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USSR PRACTICES IN HEAT AND POWER SUPPLY

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U.S.S.R. PRACTICES IN HEAT AND POWER SUPPLY

by

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On March 20, 1976, the United States and the Soviet Union signed a joint agreement on the cooperation the "Field of Housing and Other Construction". As a result of this agreement, a number of committees involving specialists in the fields of building construction, community and urban planning and supporting utilities was formed by both sides and a program of exchange visits was started.

I am a member of a subcommittee serving the broad and general committee on External Utilities. These utilities cover street lighting, water, gas, power and heat supply. The subcommittee I serve deals with district heating and cogeneration. Because Russian practices in supplying heat and power to urban areas differ appreciably from our own, this talk addresses itself to what we learned, saw and photographed in two trips to the U.S.S.R.

Central to this difference is, of course, the distinguishing characteristics of a planned versus a free market economy and the at least official absence of a monetary profit or specified return-on-investment motive in the U.S.S.R. In an era of accelerating fossil fuel shortages and uncertain fuel supplies, the energy conserving advantages of large scale district heating and central cogeneration facilities furnishing power and heat to a significant percentage of a population housed in high density areas are so important as to deserve thorough evaluation and consideration in our own future community, urban and energy planning.

On our first trip to the U.S.S.R. in 1977, the delegation made the "grand tour" - Moscow, Kiev, Leningrad. This visit, its many and often conflicting and not readily understood impressions and statements, especially in view of the language barrier, our inability to analyze and sort out a wealth of numerical data expressed in metric engineering units while being whisked about on a tight schedule, left me somewhat bewildered and confused. Not until I returned home and upon reflecting did I attempt to make sense out of the information and data given us fairly freely and willingly. Incidentally, we were allowed to photograph at will the exterior and interior views of all but hydroelectric plants.

In Moscow and Kiev the delegation met with personnel from a wide variety of U.S.S.R. ministries and institutes including: The Ministry of Power Engineering and Electrification; Ministry for Specialized Construction and Installation;

Utilities Board of Moscow; Moscow Design Institute; Central Research and Design Institute for Engineering Systems of Buildings; Kiev Office, Research and Design Institute.

To this date we were unable to either obtain an organization chart or concise clarifications as to interrelationships, authorities and responsibilities of ministries, institutes, boards, and whatever other agencies we visited. One of the difficulties on both our trips was the inability to find out in advance of our travel what we were to see and whom we were to meet. To obtain names and titles of plant managers and staff attending our meetings is always difficult, and most often incomplete. Calling cards are not available in most instances.

While our second trip clarified some of the principal interrelationships somewhat, how the whole - academy of science - engineering institutes - R&D institutes - construction and industrial complex relationship - works is a mystery.

New towns or satellite communities are built peripherally around an existing, established city so that the ultimate size of the entire community falls within a radius of a two-hour round trip by public transportation from the town center to the community's extreme periphery. This corresponds to a radius of about 100 kilometers (60 miles). We believe that the two hour travel time limit is optimistic even though public transportation in the large cities seems to be excellent.

The U.S.S.R. attempts to design new power and heat supply systems, and I suspect all infrastructures, on a five-to-ten year load prediction basis, subdivided into phased construction steps. This is heavily supported by standardization of planned communities and structures, including predictable allocation of basic industry and secondary, supporting industries. Though their ability to plan with somewhat greater accuracy than our own makes the planner's life easier, they admitted their own difficulties in accurately predicting load patterns which are directly tied to population and industrial growth. Our second trip confirmed this, when we visited Togliatti, one of the fastest growing new towns approximately 500 miles southeast of Moscow.

The installation of a district heating system which furnishes heat to one or several urban systems from a single or a number of central heating stations tied together by means of an underground pipe distribution network carrying hot water is the first step in the heat supply scheme of new Russian communities.

The Moscow hot water district heating plant shown in slide No. 1 is one of three supplying heat to a new community of about 250,000 people housed in about 62,500 apartments in 500 buildings of standardized construction shown in slide No. 2.

We were told that approximately 38 million square feet of residential area plus 20 percent service area is being added annually. U.S.S.R. standards for newly built housing prescribe 580 square feet of living space (excluding kitchen, bath and hallways) for an average family so that approximately 57,000 dwelling units are added annually to this complex.

The plant contained six gas fired hot water boilers, each having a capacity of 200 million BTU per hour, or a total installed capacity of 1.2 Billion BTU per hr., enough to heat approximately 30,000 apartments. Winter hot water supply temperature is 300°F maximum, summer for domestic hot water use 140° to 160°F. Three hot water circulation pumps, each driven by a 700 HP motor capable of pumping 6600 gallons per minute through the system provide the means to distribute heat to the complex. A pump room of this type is shown in Slide No. 3. The number of boilers fired depends upon ambient outdoor temperature and is adjusted in accordance with specifications relating hot water supply temperatures to outdoor temperatures. This is an energy conserving operating feature. On the day of our visit, June 14, 1977, only two boilers were firing to satisfy the domestic hot water demands of the entire complex.

The heating season starts in October and ends in mid-May. During that time all three plants serving the system are in operation, connected to a common network, but equally capable of being isolated from the network (in case of any one plant failure) and serving its own area. During the summer months, two plants are shut down for scheduled maintenance and repair work and only one furnishes domestic hot water to the entire community. There are 15 district heating plants serving the Moscow district having a total capacity of 16 billion BTU per hr. The Moscow heat distribution network comprises 1800 miles of pipelines. It is the most developed centralized heat supply system in the world.

The type of plant visited is of standard design which can be built in one year, having allowed eight months to one year for design time. District heating plants are normally intended for a life of six years, after which time the community has reached sufficient size to be disconnected from the heating plant and joined to a thermal power plant. As we learned on our second trip, however, the district heating plant often remains to preheat the fuel oil serving the thermal power plant boilers, or to take on the peak boiler duty of a thermal power plant.

A thermal power plant is one which coproduces power and heat.

What is the criterion for the installation of a thermal power or combined heat and power plant? (TETS - Teploelektri-cheskiyeTscentral). Once a community reaches a minimum electrical load of 200 MW_e construction of a thermal power plant appears warranted. A thermal power or cogeneration plant essentially consists of high pressure steam boilers, extraction/condensing turbo-generators and auxiliary hot water thermal peak boilers. An extraction turbine usually has one or more steam bleed points at pressures suitable for the particular application (space, domestic hot water or industrial). For space and domestic hot water use, the steam generates hot water in heat exchangers and the water is then pumped either directly through the connected pipe distribution network or through auxiliary hot water boilers where its temperature is raised sufficiently to meet extremely cold ambient outdoor temperature conditions, and then through the network. All thermal power plants are connected to their respective regional grid which already shows an astounding degree of interconnection.

Slides Nos. 4 and 5 show a 250 MW_e turbo-generator installed in the Kiev No. 5 Combined Heat-Electric Power Station, one of the newest and most modern plants belonging to the TETS utility system. Construction started in 1965, operation in 1970. This plant meets the electrical and heating needs of half of Kiev's population, approximately one million people.

The plant complex contains residences for 400 employees, two rest houses, sports complex, a (shared) health clinic, and a cultural center.

Its total capacity is 800 MW_e and 6 billion BTU per hr thermal.

We saw a similar plant in Moscow having a total capacity of 1100 MW_e and 15 billion BTU per hr thermal.

Moscow has 13 combined heat and power plants of an overall heating capacity of 80 billion BTU per hour. These, together with the district heating plants, have a total combined capacity of 96 billion BTU per hour. This enormous heating network is connected to 40,000 residential and non-residential buildings and 500 industrial enterprises.

In Leningrad we saw another combined heat and power plant of 330 MW_e and 7 billion BTU per hr thermal capacity.

The noteworthy aspects of these plants lie in their degree of standardization, their specific heat consumption which is a measure of efficiency, their large heat distribution systems, and their proliferation.

The U.S.S.R. currently designs standard TETS modules of 250 MW_e turbo-generator capacity. These modules are installed all over the country as either new plant or expansion requirements dictate. The standardized design saves a great deal of engineering and design time and expense and also simplifies equipment fabrication and spare parts inventories.

In 1975 conventional steam-electric condensing power stations in the U.S.S.R. (KES plants) had heat rates of 10,258 BTU per KWH which correspond to a thermal efficiency of 33%; heat and power (TETS) stations, however, reached heat rates as low as 7840 BTU per KWH or thermal efficiencies of 44% provided they are fueled by oil or gas. Systems that depend on low-quality solid fuels suffer from unfavorable heat rates even when their stations are modern.

Average U.S. heat rates of steam-electric condensing power stations in 1975 were estimated to be 9574 BTU per KWH or 36 percent thermally efficient. No comparison with U.S. thermal power or cogeneration stations can be made. To the best of my knowledge, no published data on such plants, even if they existed, are available.

The scale and distribution system size of Soviet District Heating and Thermal Power Plant Technology is indeed surprising. Our field trip to a Leningrad Heat and Power Station under construction exemplifies this statement. Slides Nos. 6, 7, 8 and 9 show a prefabricated, preinsulated underground hot water supply and return piping system being installed in an underground tunnel. The tunnel is made up of prefabricated panels. Standard main pipe diameters for external (outside buildings) heat distribution networks vary from 12 inches to 4 ft 7 inches in diameter and are production standardized in increments of 100 mm (approximately 4 inches).

The previously mentioned Moscow plant pumps 198,000 gallons per minute of hot water during the winter season, transmitting 15 billion BTU of heat per hour, enough to heat about 500,000 apartments. By comparison, one of the largest non-military U.S. residential complexes heated by a central plant, Co-Op City in New York, has approximately 15,000 apartments.

The share of urban heat consumption covered by Heat and Power Stations in the U.S.S.R. was 49% for industrial and 27% for residential purposes in 1975 and the 1980 plan calls for a 50% industrial and 33% residential participation. The overall urban energy consumption by 1980 is expected to be met to the tune of 44.6% from combined heat and power plants. This is an astonishing figure by our standards.

It should be kept in mind though, that the Soviet pattern of electricity consumption differs greatly from the American. In the U.S.S.R., industry consistently received the greater share of power, in contrast to the United States where the residential-commercial economy has long surpassed manufacturing as the largest power user. That is why the prime effort in effective energy conservation in our country should be directed to the residential-commercial area, industry having already posted the best record of any sector in energy savings since 1973 (though it still remains below its potential).

While industry's portion in Soviet net consumption is gradually declining, it still received 67% of all power in the mid 1970's compared with about 40% in the United States. Soviet industry is electrified to nearly four-fifths of the level of United States industry, even though per capita consumption in the U.S.S.R. is less than half of the American level. The residential-commercial sector received only 13% in 1975, with the domestic economy itself taking less than 5%. In contrast to the high level of electrification of U.S.S.R. industry, per capita consumption of power in Soviet urban households reaches but a third of that in United States homes, and in rural households less than 20%.

How does all this affect the average citizen? The degree of standardization and modular construction of power plants and massive prefabricated apartment houses affords the Soviet government the opportunity to construct large housing complexes and associated utilities fairly rapidly, labor supply and skills apparently being the limiting factor. The results are drab, shoddy and unappealing but, in terms of Soviet standards, a vast improvement over former living conditions. In a country where many people still live in dormitories on a 4 square meter (43 square feet) per person allocation, or where many families share apartments, to have one's own apartment in a large city, and especially in Moscow, is a highly valued possession.

Apartments are allocated by the government. Families having less than 4 square meters of living space per person are in line for obtaining a flat. The phrase "in line" is to be taken literally. Waiting in line is endemic to Russian life, like eating borscht or drinking vodka. Even with connections or influence (the Russians call it blat), it may take two years to be the lucky recipient of a new apartment (as was the case of a Russian engineer from Kiev, who immigrated to the United States two months ago). Incidentally, blat is a vital and pervasive system of Russian life and provides a creative outlet for the Russian entrepreneural spirit.

The above-mentioned engineer from Kiev tells me that the Soviet government allocates two types of apartments: To those who cannot afford the purchase of a cooperative apartment they rent one having 9 to 13 square meters (97 to 140 ft^2) per person of living space. Living space excludes kitchen, bathroom and hallways. Monthly rent is 17 rubles including all utilities except electricity and telephone. (One ruble = $1.33 and 100 Kopeks = 1 ruble). He, having had a friend in the cooperative purchased a 48 square meter (516 square feet) two bedroom cooperative for 7,000 rubles, of which 2,000 rubles constituted the down payment, the remainder to be paid in monthly installments of 40 rubles per month for fifteen years - excluding electricity and telephone but including all other utility and maintenance charges. After fifteen years he would have to pay 16 rubles monthly for heat, water, cooking gas and maintenance. Our friend who has two daughters, aged eight and fourteen, in effect bought 12 square meters of living space per person for a very reasonable price by our standards. His electricity cost was 4 Kopek per KWH, his average electrical consumption 100 KWH per month for a total of 4 rubles. His telephone expense 2.50 rubles per month with an unlimited number of local calls.

He and his wife are both mechanical engineers and worked for the same institute. His salary was 180 rubles per month plus 40% bonus provided the "plan" was fulfilled. His wife's 140 rubles plus 40%. He tells me the plan was always fulfilled. Their combined monthly income was 448 rubles, a comfortable income for a country where the average family, according to published statistics, has an income of about 220 rubles each month. Our friend and his wife were clearly members of the growing Soviet middle class which may earn 350 to 600 rubles a month. His monthly expenses for housing and utilities were 46.50 rubles, or approximately 10% of his income.

Since housing and utilities are heavily subsidized there is no discernible cost-to-price relationship. While subsidies also hold for other basic commodities necessary to sustain life, consumer goods as we know them by Western standards are generally very expensive or altogether unavailable. This may account to some extent for the large deposits held by state savings banks who pay two percent on savings. In 1974 the banks held 70 billion rubles in citizens' deposits, an average of 280 rubles for each man, woman and child in the Soviet Union.

As we have seen, our Russian engineer paid about 5.32 cents per KWH for electricity. Living in Consolidated Edison Company territory in New York I paid 12.5 cents plus tax last month. My estimate for the current average rate in the United States is 6 to 7 cents per KWH for the small consumer. As in the United States, the Soviet small power consumer who lives in an apartment, pays a far higher unit price for electricity than his industrial or commercial counterpart. Table 1 shows power rates for various categories in three Soviet cities.

TABLE 1

Electricity Price per KWH (in Kopeks based on 1973 Electricity Rates)

Location	Domestic Lighting & Household Needs	Large Industry (over 1000 KW Installed Capacity)	Small Industrial Consumer (Up to 100 KW Installed Capacity)	Non-Industrial Consumers Non-productive Commercial, Social & Educational Enterprises
Moscow	3.882	N.A.	2.5	2.505
Kuybishev	3.77	1.245	2.525	2.417
Sverdlovsk	3.65	1.182	2.5	2.5

Having obtained 1979 information on rents, electrical utility and telephone costs from our Russian friend, I compared them against 1979 data given to us on monthly utility costs on our second visit to the Soviet Union: Cooking gas 16 Kopeks per person; domestic hot and cold water 29 Kopeks per person; space heating 5 Kopeks per square meter; telephone 2.50 rubles; rent .55 to 13.2 Kopeks per square meter; For a family of 4 people and a 48 square meter apartment monthly utility costs excluding electricity and telephone amount to 4.20 rubles. Monthly rents, based on 48 sq. meters vary from 2.64 to 6.34 rubles. If we add the utilities and rent the total varies from 6.84 to 10.54 rubles. Allowing for building maintenance and repairs the 16 to 17 rubles monthly rent previously mentioned seems to fall within plausible range as does the 5,000 ruble amortization spread over 15 years of monthly 40 ruble installments in the purchase of the cooperative.

At the outset I mentioned that our second visit clarified some of the agency interrelationships. This is true to the extent that when we visited Novosibirsk and Tol'yatti in May 1979 it began to sink in that no matter where you are, be it Omsk, Tomsk, Minsk, Pinsk, or Leninsk, Moscow calls the shots. All major design and construction projects must have the blessing and obtain final approval from Moscow. Local design institutes have the power to propose projects in their area to the central construction institute and, once approved, may make modifications to suit local conditions to those standard designs either provided by Moscow or developed locally with Moscow. Thus the astonishing degree of standardization, an excellent example of which is the new city of Tol'yatti on the Volga River, a city which had a population in excess of 500,000 at the beginning of 1979 - having more than doubled during the 1970's and increased by seven times in the last two decades.

This rapid expansion was due to the development in the 1950's of a hydroelectric complex and, in 1966, the start of the Volga Motor Vehicle Plant, one of the largest producers of passenger cars in the Soviet Union. Thousands of young workers and their families from all over the Soviet Union have flocked to Tol'yatti because the automobile plant was declared a Komsomol (Communist youth organization) "shock construction site". The average age of Tol'yatti's population is 27½.

Slides 10, 11, and 12 show the standard nine and sixteen story apartment buildings of panel type construction which, in addition to the standard 5 story structure comprise the entire housing stock of new Tol'yatti.

The city is served by the same type of power and heat generation and distribution system as seen elsewhere in the Soviet Union and described in this paper. An extensive underground system of utility tunnels and subterranean control stations supply heat and domestic hot water to the city.

Before leaving Moscow in May 1979 the delegation was received by Mr. Rodin, Deputy Chairman of the Central Construction Institute for the entire U.S.S.R. He gave us some interesting statistics:

Present apartment construction in the U.S.S.R. is 2.2 million annually. While the Soviet Union would like to increase this number, labor shortages prevent it from doing so. 80% of the U.S.S.R. labor force is employed inside plants and factories. Twelve million people are involved in construction work.

There are now 2.1 billion square meters of apartment area in place (22.6 billion square feet). During World War II 1710 cities and 70,000 villages were destroyed which resulted in massive housing shortages and far-reaching relocation of industries and cities.

There are 127 types of standardized building designs in the U.S.S.R. resulting in two thousand building models having architectural differences, each adapted to local climatic conditions. Standardized construction is 30% less expensive than individualized structures.

Two design institutes, one in Moscow for "normal" construction, the other in Tbilisi for seismic construction, are responsible for all government building and industrial building construction for the entire 15 republics of the U.S.S.R.

While I have no comparable building construction figures available for the U.S.A., I believe that we average two million housing starts in a "normal" economic climate. Thus it appears that our total area of construction added annually exceeds that of the U.S.S.R., though the type of dwellings are very different.

The energy supply system of the U.S.S.R. also differs greatly from our own. Due to the differences in political and economic systems, the U.S.S.R. can virtually legislate cogeneration plants and large underground distribution networks without consideration to market conditions. The massive destruction of Soviet cities caused their revitalization to use the latest available technology. This enabled them to install energy conserving systems which, until the advent of the energy crisis, were found to be uneconomical and unnecessary in the U.S.A.

LIST OF REFERENCES

1. "The Soviet Energy System" by Leslie Dienes & Theodore Shabad John Wiley - Halsted Press, 1979.

2. "District Heating System of Moscow" by E. Antonov, Mosenergo, U.S.S.R. - Paper delivered at EEC/UND Seminar on District Heating. Hamburg, 1978.

3. "Energy Data Reports" Steam-Electric Plant Construction Cost and Annual Production Expenses. 1975 - 28th Annual Supplement Published January 1978 - DOE/EIA-0033/1.

4. "U.S.S.R. Trip Report" by William Diskant, District Heating, Volume 64, No. 3, Jan-Feb-March 1979.

5. "Russia - The People and the Power" by Robert G. Kaiser - Pocket Books Edition 1976.

6. "The Russians" by Hedrick Smith, Ballantine Books, 1977.

7. Personal communications with Prof. Leslie Dienes, Dept. of Geography, University of Kansas.

8. "Soviet Censors in a Losing Battle to Keep Space City Out of Print" by Theodore Shabad, New York Times, October 22, 1979.

LIST OF SLIDES

NO.	TRAY NO.	TITLE
1		Moscow Housing Project
2		District Heating Plant serving Housing Project
3		District Heating Plant - Pump Room
4		Kiev #5 CHP 250 MW_e Turbo-Generator - End View
5		Kiev #5 CHP 250 MW_e Turbo-Generator - Longitudinal View
6	39	Prefab, preinsulated 1400 mm (4'-7") dia. pipe
7	41	Prefab, preinsulated 1400 mm pipe installed on bottom tunnel panel
8	47	Prefab, preinsulated 1400 mm pipe installed tunnel side panels up
9	48	Completed Tunnel
10	97	Tol'yatti Type 9 Story Apartment Building
11	98	Tol'yatti Type 17 Story Apartment Building
12	99	Row of 9 Story Apartment Houses