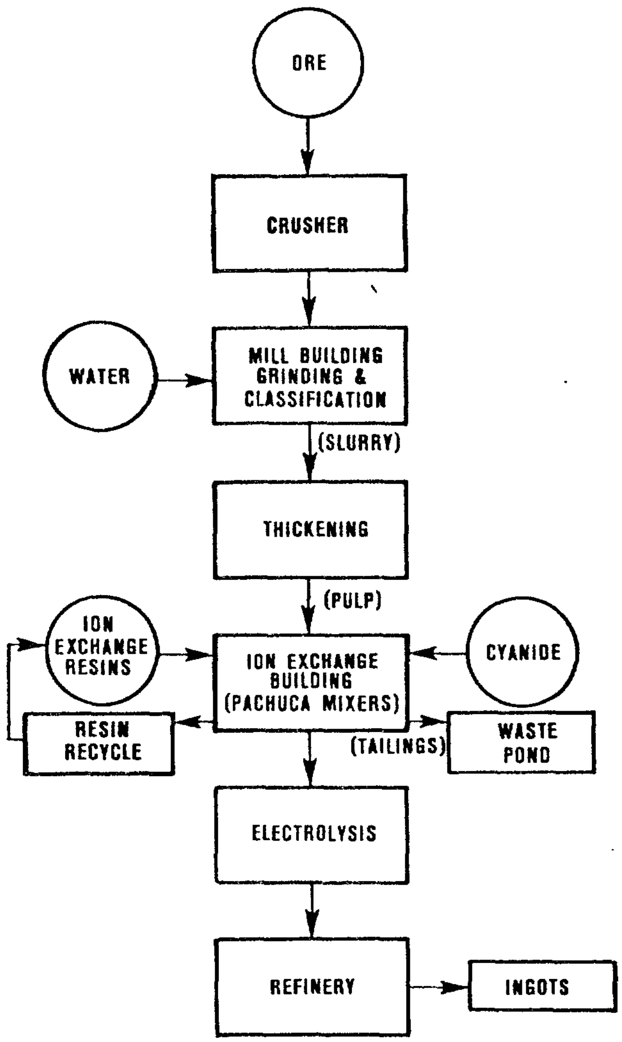

Figure 4. Ion Exchange in the Pulp Process (Simplified Flow Diagram)

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takes place in the mill building. The ore is ground to a fine powder. Water is added in the final grinding stage to obtain a water solution, or slurry, with a solid content of about 15 percent. The slurry is sorted in spiral classifiers to insure uniform fineness and then is pumped from the mill building to the thickening tanks.

In the thickening tanks, the solid content of the slurry is raised to about 50 percent by allowing the solids to settle to the bottom of the tank, a process taking 16 to 18 hours. Rotating rake arms push the settled solids toward a discharge point at the center of the tank bottom. When the desired 50/50 liquid-to-solid ratio is achieved, the viscous residue, called pulp, is pumped through pipes to ion exchange buildings.

The ion exchange buildings house the Pachuca mixers. The pulp enters the mixers and is dissolved in a cyanide solution for about 10 hours to form the electrolyte sodium gold cyanide—$NaAu(CN)_2$. The electrolyte is then treated with ion exchange resins (plastic polymers with an affinity for gold) which extract the gold from the electrolyte. Resins that have stripped gold from the electrolyte are removed from the Pachuca mixers and pulverized to a powder.

Gold is separated from this powder by an electrolytic process in which gold is deposited on titanium sheets (cathodes) set in electrolytic cells and then manually peeled from the cathodes. At this point the gold has a purity of 99 percent. Such a degree of purity cannot be achieved prior to final refining by other processes. Final purification of the gold is performed in the refinery, adjacent to the ion exchange building, using a fire refining process to produce gold that is 99.99 percent pure. Muruntau is one of only two plants in the USSR capable of producing gold with this purity. The other is the All-Union Precious Metals Plant in Novosibirsk, which performs final purification for all the gold produced in the Northeast Region.

Construction Chronology

Photographic analysis indicates that the processing complex was designed from the beginning in 1967 for the configuration that it will have upon completion. This was not apparent until recently, however, because construction has proceeded in three stages.

The cornerstone of the plant was laid on 14 May 1967, according to Soviet press sources, and construction proceeded rapidly thereafter. Photography of March 1968 showed the frame of a mill building 500 feet long, part of the roof structure in place, three thickening tanks under construction, and the ground cleared for three more tanks. On 12 June 1969, the first gold was produced and ceremoniously announced in the Soviet press, and on 1 July 1969 the plant was officially commissioned. Photography of January 1971 revealed that the length of the mill building had been extended to 1,100 feet and that the six thickening tanks had been completed. In addition, an ion exchange building housing 28 Pachuca mixers, and a refinery 435 feet long had been built.

Photography of July 1973 revealed that additional construction had doubled the capacity of the Muruntau plant. The mill building had been extended 400 feet, six additional thickening tanks were installed, and a second ion exchange building, identical to the first, had been completed. Photography of April 1974 revealed that the mill building is being extended by an additional 1,000 feet, six additional tanks are in various stages of construction, and a third ion exchange building is in an early stage of construction. The pace of construction as observed in mid-1975 suggests that the facilities will be completed and fully operational by 1977. Space limitations imposed by other buildings and topography indicate that further expansion of the central processing area is unlikely. (A comparison of the three stages of construction of the Muruntau, identified as Stages 1, 2, and 3, is shown in Table 2.)

Having gained an understanding of the key aspects of the Muruntau plant, and of the pace of its construction, we were in a position to begin integrating all the disparate information into a formal methodology for estimating the capacity of the plant.

The Methodology

We concluded that the capacity of any gold plant can be estimated with a high degree of accuracy on the basis of the following information: a) the surface area of the thickening tanks; b) the number of tanks installed; c) the settling characteristics of the ore—that is, the rate at which the powdered ore precipitates from the slurry in the thickening tank. For any particular settling rate, the amount of gold-bearing ore that can be processed per unit of time is directly correlated with the surface area of the thickening tank.

In the case of Muruntau, U.S. engineers estimate that four square feet of thickening tank surface area are needed to process one ton of ore per day. This estimate is based on the elevation of the plant, the settling characteristic of the ore, and the production process. In the extreme, no more than five square feet would be needed. Upon completion of present construction, Muruntau will have 18 thickening tanks, each with a surface area of 21,382 square feet, or a total surface area for all tanks of about 384,876 square feet. Hence, at four square feet per ton, Muruntau could process 96,200 metric tons of ore per day, and at five square feet, 77,000 metric tons.

Given a range for the amount of ore that can be processed, final output of gold will depend upon the gold content of the ore, the rate of plant utilization, and the recovery rate. We had estimated the average gold content of the ore at 0.15 troy ounce per metric ton at a minimum. Some experts in the U.S. gold industry argued that the probability was high that the ore was richer, perhaps 0.20 troy ounce per metric ton. In the judgment of U.S. engineers, the Muruntau plant probably operates at 95 percent of capacity (which is a fairly standard plant utilization rate in the gold industry), although a higher utilization rate is possible. Lower rates of utilization are unlikely. Finally, it is unlikely that the recovery rate at Muruntau is less than 92 percent. (The

Table 2

Sequence of Construction at Muruntau

	Stage 1 Complete As of January 1971	Stage 2 Complete As of April 1974	Stage 3 Under Construction As of April 1975	Total Plant
Length of Mill (feet)	1,100	230	580	2,130
Number of Thickening Tanks (units)	6	6	6	18
Area of Thickening Tanks (square feet)	128,295	128,295	128,295	384,885
Ion Exchange Buildings	1	1	1	3
Pachuca Mixers (units)	28	28	28	84
Capacity of Mixers (cubic feet)	630,000	630,000	630,000	1,890,000
Length of Refinery (feet)	435	—	—	435

recovery rate is the amount of gold actually recovered as a percent of the total that would be recovered if the production process were perfect.) In U.S. practice, recovery rates normally exceed 95 percent and on occasion run as high as 98 percent. The effects of these variants on the annual output of gold (based on a 360-day work year) are shown below for two cases.

The tabulation summarizes the possible ranges of output at Muruntau. The widest range implied is from 112.9 to 208.9 metric tons per year. Only the values given in Case 1 for 95 percent capacity utilization were considered to be "real" possibilities, however. Thus, potential output at Muruntau falls within a range of 112.9 tons to 148.9 tons. The mean and median value is 130.9 tons.

A crosscheck, calculated by an alternative technique, supports a somewhat higher figure. Output was computed for crosschecking purposes on the basis of the dimensions of the Pachuca mixers, because a correlation exists between the volume of a mixer and its processing capability per unit of time. Analysis of ground-level photography published in *Sputnik*, a Soviet magazine, revealed that the volume of each mixer is about 22,500 cubic feet. When present construction at Muruntau is complete, 84 mixers, with a total volume of 1.89 million cubic feet, will be in place. U.S. experts calculated that about 20 cubic feet of mixer are needed to process one ton per day. By dividing total volume by the constant factor of 20 cubic feet, it follows that the Pachuca mixers have a daily throughput capacity of 94,500 tons, compared with 77,000 to 96,200 tons calculated on the basis of the surface area of the thickening tanks. Applying the same values for ore richness (0.15 troy ounce) recovery rate (92 percent), and plant utilization rate (95 percent) yields an estimate of 138.7 tons of gold per year. As a "best" estimate, 135 tons of gold per year was used. This figure is both the mean and median value of the estimates derived from the thickening tank and Pachuca mixer estimating techniques.

Significance of Muruntau

Using the foregoing methodology, in conjunction with photographic information on the rate of plant construction, OER estimated that gold production at Muruntau increased from 1 ton in 1969 to 45 tons in 1974. In 1975 the plant was capable of producing 90 tons, and upon completion of present construction in 1977 it will have a capacity of 135 tons. (See Table 4.) These estimates are supported by a Soviet

Table 3

Recovery Rate	Case 1[a] 4 Square Feet[b]	Case 1[a] 5 Square Feet[b]	Case 2[a] 4 Square Feet[b]	Case 2[a] 5 Square Feet[b]
	Metric Tons			
At 100% of capacity				
92%	148.6	118.9	198.3	158.5
97%	156.7	125.4	208.9	167.2
At 95% of capacity				
92%	141.3	112.9	188.2	150.6
97%	148.9	119.1	198.6	158.8

[a]Case 1 is based on an ore content of 0.15 ounce per ton, Case 2 on a content of 0.20. Recovery rates of 92% and 97% are specified at plant utilization rates of 100% and 95%.
[b]Surface area needed to process one ton of gold-bearing ore.

Table 4

Gold Production in the USSR,

(Metric Tons)

Year	Muruntau	All Other	Total
1969	1	191	192
1970	5	196	201
1971	20	198	218
1972	45	207	252
1973	45	216	261
1974	45	225	270
1975	90	236	326
1976	90	NA	NA
1977	135	NA	NA

monetary specialist who confided to a former member of the President's Council of Economic Advisors that output at Muruntau will be at least equal to that of Magadanskaya Oblast, traditionally the country's largest gold producing area. Magadanskaya Oblast currently produces about 85 tons of gold annually.

Muruntau's production in 1974 surpassed total U.S. output of 35 tons and was not far behind that of Canada (52 tons). Muruntau's production in 1975 probably was six times that of the largest gold plant in the United States and surpassed the record level of 88 tons achieved by the largest South African plant at West Driefontein in 1971. When Muruntau is complete and fully operational in 1977, its annual output will account for about 40 to 45 percent of total Soviet gold production.

During 1975-77, Muruntau will produce an estimated 315 tons of gold, which at free market prices of $170 per ounce could bring in about $1.7 billion in hard currency to help the Soviet government pay for imported grain and badly needed Western equipment and technology. Without meaning to, OER seems inadvertently to have given some credibility to an old Uzbek proverb, "In the Kyzyl-Kum desert, it is harder not to find gold than to find it."

OER now is working to apply the methodology developed for the Muruntau gold plant to other nonferrous metals plants. The most promising possibility is a new gold plant the Soviets are building at Zod, on the eastern slope of Mt. Ararat, in the Armenian SSR. This plant is under construction and is similar to Muruntau in external configuration, but smaller. According to published Soviet press reports, it will also use an ion exchange in the pulp process. As more photography becomes available, and as we obtain more information on the geological composition of the Zod deposit, an estimate of the capacity of the Zod plant will be made, thereby further unraveling the "secret" of Soviet gold production.