Somewhere in Siberia

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Early analysis of the Soviet atomic program

Henry S. Lowenhaupt

At the halfway point in the September 1958 Second Conference on the Peaceful Uses of Atomic Energy at Geneva, Switzerland, the Russians announced that they had just put into operation an atomic power station "somewhere in Siberia." We were able to start collecting information on it immediately, for we had laid extensive plans for the intelligence exploitation of this conference.[1] Nevertheless, enthusiastic though we were, I doubt that any of us expected this information to be, as it indeed became, the key to understanding Russian facilities for the production of plutonium for nuclear weapons.

At Geneva, Dr. Charles Reichardt, Director of Intelligence, AEC, had been given office space in the secured area at American delegation headquarters so that he could provide liaison between the intelligence personnel and the scientists attending the conference. This included direct support to overt and, if needed, covert collection activities. It was his task to attend all steering committee and all technical group-leader meetings at delegation headquarters. He discussed with selected AEC persons our needs in connection with both specific formal meetings and private conversations between them and foreign scientists. He cabled back to Washington what these persons had learned that was not already known. To assist his operation, I had available personality files and summary data on what the Russians had already published in the atomic field. In addition, I had tried to memorize the 1957 U-2 photography of atomic facilities in Siberia so that we could have this highly sequestered information immediately available without actually having the photography in Geneva.

Following their announcement, the Russian delegation released a movie on their Siberian atomic power station and placed an exhibit on it in the conference exhibition hall. The movie attracted wide attention and a number of Americans visited the English language shows. Their descriptions of the facility in the movie certainly seemed very like that seen under construction in the 1957 U-2 photography of the atomic facility north of Tomsk in Central Siberia,[2] although, of course, it could conceivably have been of a similar one elsewhere in the USSR.

They reported that only the first of six atomic power units had been completed. Each unit was to develop 100 megawatts of electricity at a thermodynamic efficiency of 22 percent from a graphite moderated, watercooled reactor fueled with 200 metric tons of uranium metal of natural isotopic composition. They described the reactor building as looking like a large office structure, rather than the functional cubism of an American reactor facility. The 300 foot high vent stack was placed with the blower and air filter building behind the turbine building and away from the reactor building. Several large centrifugal pumps pushed water under pressure through the reactor; the resulting radioactive, thermally hot water then passed through steam generators and—it was left to the viewer to infer, if he so chose—back to the centrifugal pumps. The secondary circuit of the steam generator produced nonradioactive steam to drive three low pressure turboelectric generators. Each of the three 33 MW turbogenerators was connected directly to a transformer located in front of the turbine hall. The spent steam was condensed in the basement of the turbine hall and returned to the steam generators. The condenser cooling water circulated through several large natural draft cooling towers. It looked like a very adequate design. The Russians had good reason to feel proud of their achievement.

Oddly enough, it was the number of cooling towers that was the item of real disagreement. The number reported varied from two to five: as witnesses, scientists are apparently no better observers than most people. To both Dr. Reichardt and me, the number was of considerable importance. We knew that there had been six under construction in 1957, three presumably for each of the two dual purpose reactors under construction. We expected them to be used in modern Russian "in-line" fashion as at the GRES 11 thermal electric power plant in downtown Tomsk City. Here each large coal-fired boiler served a 100 MW turboelectric generator in turn cooled by a single large cooling tower. We remembered that at the atomic plant the cooling tower nearest completion had had dimensions similar to the ones at GRES 11, and that we had found enough information in the Russian technical literature to be certain that the GRES 11 cooling towers dissipated 200-220 megawatts of heat. Also in 1957, half the turbine hall and one reactor building had been nearing completion, while foundation work had only just been started on the second power reactor building and on the extension of the turbine hall. Thus we expected to find in the movie at Geneva three cooling towers operating with, perhaps, a spare in addition. Three turbines would thus generate 100 megawatts of electricity and dump three times 200 to 600 megawatts of heat through the cooling towers to yield an over-all thermal efficiency of 15 percent, rather than 22 percent. Had the Russians fibbed just a little bit?

Those reactor experts who had seen the film tended to favor the lower efficiency. The reactor looked like our earliest Hanford type, except the tubes were vertical instead of horizontal. They felt it was a reactor optimized for plutonium production, but producing by-product electricity, a so-called dual purpose reactor. The electrical efficiency of such reactors was known to be low and, indeed, no one reported the mention of a high pressure steam circuit, or had seen in the movie a high pressure end to the low pressure turbines. Eventually I settled the question on the number of cooling towers by visiting the last showing of the movie: there were four, one apparently installed ahead of schedule as a spare in case of a failure in one of the other three. The efficiency was almost certainly not 22 percent.

At the movie, I was reminded of Richard Kroeck's wish to walk around on the site. After spending five months photo interpreting the Tomsk photography, he had felt it would be like returning to a childhood home—and, of course, he really wanted to see how accurate his photointerpretation had been. My reaction was one of less familiarity. I simply did not recognize in the movie the main housing area with its imposing six-story apartment houses set back from the statue of Lenin on horseback and its large children's playground. The paved sidewalks and the planted grass and bushes in the reactor area bothered me also, for the ground there had been a construction shambles in the U-2 photography. Nevertheless, the reactor area seemed "right" and within seconds I had picked in my mind the spot from where the initial "shot" of the reactor complex had been taken. Compare Figure Ia, one of the 1958 movie frames later released by the Russians, with Figure Ib, the 1957 aerial view. The location of the camera in 1958 is marked with an "X" on the aerial photography, and the solid lines from the "X" show the angular view subtended by the frame from the 1958 Russian movie.

Within hours after the first showing of the Russian film reports began to come in—both from American technical information people and from more covert sources of information—that the Russians had no intention of letting the actual film of the movie out of their possession. We had learned that Dr. Vasilly Semenovich Yemel'yanov, the head of the Russian Delegation, had already privately asked Dr. Isador 1. Rabi, the head of the US Delegation, for copies of all the US movies shown and had obtained the latter's acquiescence.

Under these circumstances, Dr. Reichardt felt that the US might not ever obtain copies of the Russian film. He obtained permission to press the US technical information staff to continue attempts to obtain copies of the film through exchange. In addition he enlisted the special services of a group of reactor design engineers visiting the conference with whom we maintained liaison through John R. (Jack) Craig, also a staff employee of CIA's Office of Scientific Intelligence. The design engineers were employed by a US reactor-engineering firm under contract to OSI to produce an evaluation of Russian reactor engineering practices. Pointing them toward the Siberian power station seemed eminently reasonable. Craig soon brought back a detailed plan dividing up the functions of an atomic power station amongst the engineers so that each would be viewing and listening to the movie for very specific facets. In addition, they proposed taking still photographs of the movie with the two very fine Leicas and the exceptionally high speed film Craig and I had brought to Geneva.[3]

The plan was implemented. The engineers' notes were by far the best on what was seen and heard by all at the movie and they took many successful "in cinema" photographs. Eventually the Russians did release portions of the film; however, most of the sound track and many of the more interesting "shots" had been deleted. Only information collected at the movie showings in Geneva could cover these deleted items, and several of the "in cinema" photographs turned out to be crucial in the later analyses.

Meanwhile, we had been suggesting to AEC atomic power experts in the delegation that they should discuss technical details on the Siberian station with Russian reactor designers and with Russians manning exhibits in Exhibition Hall. A number of non-AEC American delegates had already been the recipients of questions in their particular fields served through CIA's Domestic Contact Service before they had left the continental US. These, we correctly felt, could be trusted to ask questions on their own initiative. Still others were carrying out situational gambits devised by their Air Force case officer, who in turn was in touch with us at delegation headquarters.

Much of what these contacts learned was later to be found in the printed technical papers, but some of it came to us in no other way. For instance, one source, a chemical engineer specializing in nuclear reactions, was told by a friend that Russia's S. M. Feinberg said "the reactor has two steam circuits, one operating at 180 degrees C, the other at 30 lbs. per square inch [sic] . The fuel elements are cylindrical tubes holding graphite moderator and the fuel elements themselves. The latter are cylindrical, 10 mm. internal diameter. Through them flows water. The fuel consists of uranium-magnesium, 0.7 mm. thick (presumably cladding thickness) and clad on both sides with aluminum." Source adds that his friend had language difficulties in understanding the fuel element description: he understood the fuel to be "compressed powder." Perhaps, powder metallurgy was used to obtain a uranium-magnesium alloy. Source was very surprised at this design, which was "quite different from our design."

Another source stated "the reactor has 20 control rods—which N:,ere identified by green squares on the 'map.' The control room has an illuminated panel for fuel channel temperature, and there is 'automatic replacement' of fuel by a key at the control panel. ... Under the reactor there is a shielded two-man carriage or gondola for the servicing of mechanical difficulties at the discharge face ..."

A third source stated "... the Soviets were asked directly (by a US scientist) where this reactor was located, but the question was completely ignored ` due to translation difficulties.' This reactor operates on natural uranium fuel elements clad with aluminum silicon (AlSi) alloy of 1-2 percent silicon content. ... Since the AlSi alloy is good only to 200-250 degrees C, I asked the Soviets why they had selected this alloy and not an aluminum nickel alloy (which the Soviets had tested and found to be good to about 300 degrees C). They replied the aluminum nickel alloy absorbed too many neutrons ..."

As one can see from even this limited sampling of reports, each observer found several things to comment on. In addition, there were differences in reporting on many points, and it was impossible to judge offhand what was crucial information and what was merely the expected. Only detailed analysis could answer questions beyond those obvious ones which we could and did pose in Geneva.

So, let us turn to the analysis that was performed in Washington after all the reports on Geneva had been published. The late Frank D. McKeon in CIA's Office of Scientific Intelligence started the analysis by spending hours examining the photographs from Geneva and the U-2 photography of the reactor area at Tomsk. In Manhattan District days during World War II, he had been a procurement officer specializing in the procurement of specialized equipment for the Hanford reactors. Reactor physics was beyond his training, but he thoroughly understood pumps, instrumentation, and safety. He decided the photographs of the reactor upper face, Figures 2a and 2b, and those of the three instrument "boards," Figures 4a and 4b, at the reactor control station supported one another: using the control panels, which were photographically clearer, he counted 20 control rods, 20 safety rods and 2,100 fuel rod positions. In the picture of the upper surface of the reactor (Figures 2a and 2b) each square with a "hole" in the center is positioned over four fuel rods like the one hanging down in Figure 2a. The objects with white tops that stick up like fence posts in Figure 2a are either control or safety rod activating mechanisms. From the appearance of the control rod drive mechanisms Frank concluded the Russians were using a motor and sheave to propel two halves of a vertical control rod; that as one-half was drawn up out of the core into the top shield, the other half was dropped down from the lower half of the core into the lower shield. (His conclusion on the mechanics of the control rods has not stood the test of time, and it is probable that they are much simpler in construction.)

Having determined there were 2,100 fuel rods, there seemed to be a real chance of getting at the physical size and internal details of the reactor. The spacing between fuel rods, for instance, is diagnostic for it depends rather specifically on the type of reactor. For a dual purpose graphite moderated reactor—that is to say for a natural uranium reactor operating in the thermal neutron energy band—this value should be quite close to 8 inches, the variability being mostly due to how dense the synthetic, ultrapure graphite might be and on the physical dimensions of the fuel rods.

The Russians had not happened to mention any reactor dimensions, and it was characteristic of the photographs we had, and indeed of photographs in general, that one known dimension in each picture is needed before detailed measurements can be derived from them. Frank McKeon spent many hours looking for standard items whose dimensions were known. There were none.

Then the hours of staring at the photographs paid off. In one photograph, Figure 3a, there was a fuel element hanging down one wall next to the vertical beam between the first and second windows. Another picture, Figure 3b, showed the wall, the fuel rod, and an air vent in the wall (which looked like a square window) directly below the fuel element. Another (taken "in cinema") showed just the tip of the fuel rod, the air vent, the floor, and part of the reactor upper surface. A final one, Figure 2a, showed the reactor upper surface, the floor and the air vent. We had good (Russian) ground photographs of the exterior of the reactor building, Figure 6a, so the positions of the windows could be judged. And, most important, we had a measured aerial photograph of the reactor building "high hat."

We could get a usable measurement of the upper reactor face, and of the lattice spacing between fuel elements!

One problem remained. Which wall were the windows in? The windows (Figure 6a) in the front, or west, wall of the reactor building "high hat" were visibly closer together than those on the south wall. After much study, Frank McKeon realized that the highlights and the shadows on the wall with the "important" fuel element, Figure 3a, probably were caused by sunlight, rather than by banks of floodlights like those visible in the picture. Floodlights would not be placed to give downward sloping shadows. Furthermore, assuming sunlight was the cause, there is no way to get sunlight shining toward the south at 57 degrees north latitude. It must be a late afternoon sun shining through a west window onto a north wall. In confirmation of this conclusion, the reason the window on the far right of Figure 3a was not readily apparent was because none was in fact there. The aerial photograph showed a square tower elevated 20 feet above the general building roofline on the northeast side. Frank reasoned this was where the emergency reactor cooling water was stored and that it simply blocked where the windows on the eastern half of the north wall would have been placed. So there was quite adequate evidence that the "important" fuel rod was on the north wall.

The measurements branch of what is now the National Photointerpretation Center (NPIC) was now in a position to make the needed measurements. Recognizing that there were five windows on the south wall and, judging from the interior photographs, such as Figure 3a that there was space for seven heavy vertical steel beams, one between each window and one at either end, the length of the "high hat" would be seven beam spacings plus walls and eaves. Assuming six feet for each wall and eave combination, seven beam spacings would be the 126 feet judged from aerial photographs less walls and eaves, or 114 feet (34% meters). So, the heavy vertical members on which the heavy-lift traveling crane rests were probably spaced at 5 meter or 161/2 foot intervals. Recognizing that the "important" fuel rod was somewhat to the left of the third vertical beam while the interior wall surface was to the right of the inner edge of the first beam, NPIC settled on 29 feet for the distance between the corner and the fuel rod.

Working from photograph to photograph, NPIC then derived the measurements given in the illustrations by using standard photomeasurement techniques derived from projective geometry. The reactor turned out to be 37 feet across, with its circular edge 20 feet from the north, west, and, presumably, south walls. Allowing 12 feet for walls and eaves, the building would be 89 feet across, thus agreeing with the 89 feet width derived from aerial photography, a most gratifying check on the methodology. Space was provided toward the eastern wall where heavy objects such as top shield sections could be set down by the crane, should major repairs be required. The 26 square blocks across the reactor face were each 1.42 feet across. To get 2,100 fuel rods in the space given, four fuel rod positions would be needed per square block. In a "square lattice" configuration, the distance between fuel rods would be 0.71 feet or 8Va inches: close enough, considering the precision of measurement, to the 8 inches value expected for a graphite moderated natural uranium reactor!

While waiting for the NPIC measurements to be made, Frank tackled the problem of fuel rod construction. First he looked for some way to measure how long they were. This failed. There were no pictures available showing the tops of the fuel rods and, thus, no way to get a specific measurement of their length. However, he did conclude from Figure 3a and Figure 1 a that if the top of the reactor were at the second story floor level, the rods would have to be somewhat more than 52 feet long.

Then he noticed in one of the "in cinema"[4] photographs that there was a close up of the control rod indicator panel. Each control rod had a gauge in the same position on the panel as the control rod had on the upper reactor surface. The gauge reporting control rod movements on the reactor control panel (upper left in Figure 5a) had a maximum value of 7.5 meters, or 24th feet. The difference between the fully in and fully out positions of a control rod is the length of the active core in a reactor. He had determined that the core of the Siberian power reactor was a vertical cylinder 37 feet in diameter and 24 1/2 feet high!

Knowing that the fuel in the 2,100 fuel rods was about 24 feet long and assuming that the Russians were, in fact, being truthful about the reactor being loaded with 200 metric tons of uranium metal, Frank was able to calculate fuel diameters. These came out as 1.18 inch diameter for the uranium alone if the uranium in the fuel rod were a solid cylinder, and 11/4 inch diameter if the fuel rod had one centimeter hole in the center as suggested earlier in the quote from a DCS source. Frank knew that these shapes and diameters were in excellent agreement with ones then in use in the several Hanford reactors, thereby adding fuel to the concept that the Siberian reactor was a plutonium production reactor modified for dual purpose usage.

Frank also thought it important that there was as much instrumentation on the Siberian reactor as there ever was on the ones at Hanford. The Russians were measuring temperatures, pressures, and flow rates. They were taking no chances that something might go wrong unnoticed. Some of the instrumentation was very bulky compared to ours and awkward to monitor just because of its sheer size. The shot of one of the temperature or pressure recording panels (Figure 5b) is a good illustration. At an American reactor, this enormous installation would be a panel merely 8 feet by 10 feet. But the American installation would do no more, and might not be quite as reliable. So went the old myth that the Russians were sloppy people who did not care who got hurt in their heedless, inept race for nuclear weapons.

At about this point in the analysis, Frank McKeon was transferred to the burgeoning problem of atomic energy in China. Responsibility for analysis of the Tomsk Reactor Area was passed to Jack Lundin, a physical chemist with reactor physics training.[5] Jack called on Charles Reeves[6] to help him identify uniquely the electric power generators and handling equipment visible in the Geneva movie.

Charlie had been collecting Russian books and periodicals on electric power generation for years, and he read technical Russian fluently. First, he noticed in an "in cinema" photograph that the windows behind the turbines were placed equidistant between roof beams, and, presumably, vertical members. Knowing from drawings in the literature that the Russians used 6 meter beam spacing in generator hall construction, he was able to give NPIC an accurate distance on the best photography of the interior of the turbine hall. After checking this assumption against the 1957 aerial photography of the incomplete turbine hall, NPIC in turn was able to give him quite accurate dimensions on the turbines.

Charlie then spent days hunting up engineering drawings of Russian turbines, starting with his five-shelf library. The Leningrad VK-100-2, 100 MW turbine, shown on page 327 of "Energetecheskoe Stroitel'stvo SSSR Za 40 Let," which he fortunately possessed, or the Leningrad SVK-150 MW turbine, shown in the same anniversary volume, did not resemble the Siberian turbines, Figure 7a, at all closely. The Kharkov KhTGZ type PVK-150 was more like the turbine in the Siberian station in pattern, but it did not have a flared base nor manholes low on the side. He hunted further. On page 46 of the journal "Elektricheskie Stantsii" for November 1957, he found a picture of the low pressure end of the Kharkov KhTGZ type VKT-100 turbine which was what he was looking for. The inlet steam temperature would have to be about 108 degrees C. at 1.36 atmosphere pressure. Steam flow would be 298 metric tons per hour to yield 32 MW of electricity. There was no sign of a high pressure end to the turbines in the pictures of the Siberian station. Station efficiency must indeed be 14 percent, not the 22 percent stated by the Russians.

These values on turbine operation were of great importance. They bore directly on the possible power levels of the reactor and on the range of likely flow rates in the primary cooling circuit through the reactor, both prime factors in defining the 1958 status of Russian reactor technology. Jack and Charlie compared the photographs and the technical drawings of the VKT-100 turbine exhaustively. They matched bolt to bolt, hatch to hatch, dimension to dimension. They made sure the cooling towers would dissipate 200 MW of heat. They checked the transformers (Figure 7b) to be sure they were a compatible size. All the pieces were consistent with one another.

Two additional facts were available. First, the published papers from Geneva confirmed the maximum fuel rod temperature of 220 C. reported by a DCS source. Secondly, the 1957 U-2 photography of the dual purpose reactor under construction showed an effluent line from the main reactor pumphouse: the dual purpose reactor was designed so that hot water could be pumped round and round through the reactor; or alternatively cold water could be pumped into the reactor, heated there, have its temperature reduced in the steam generators to near the boiling point, and then discharged to the effluent line after mixing with a bit of cold water.

Taking both these additional facts into account provided unique answers: the flow through the reactors should be about 42,000 gallons of primary circuit cooling water. If operated so the primary circuit recirculated through the main pumphouse (see Figure 6b), the reactor would produce 700 MW, of which 100 MW was turned into electricity and the remaining 600 MW was discharged through the four cooling towers. If the primary circuit water was discharged as steaming hot water into the effluent channel, the reactor power level would be 1,700 MW—and plutonium production would be correspondingly large; electrical production would remain at 100 MW, and the cooling towers would steam off 600 MW as in the closed cycle case. Truly the Siberian reactor was designed to produce plutonium and a bit of by-product electric power.

This, then, is the story of how we had been able to collect the pictures, the technical papers, the intelligence reports from the Second Geneva Conference on the Peaceful Uses of Atomic Energy and deduce from them with very great precision indeed the technical characteristics of Russian plutonium production reactors—one of the great "military" secrets of the USSR.

BIBLIOGRAPHY

1 In response to requirements by the Joint Atomic Energy Intelligence Committee.

2 See "Mission to Birch Woods," *Studies* Vol. 12, No. 4, p. 1

3 Despite my all too vocal insistence that it could not be done!

4 The "in cinema" photographs have not been reproduced because of their lack of sharpness, a result of the adverse conditions under which they were taken.

5 See "The Red Nautilus," *Studies* Vol. 11, No. 2, p_ 59

6 See "How to Decrypt a Picture," *Studies* Vol. 11, No. 3, p. 41

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