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Research Article

TES-3 – transportable nuclear power plant mounted on self-propelled tracked vehicles*

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Abstract

Until the mid-1950s, scientists and engineers at the Obninsk Institute of Physics and Power Engineering (IPPE) had worked out a number of unique projects that served as the foundation for the development of domestic and world nuclear power engineering. The list of these projects includes, in particular, TES-3, the first mobile nuclear power plant, which has become a symbol of small-scale nuclear power engineering, a historical achievement of Russian scientists, and part of the heritage of the City of Peaceful Atom.

TES-3, a demonstration and experimental plant, being one of the possible nuclear power sources for remote areas, was a mobile power-generating unit consisting of four tracked platforms with a reactor unit equipped with a water-cooled and water-moderated reactor with a 1.5 MW turbogenerator. The "self-propelled uranium-fueled machine" was created in record-breaking time due to the scale and cooperation of the project participants under the scientific guidance of the Laboratory V staff. The plant showed reliability in operation, good controllability, safety and maintainability. Over the entire operating period in the power generation mode, TES-3 worked for about 1300 hours without any radiation accidents. After the completion of the first fuel campaign in 1965, the reactor was shut down, but the idea of mobile low-capacity large-component nuclear power plants was further developed in the form of mobile nuclear power plants of the next generation.

Keywords

TES-3, nuclear power train, the first mobile low-capacity nuclear power plant, transportable land-based nuclear power plant, self-propelled power plant, water-cooled and water-moderated reactor, history of peaceful atom, "Atom mirny", Laboratory "V"

October 2021 marked the 60th anniversary of the start-up of the first domestic low-capacity mobile nuclear power plant, TES-3, in Obninsk.

In the 1950s, when nuclear power was in its infancy, incredibly bold ideas appeared. One of them was to make a self-propelled nuclear power plant to operate in the Far North. This idea was first expressed by the Minister Yefim Pavlovich Slavsky. In 1955, he visited the Leningrad Kirov Plant. It was in a conversation with the director of the plant N.M. Sinev that a proposal was first made to develop a mobile nuclear power plant that could supply electricity to remote civilian and military facilities.

By its design and purpose, the transportable nuclear power plant was a demonstration and experimental facility. The plant was intended to study the design experience and experimental data necessary for the development of mobile autonomous power sources that could be used in hard-to-reach areas of the Far North and Siberia.

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Slavsky's proposal became a guide to action, and soon the Kirov Plant, in cooperation with the Yaroslavl Locomotive Plant, prepared projects for a nuclear power train, i.e., a low-capacity mobile nuclear power plant to be transported by rail. Two options were envisaged, namely: (1) a single-circuit scheme with a gas turbine plant and (2) a scheme using a steam turbine plant of the locomotive itself. Slavsky entrusted the Institute of Physics and Power Engineering (then called "Laboratory V") with developing the project. The development of TES-3 was carried out in accordance with the Decree of the Council of Ministers of the USSR in 1956.

The task was to create a low-capacity nuclear power plant manufactured in maximum factory readiness and, at the same time, satisfying the rail transportation requirements.

The TNPP was designed to operate in autonomous conditions. It was also necessary to ensure the possibility of relocating the plant with the unloaded core after operation at power.

Soon (in 1957) the preliminary design of the plant was ready. Its authors were Yuri Anatolyevich Sergeev and Dmitry Leonidovich Broder. The scientists proposed to put the transportable nuclear power plant on tracks, making it almost self-propelled. The idea seemed tempting: the plant on tracks would approach some ore or coal mine, or settlement, on its own and begin to provide it with power. And in a year or three would move to another place. Why build an on-site plant in permafrost conditions, when there was a more economical and progressive option at hand?

Work on the TES-3 reactor began at the IPPE in the laboratory of M.Ye. Minashin by a group of five people led by Yu.A. Sergeyev. This group, together with the staff of B.G. Dubovsky and D.L. Broder's laboratory, as well as the Design Bureau of the Leningrad Kirov Plant, formulated the main proposals for the reactor design concept.

In 1957, in connection with the further development at the IPPE of work on small-sized reactors (including those for transport units) on the basis of Yu.A. Sergeyev's group, Laboratory No. 30 was formed, which coordinated work on the TES-3 project.

The project implementation additionally involved a number of design, engineering and research organizations: LPI, TsNII-45, SKBK-189, TsKBA, TsKBS-4, GPI TPEP, LKB-12, NII-8, OKB-12, NII-9, NII-627; and factories: Elektrosila, Vagonostroitelny n.a. Yegorov, Ekonomaizer, Krasnaya Zarya, Electropult and others. The prototype TES-3 was manufactured by the Leningrad Kirov Plant with the participation of more than a hundred suppliers of standard equipment, instruments and special equipment. The scientific management of the creation of this unique object was carried out by the Laboratory V. The main participants were Yu.A. Sergeyev, V.I. Orekhov, V.A. Naumov, G.Ya. Rumyantsev, M.Ye. Minashin, and V.V. Orlov.

Experiments for TES-3 were carried out on three successively created physical facilities in the laboratory under the direction of I.G. Morozov. The first critical assembly modeled the reactor very roughly, as it was mounted on the available fuel rods previously used for AM-1 (the Russian abbreviation AM stands for "Atom mirny" (Peaceful Atom), it encrypted the reactor of the First NPP). The second and third hot assemblies (the TES-3 facility) could be heated almost to the design temperatures. For the created hot assemblies, the temperature effect was imitated by diluting water with formic acid. The main participants in the experiments were B.G. Dubovsky, I.G. Morozov, M.N. Lantsov, Ye.A. Plaksin, and V.I. Fedorov.

In 1961, the TES-3 TNPP was already manufactured and prepared for startup at the IPPE site. The physical launch was carried out by the staff of Laboratory No. 2. The reactor reached criticality on June 7, and on October 13, 1961, TES-3 received the first electrical load.

The scale and cooperation of the project participants made it possible to create a "self-propelled uranium machine" in record time. Less than five years passed from the receipt of the technical assignment (December 1956) to the reactor power startup (October 1961).

The control of TES-3 is described in detail in Report No. 310 at the 3rd Geneva Conference in 1964 (Petrosyants 1964), and the archival documents of the IPPE containing the technical diagrams of the TES-3 self-propelled vehicles were declassified relatively recently, in 2016.

The TES-3 TNPP, with an electric power of 1500 kW, which became the first in the USSR (and in the world) practical experience in creating a transportable land-based nuclear power plant, consisted of four self-propelled platforms on elongated tracked chassis of a heavy tank with wagon-type bodies, functionally arranged in reactor and turbine units, auxiliary unit and control unit (Figs 1–3).

Figure 1. TES-3 power unit.

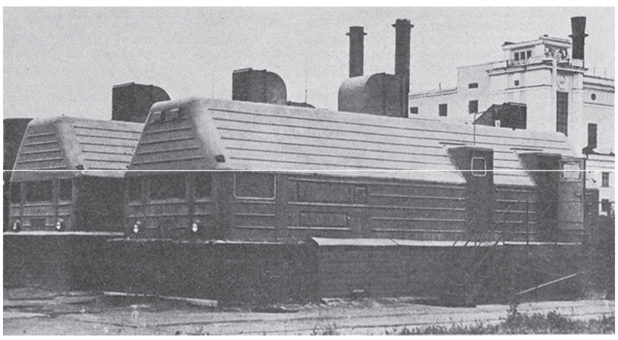

Figure 2. View of the self-propelled vehicles with a control panel and a turbogenerator. The tracks are closed for winterizing (Sinev et al. 1964).

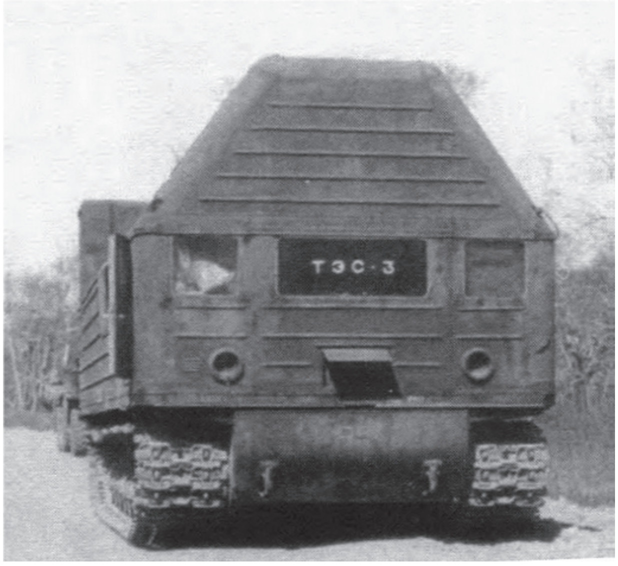

Figure 3. TES-3 on the move.

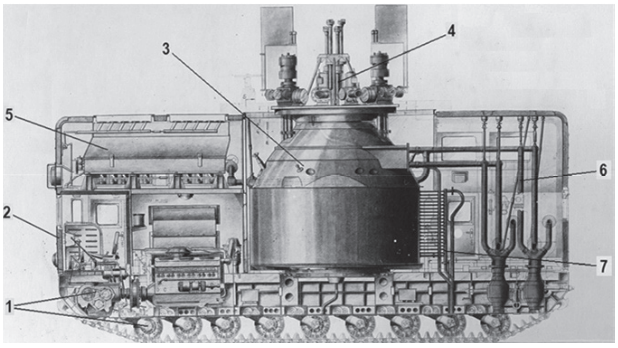

Figure 4. Scheme of the self-propelled vehicle with a reactor and service systems: 1. Self-propelled platform; 2. Body; 3. Reactor with shielding; 4. CPS actuators; 5. Radiator; 6. Pipeline of the primary circuit; 7. Technical water pipeline.

The reactor and support systems were installed in the first vehicle (Fig. 4); the steam generator with various equipment and circulation pumps for feeding the primary circuit and the heat exchanger, through which heat is transferred to the working fluid were in the second one; the 1.5 MW turbogenerator was in the third one; and, finally, the control panel with auxiliary equipment was in the fourth one.

The reactor block was equipped with a pressurized water reactor containing highly enriched uranium fuel assemblies. The system used ordinary water as a moderator and coolant. The water consumption in the primary circuit of the plant was 320 t/h. The water temperature was 270 °C at the inlet to the reactor and 300 °C at the outlet of the reactor. The weight of the plant equipment (including the biological protection) was 210 tons, the weight of all the self-propelled vehicles was 310 tons. The reactor core, shaped like a cylinder 600 mm high and 660 mm in diameter, contained 74 fuel assemblies with highly enriched uranium. The average heat load in the reactor was $0.6 \cdot 10^6$ kcal/($m^2 \cdot$ h), the maximum was $1.3 \cdot 10^6$ kcal/($m^2 \cdot$ h). The power of the turbogenerator is 1.5 MW, but the plant three steam generators could produce steam at a pressure of 20 atm and a temperature of 285 °C in an amount sufficient to obtain power at the turbine shaft up to 2 MW.

At the site of operation, the four objects were interconnected by cables and pipelines. The reactor campaign length was calculated for a period from 250 days to one year.

To provide protection against radiation during operation, an earth shield was constructed around the first two self-propelled vehicles at the site of operation. The reactor self-propelled vehicle was equipped with a transportable biological shield, due to which it was possible to carry out assembly and disassembly within a few hours after the reactor shutdown as well as to transport the reactor with a partially or completely burned-up core. During transportation, the reactor was cooled using an air cooler, which ensured the removal of up to 0.3% of the rated power of the plant.

The TES-3 TNPP, being one of the possible options of a nuclear power source for remote areas, showed reliability in operation, good controllability, safety and ease of maintenance (Sinev et al. 1964), which at the last stages of work was carried out by the staff of the First NPP (a shift of three people).

For the entire period of operation in the power mode (from October 13, 1961 to June 18, 1965), TES-3 operated for about 13,000 hours without any accidents due to violations of radiation safety limits.

The program was subsequently scrapped. After the first core campaign was completed, the reactor was shut down, the facility was mothballed and has been at the IPPE storage site ever since. In the 1980s, the idea of transportable low-capacity large-component nuclear power plants was further developed in the form of TES-7 and TES-8.

The model of TES-3 was exhibited in many countries of the world. In 1968, the TES-3 TNPP was presented at the All-Union Exhibition of Achievements of National Economy (VDNKh) in Moscow in the Atomic Energy Pavilion and was awarded the First Degree Diploma (Frolov et al. 2021). A large group of IPPE specialists who participated in the project were awarded VDNKh medals and government awards. A simplified scheme and principle of operation of the TES-3 TNPP could be seen on the working model presented in the Moscow Polytechnic Museum since 1965.

Numerous delegations from near and far abroad visited the IPPE and examined the unique object with interest. Thus, from May 19 to May 30, 1963, a delegation of the US Atomic Energy Commission (AEC) headed by the Chairman Glenn T. Seaborg was in the Soviet Union. The delegation included the Chairman of the General Advisory Committee of the AEC Benedict Menson, the General Manager of the AEC A. Ludeke, the Head of the International Affairs Department A. Wells, the Director of the Argonne National Laboratory A. Crewe and others. On May 23, the delegation visited the Institute of Physics and Power Engineering, where they were shown the First Nuclear Power Plant, BR-1 and BR-5 fast reactors, the mobile nuclear power plant and the sodium laboratory (Bochvar 1963). Yu.A. Gagarin, who was in Obninsk in 1966, also saw the TES-3 plant, as evidenced by the historical photograph below (Fig. 5).

Figure 5. First cosmonaut Yu.A. Gagarin at TES-3 (May 31, 1966).

It is likely that in the near future a new historical monument based on the original TES-3 TNPP may appear in Obninsk. It can become one more element of the already existing system of symbols for the achievements of Obninsk scientists in the field of nuclear power, including the world's first nuclear power plant. The initiative to create an exposition of this unique object is being actively discussed by the scientific community of the IPPE, representatives of the Museum of World Atomic Energy and the city administration (Kosheleva 2021).

This monument will have to remind contemporaries of the great achievements of Russian engineering, serve as a role model in purposefulness, diligence, readiness to solve complex technological problems, and that Obninsk is the cradle of nuclear power engineering in the country and the world. And, of course, it will have to play its role in shaping the worldview of the students of the Obninsk Institute for Nuclear Power Engineering.

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