Puzzling out the power supply to Urals atom plants.

THE DECRYPTION OF A PICTURE

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One day in August 1958 Charles V. Reeves showed me a picture of the Sverdlovsk Central Despatching Office of the Urals Electric Power System which he had found in the July issue of *Ogonëk*, the Soviet equivalent of *Look* magazine. He remarked that at the Boston Edison Company he had controlled electric power generation and flow in the Boston metropolitan area from just such a despatching station.

Charlie had been recommended to us in CIA's Nuclear Energy Division by the President of the New England Electric Power Company (and Chairman of the DCI's Panel on Nuclear Energy) because of his professional experience and linguistic ability. His task was to assemble data on generating stations and transmission lines in the neighborhood of known or suspected Soviet atomic energy sites as a basis for determining the electric power consumption at those sites. (The output of fissionable materials from a plant is directly proportional to the amount of power it consumes.) This work was to complement that being done by the Electric Power Branch of the CIA economic research organization, which was attempting to estimate power generation and ordinary consumption in atomic industry areas in order, *inter alia*, to arrive at the consumption of the atomic facilities by subtraction. Symbolically Charlie worked in megawatts or power flow; the economic analysts worked in kilowatt hours or energy produced and consumed, the method appropriate to the varying loads of most normal industry. There was considerable doubt at the management level whether either method, or both combined, would ever yield reliable estimates on the power consumption of atomic industry.

The Urals of course constituted a most important atomic energy region. Kyshtym, between Sverdlovsk and Chelyabinsk, was the site of the Soviets' major plutonium-producing complex. North of Sverdlovsk, at Verkh Neyvinsk, was a gaseous diffusion plant producing U-235. Still farther north, near Nizhnyaya Tura, was an unidentified atomic complex in a firmly closed area. The nub of Charlie's problem was to pin down the power flow to these three facilities.

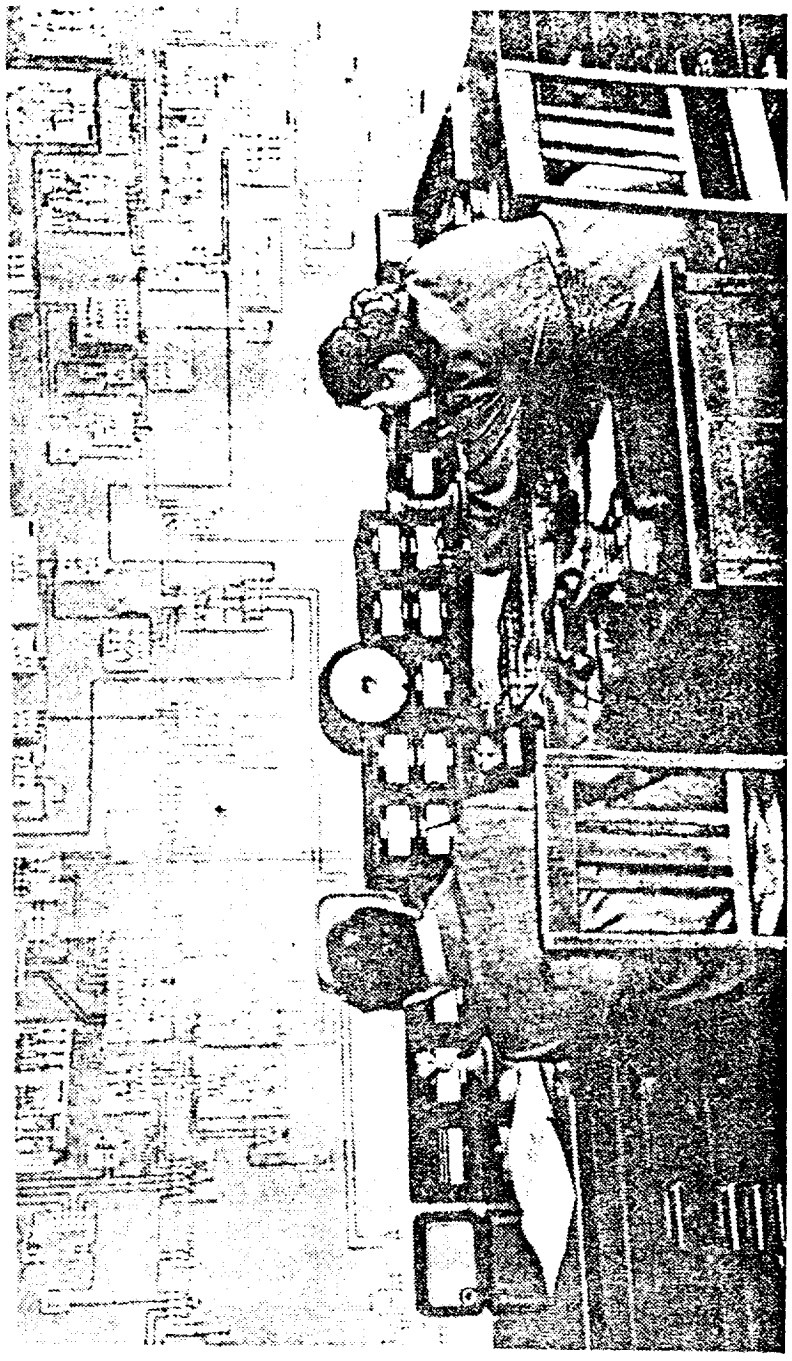

FIGURE 1. The Central Despatching Office in Sverdlovsk

The Soviets considered electric power generation, transmission, and usage in the Urals a classified subject. All published articles were censored, and the censor knew his business. Travel in the area except to and through Perm (then Molotov), Sverdlovsk, and Chelyabinsk was severely restricted. The only available serious discussions of the Urals power network as a whole were two intelligence reports produced in 1944 for the German general staff.

A Riddle to Read

The board on the wall in *Ogonëk*'s picture looked like a schematic diagram of major power plants, with their transmission lines and the users' substations—all the information necessary for pushbutton and telephonic control of the whole Urals electric system. Charlie teasingly suggested that the very thing we were looking for, the disposition of electric power feeds to the atomic sites, was actually laid before us in this photograph. Naturally, I rose to the bait and proposed that "we" read it out. Charlie smiled gently and pointed to the taped-over names and meters, showing the usual careful censorship. Charlie is very tolerant of the foibles of the young; one would never guess that he had worked his way through MIT as a heavyweight boxer.

Yet I couldn't put it down. In vain Charlie pointed out that the photograph did not cover the whole board; it had been clipped. The censorship had probably been even more thorough than it appeared. He had never seen a Russian despatching station. He did not know the meaning of the indistinct symbols on the board, nor did he know of anyone else in America or Britain who did.

I continued to badger him. I suggested this, I suggested that. The discussion went on intermittently for days. Never have I lost so many arguments in a good cause.

The problem gradually shook down into a number of distinct questions. Was this just the Sverdlovsk area, or did it represent a substantial portion of the total Urals network? If the latter, did it include electric power producers in Perm, Sverdlovsk, Chelyabinsk, Kurgan, and Chkalov (Orenburg) oblasts, along with Bashkir and Udmurt ASSRs, or only the Uralenergo-operated stations in Sverdlovsk and Chelyabinsk oblasts? Charlie had citations to prove that the Russian terminology was ambiguous on this point.

Did the board depict only the big 220 kilovolt and 110 kilovolt transmission lines, or did it include perhaps 35 KV, 10 KV, and even lower-voltage lines? The main Urals transmission network runs generally

north and south: were north and south left and right in the picture—or was it really as scrambled as it looked?

What was represented by the indistinct symbols on the individual rectangular boards? Did these indicate just the switches, which might be expected to be under centralized control, or did they include transformers and generators as well? Since each generator puts out three alternating currents of differing phase, each transmission line contains three separate conductors and each switch is really three switches: were these shown separately?

Inspection showed at least two kinds of boards, one containing many different types of symbols, the other fewer types. Could the one represent the complicated generating stations and the other the simpler main substations? If the simpler boards were substations, did the dots on them mean switches, or transformers? If the latter, one could estimate within narrow limits the amount of power flowing through the large main substations. If they were switches, one could not use the substation boards for estimating power flow but would have to calculate it on the basis of network theory from the number of transmission lines and the output of the generating plants connected to them.

If the more complicated boards represented generating stations, the dots on them on the side opposite the transmission lines might represent turbogenerators. The number of such dots on a board might then identify it with a plant known to have that number of generators. Here Charlie had a few straws in the vast sea of ignorance. In 1957 a British power delegation had visited the Mid-Urals GRES (regional power plant) north of Sverdlovsk and the South Urals GRES outside Chelyabinsk. These definitely had 5 and 8 turbogenerators respectively. Beyond that it was mostly conjecture. He had a single press reference to the eleventh and twelfth boilers in the power plant at Nizhnyaya Tura near the northern mystery complex, but no way to relate the number of boilers to the number of turbogenerators. He had found brief references to 6 or 7 turbines at Verkhniy Tagil GRES near Kirovgrad, at least 5 turbines at Serov in the far north. He knew that Argayash TETS (steam-heat-and-power plant), presumably serving Kyshtym, had reached "full capacity" in 1957, but had no idea of the number of turbines or their sizes. He knew of the existence of a "large" generating station east southeast of Sverdlovsk, at Kamensk Ural'sk, mainly supplying the aluminum plant there, and of two power

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plants supplying the town and local industry at Nizhniy Tagil, back to the north. He had references to dozens of smaller plants.

Thus "we" were faced with a series of multiple choices which had to be clearly understood before any solution was possible. The purpose of these preliminary (though lengthy) discussions between Charlie and me was so to structure the problem that the choices became clear and improbable solutions were discarded. Once this was thoroughly accomplished, the type of evidence needed to select between alternatives could be rationally discussed and ferreted out.

Frame of Reference

One day light dawned. Charlie recognized the big board in the lower left corner of the picture as Kama Hydroelectric Station near Perm. The station was unusual, having 24 small hydroelectric generators. When I objected that the meter in front of the board obscured the number of generators on it, Charlie only shrugged. The board was so long that it had to have a lot of generators on it; but what he had recognized, from a diagram in a Soviet trade journal, was the hookup of its transmission lines!

From there he went on: The Soviets had published the information that in 1955-57 two 220 KV lines had been built from Kama Hydroelectric Station to South Substation serving Sverdlovsk. There they met a 220 KV line coming in from the east, from Kamensk; but originating at the South Urals GRES and running north by way of Shagol Substation in Chelyabinsk. This made the Sverdlovsk South Substation the large vertical board in the middle of the picture, Kamensk the small one above its right edge (the transmission line apparently passed by there without connecting), the South Urals GRES the large horizontal one at the far right, and the Shagol Substation the one to the left above its top edge.

If he was reading the symbols for turbogenerators correctly, the South Urals GRES board showed 8 of them, in agreement with both the 1957 observations of the British power delegation and a schematic diagram of turbines and boilers at this station appearing on the back cover of the June 1957 issue of *Teploenergetika*. As for the Mid-Urals GRES north of Sverdlovsk, the horizontal rectangle second to the left from South Substation seemed to have symbols indicating 5 turbogenerators, as noted by the British power delegation.

Identifying these stations, in a preliminary fashion at least, he could also conclude that by and large only 220 KV and 110 KV

transmission lines were depicted and that the board probably covered all of the Urals and adjacent oblasts, oriented roughly with south to the right, east toward the top, and north to the left. The original 110 KV line running the length of the Urals in the early 1940's therefore corresponded to the more or less horizontal line structure running all the way across the board about half way up. Thus, as one does in assembling a puzzle, he had found some pieces to start framing in the picture and an interesting grouping in the middle.

Filling In

It took Charlie another three months before he was sure of his understanding of all the detail in the picture, and two more months after that before he had worked out all the implications. He said later that he had used 103 references from Soviet newpapers and technical journals, 4 reports of delegation visits, 11 POW returnee reports, and perhaps 25 local photographs. While this estimate may be low in the sense that he probably recalled only the more important items of information, it does illustrate the tremendous amount of detail he had to assemble in order to accomplish his purpose.

He was aided by several strokes of good fortune. First, he had found in *Elektricheskiye Stantsii* No. 12, 1948, a short report on a three-day conference in Moscow which laid out a major plan for power expansion in the Urals. He followed this religiously as being a published blueprint of intended expansion mostly for atomic energy purposes, and he turned out to be right. Secondly, the Soviets published in late 1958 a book celebrating the 40th anniversary of electric power in the Urals, *Energetika Urala za 40 Let*, which contained much useful information, not the least of it an authoritative diagram of the Urals power network in 1945. (See Figure 2.) Thirdly, two photographic balloons were recovered belatedly with photographs that showed power line traces south and west of Sverdlovsk and in the Nizhniy Tagil area. Finally, he found a copy of the July 1958 Ogonëk picture that had been cropped just a bit higher up. This enabled him to infer the existence of a 220 KV substation at Verkh Neyvinsk, presumably for the U-235 gaseous diffusion plant, that had not been indicated in the original copy.

Even after Charlie had firmly established what the visible portion of board in the picture generally comprised (for the completed layout see the overlay in Figure 3), he had several major problems. It was easy to suggest the positions of the three atomic energy complexes—Kyshtym at right middle, Verkh Neyvinsk at left center top and

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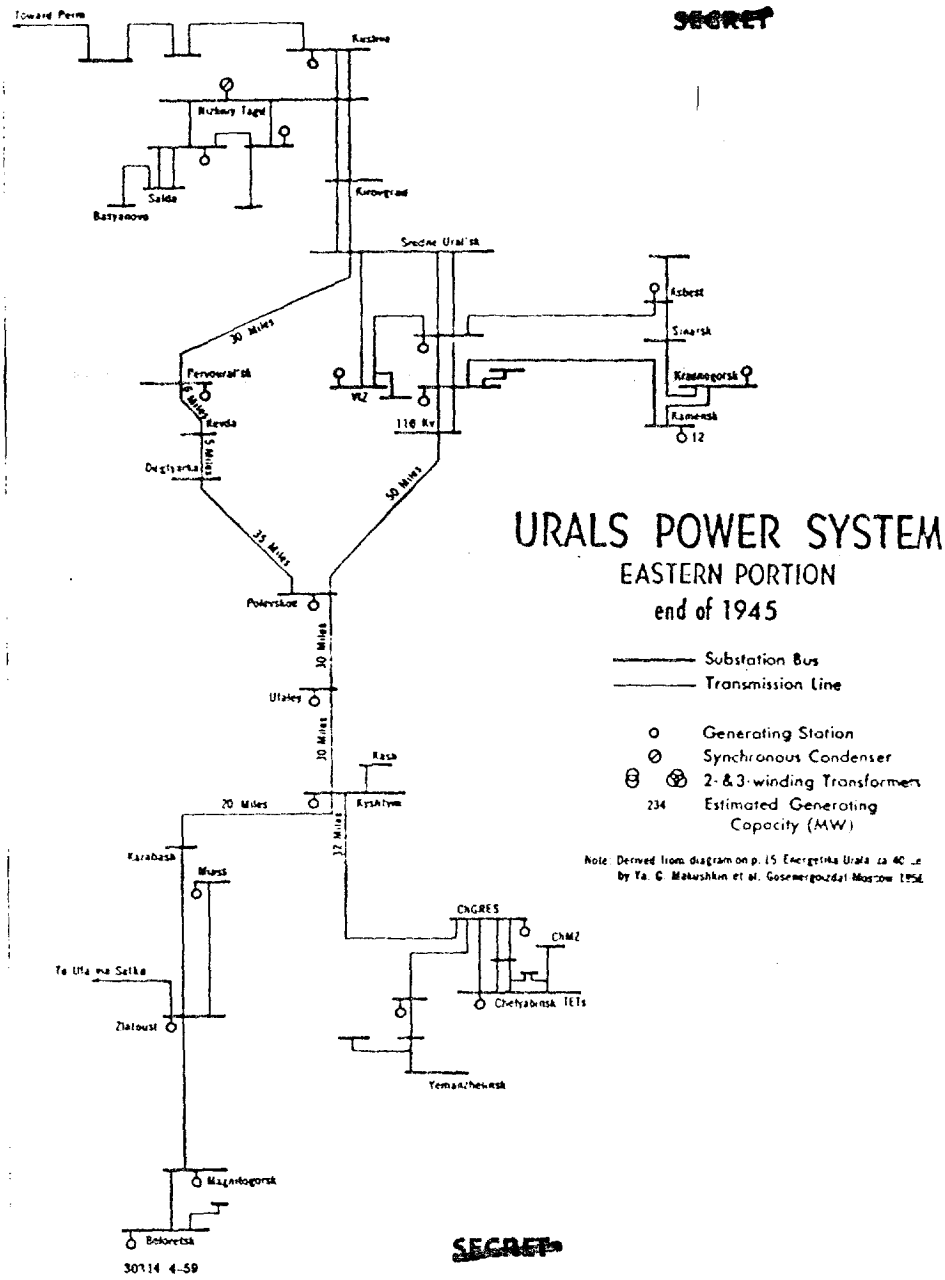

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FIGURE 2

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Nizhnyaya Tura probably at left edge—for they were represented by large substations not needed to serve cities. Then, assuming that the large power station in the far north at Serov was not included on the visible part of the board, he could infer that the big rectangle at upper left was Nizhnyaya Tura GRES; but until late 1958 he could not be sure because none of the seven references he had to the plant indicated the total number of generators. The fortieth anniversary volume finally confirmed his deductions by mentioning turbogenerator No. 9, which agreed with the nine dots in the photo.

Trouble began with the fact that the lines between Kama Hydroelectric Station and Nizhnyaya Tura GRES were cropped by the left edge of the picture, so that it was impossible to decrypt this section of the network by counting known substations. Charlie would have to start in Sverdlovsk or Chelyabinsk (with their complex generation and usage patterns) and work outwards. But even his understanding of the Sverdlovsk area was impeded, oddly, by the fact that the transmission lines out of the Nizhnyaya Tura GRES, more than 100 miles to the north, were cropped from the top of picture: the technical press had recorded the construction of two 220 KV transmission lines from there to Sverdlovsk, but the picture showed only one line leading to the Sverdlovsk South Substation from the north.

Charlie went at the problem logically, step by step. First he assembled every POW report and ground photograph of transmission lines in the general Sverdlovsk area. (Most of these had come in as a result of general requirements he had circulated two years earlier.) He plotted each reference on a large-scale map, comparing results with what he expected. That he did not know within 20 miles the location of South Substation was a considerable disadvantage; it was the one Sverdlovsk substation he had surely identified on the board. In the absence of any attaché or POW reporting that identified a north-south 220 KV line passing through Sverdlovsk, he had to consider the possibility that South Substation was really a cover name for the one serving the gaseous diffusion plant at Verkh Neyvinsk to the north.

His plotting of all the collateral information did enable him to establish a 110 KV loop from Sverdlovsk east through Kamensk, north via Krasnogorsk, Sinarsk, and Asbest, then back to Sverdlovsk. He also had bits and pieces of what looked like a loop from the Mid-Urals GRES north of Sverdlovsk westward to Pervoural'sk, then south to Revda and Degtyarka, and then perhaps east either to Sverdlovsk again

or more southerly to Polevskoy. Most of this loop had been hidden by foreground in the Ogonëk picture.

Then, checking the photographic record of all balloon flights in the Urals area, he discovered west of Sverdlovsk the trace of the 220 KV lines from Kama Hydroelectric Station to South Substation at a point far south of its expected route. This proved that South Substation was well south of Sverdlovsk and south of any other unknown substation likely to serve Sverdlovsk. The 85 miles of 220 KV line that had been reported built between South Substation and Kamensk on the east (connecting with the southerly leg from Shagol/Chelyabinsk) measured out accurately on the map.

Inspection of another balloon photograph proved that there was no 220 KV line between South Substation and Polevskoy. At the same time it located the path of the 110 KV lines between these two locations and established from the width of the trace through the trees that this section of the Urals power network consisted of probably two 110 KV lines. On the despatchers' board this made Polevskoy the rectangle just to the right of South Substation, and the terminus of the 110 KV loop via Pervoural'sk and Degtyarka as well.

Solution

It was the fortieth anniversary volume on Urals power that found the missing 220 KV line from Nizhnyaya Tura "to Sverdlovsk." It stated that the 102 miles of the first such line went into service in August 1951. Charlie methodically measured off 102 miles from Nizhnyaya Tura along the railroad and found he had reached Verkh Neyvinsk, not Sverdlovsk. He measured off several more transmission line distances and checked these against all the press references in his files to numbers of miles of transmission line built each quarter or year. All these figures were explainable. Thus, even though the 220 KV lines from Nizhnyaya Tura to Verkh Neyvinsk were cropped off the Ogonëk picture, he was able to prove the existence of two such lines and show that only one went on at that time from Verkh Neyvinsk to South Substation.

Eventually a photographic balloon was recovered in Iceland from a watery resting place. This proved that the 220 KV right of way bypassed Nizhniy Tagil, so that the whole purpose of Nizhnyaya Tura GRES was to supply the unknown atomic industry at Nizhnyaya Tura and the U-235 plant in Verkh Neyvinsk.

Once this was all worked out, the rest of the north Urals fell into place rapidly. Verkhniy Tagil GRES was identified below the right edge

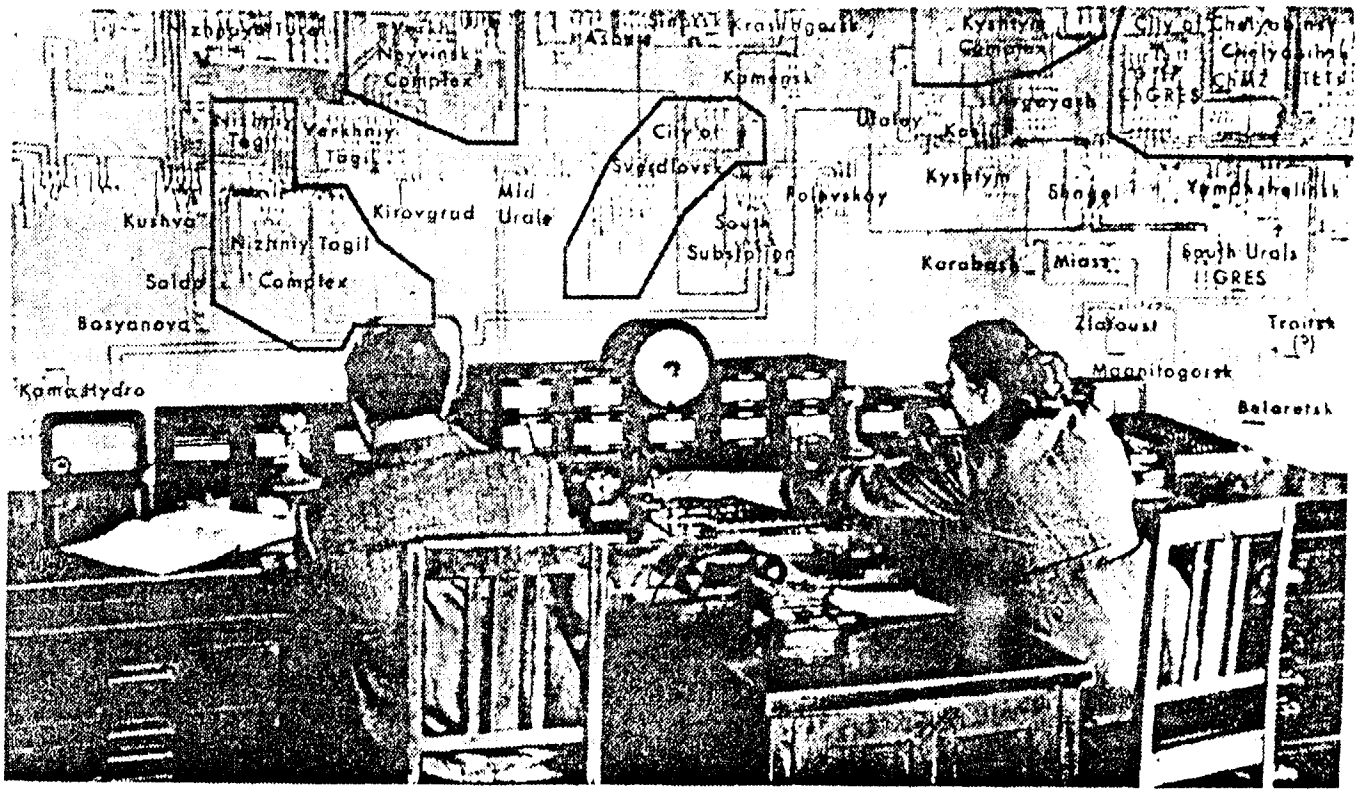

Kushva
Nizhniy Tagil Complex
Kirovgrad
Mid Urals
City of Sverdlovsk
South Subsystem
Polevskoy
Kyshtym Complex
Kamensk
Asbest
Karabash
Miass
South Urals GRES
Zlatoust
Magnitogorsk
Beloretsk
Kama Hydro
Basyanova
Soldp

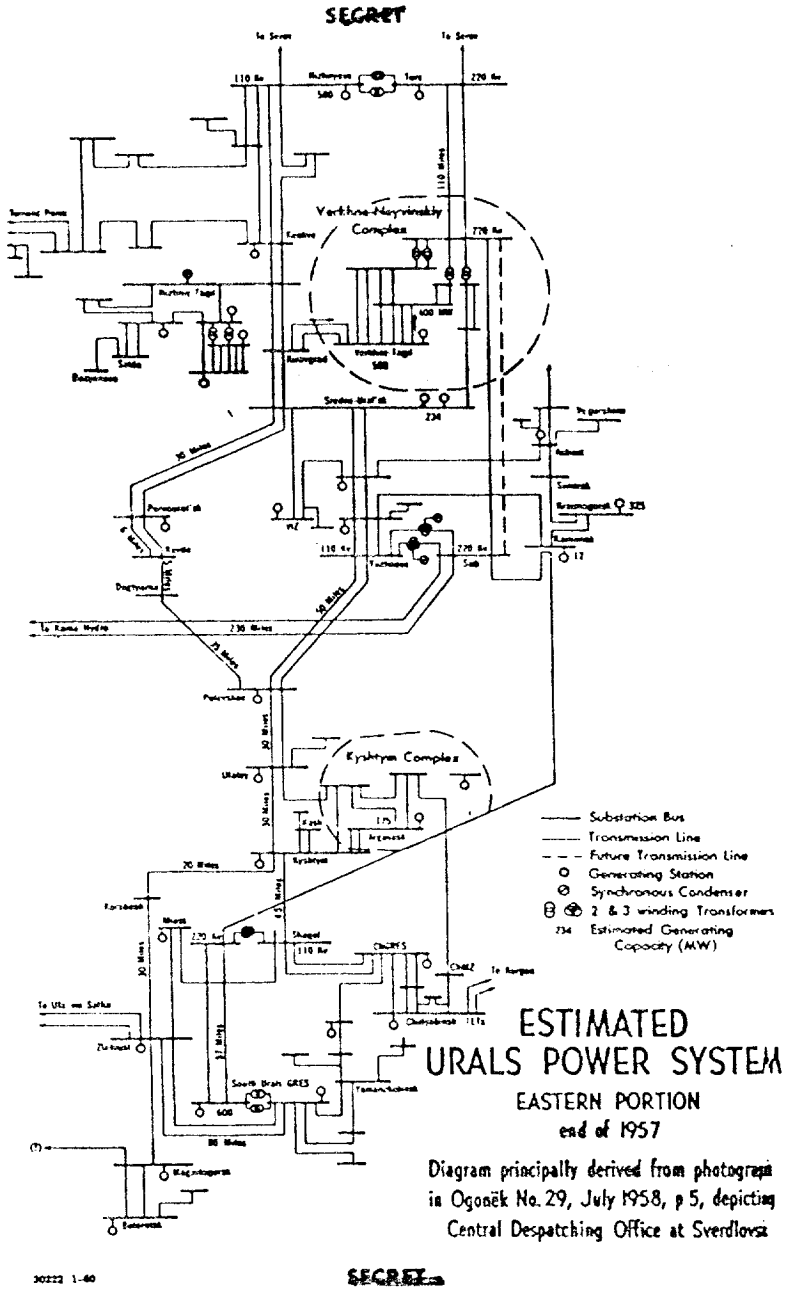
FIGURE 3

of Nizhnyaya Tura GRES and seen to have 5, rather than "6 or 7" generators on stream at the time of the photograph (and the date of the photograph thus established as between mid-1957 and July 1958). The power supply to the Verkh Neyvinsk complex could be estimated with assurance to be carried over seven 110 KV lines and three 220 KV lines.

When the location of Polevskoy on the board was definitely established, the south and east Urals transmission network likewise soon became clear. Argayash TETS was identified as the big board above and to the left of Shagol Substation and could be seen to have seven turbines. The electric power (and steam) supply to the Kyshtym reactor site proved to be mainly from Argayash TETS, with backup from all nearby stations north, south, and west.

Thus in April 1959 Charlie was able, on the basis of network theory, to state confidently that the electric power supply to the U-235 production plant at Verkh Neyvinsk was 1,000 megawatts plus or minus 15 percent, about one-half of that consumed by the Oak Ridge installation in the United States. He judged the power consumption of the plutonium reactor at Kyshtym to be 150 megawatts plus or minus 30 percent. Up to 100 megawatts was apparently consumed by the unidentified complex near Nizhnyaya Tura in the north. His final diagram of the Urals power network is given in Figure 4. A complete history and carefully devised estimate of electric power supply to atomic sites in the Urals from 1947 through 1957 lay in the future—a year's hard, detailed work in conjunction with the economic analysts, reference by reference and report by report.

Charlie was to get confirmation of his theories and deductions within the year, an event that happens all too seldom in the intelligence business—except when catastrophe strikes. In July 1959 a U-2 photographed both Nizhnyaya Tura and Verkh Neyvinsk, Kyshtym being cloud-covered. Charlie was right on the substation array at the Nizhnyaya Tura complex, which turned out to be a nuclear weapons fabrication and stockpile site. The Verkh Neyvinsk gaseous diffusion plant had substations much like Charlie had deduced, though one had been cropped from the Ogonëk picture. His view that the dots nearest the transmission lines represented switches rather than transformers proved correct, and his decision to estimate power usage from lines and generating stations rather than from substations was vindicated. Detailed examination of the U-2 photography showed that his estimate on power usage at Verkh Neyvinsk was only about 10 percent high, a truly remarkable achievement from a censored photograph.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Verkhne-Neyvinskiy Complex
Kyshtym Complex
Substation Bus
Transmission Line
Future Transmission Line
Generating Station
Synchronous Condenser
2 & 3 winding Transformers
Estimated Generating Capacity (MW)
ESTIMATED
URALS POWER SYSTEM
EASTERN PORTION
end of 1957
Diagram principally derived from photograph in Ogonëk No. 29, July 1958, p 5, depicting Central Despatching Office at Sverdlovsk
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FIGURE 4