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DEVELOPMENT AND CONSTRUCTION OF A HIGH-POWER, 3000 m^3/h, 0.5 MPa, SODIUM PUMP WITHOUT WATER COOLING

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The concept of modular flat linear induction pumps (FLIP) without water cooling of the winding has been proposed and developed at the MHD Laboratory, Khar'kov, Ukraine. In these pumps, the total flow rate is equal to the sum of the flow rates of all the modules. The concept proposed can be useful when designing high-power electromagnetic pumps for the main loops of a fast breeder reactor with liquid sodium as the heat carrier. As a prototype, a high-power modular FLIP was developed and built in cooperation with the MHD Laboratory and two plants, the Electromechanical plant and the Turbine Plant at Khar'kov. This was a two-module FLIP, with the following design parameters: liquid to be pumped is sodium at 350°C, flowrate 3000 m^3/h, head 0.5 MPa, frequency 37.5 Hz, efficiency 38%, number of poles 10, pole pitch 276 mm, wall thickness 6 mm, and mass 25 tons. No-load tests of the inductors and the hermeticity of the ducts have been carried out. The problem of "hot" operation tests is still to be solved.

The development of nuclear power engineering is associated with the construction of fast breeder reactors; in these, liquid sodium serves as the heat carrier. Different electromagnetic pumps have been used in the auxiliary loops of such reactors for a long time and have proved to be quite reliable. However, only mechanical (centrifugal) pumps have been employed as the circulating pumps in the main heat carrier loops.

In several organizations, efforts have been made to find another technical solution of the problem — to develop and to build large electromagnetic induction pumps to be used in the main loops of fast breeders. We note the work [1] (General Electric Company, U.S.A.) describing a large ALIP for sodium (3300 m^3/h, 12.9 kgf/cm^2, 20 Hz; efficiency 45%, mass 52.3 tons; nitrogen cooling of windings). The pump has not been tested.

In [2] (Research Institute of Electrophysical Equipment, St. Petersburg, Russia), the test results of a large ALIP (sodium at 300°C, 3000 m^3/h, 3 kgf/cm^2, 50 Hz; efficiency 28%, water cooling of windings) have been described. The tests were successful. Some disagreement between the predicted and measured characteristics has been shown which was, as one may think, caused by some complicated MHD phenomena in the cylindrical pump duct.

The MHD Laboratory at Kharkov has also contributed to the development of large power electromagnetic pumps. As the basic idea, the concept of modular FLIPs was chosen. The number of modules (channels) can be two, three, four, and so on. The concept of modular design has several advantages, the main one of which is to make the problem of calculating the duct strength easier because the flowrate of one module is smaller than the total flowrate, and therefore the channel size is also smaller.

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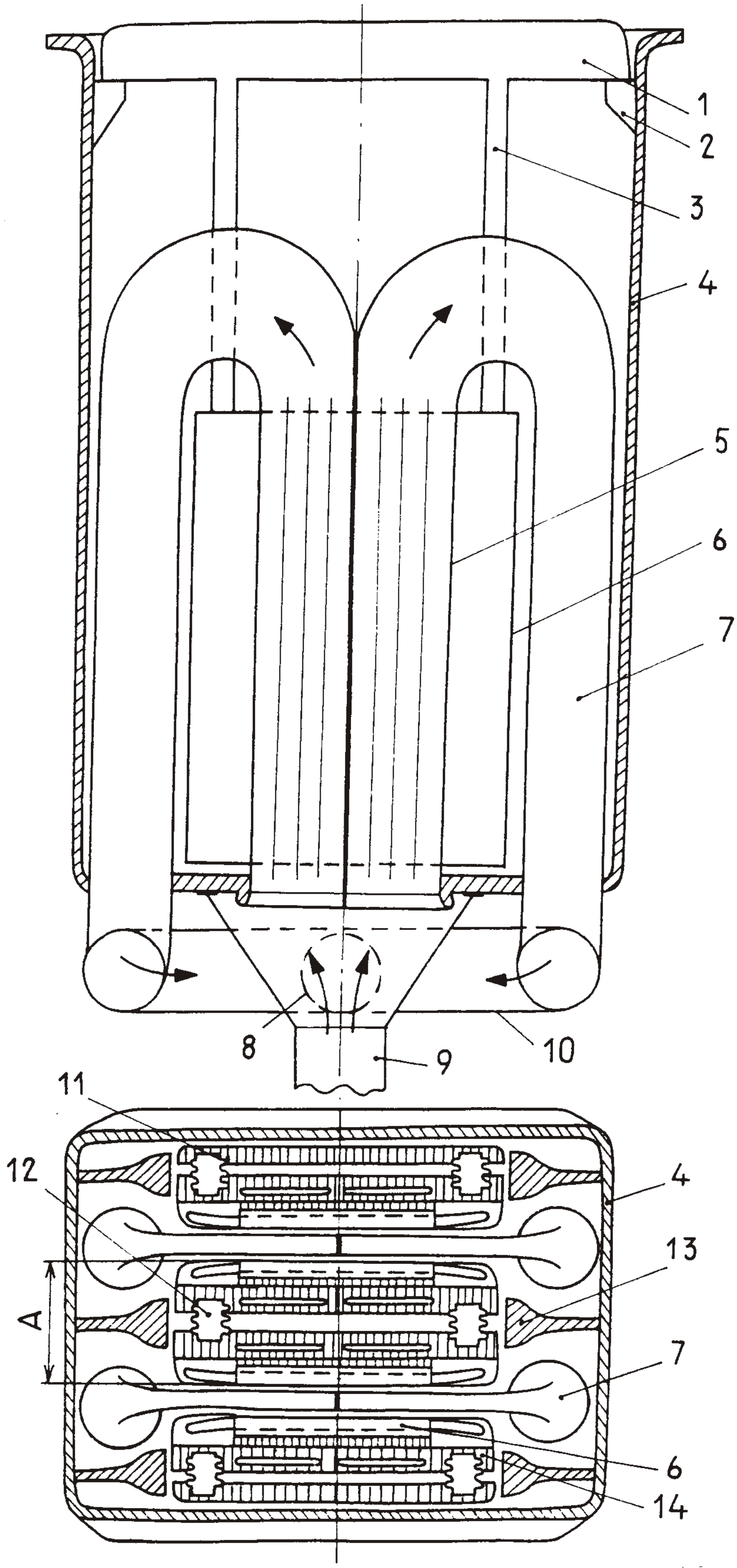

Fig. 1. Design scheme of the two-module induction pump AMH 3500/6 (3000 m^3/h; 0.5 MPa; sodium at 350°C). Explanations in text.

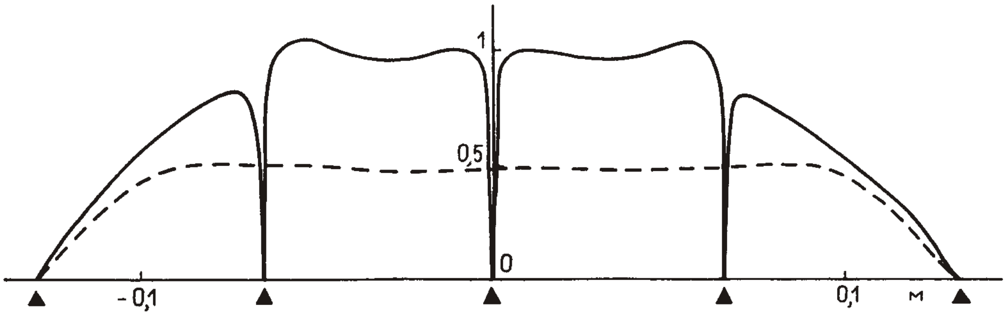

Fig. 2. Predicted distributions of velocity (solid line) and electromagnetic force density (dashed line) in the duct section. Velocity is normalized with respect to the traveling field velocity; force density is in arbitrary units. The subsection boundaries are marked by ▲.

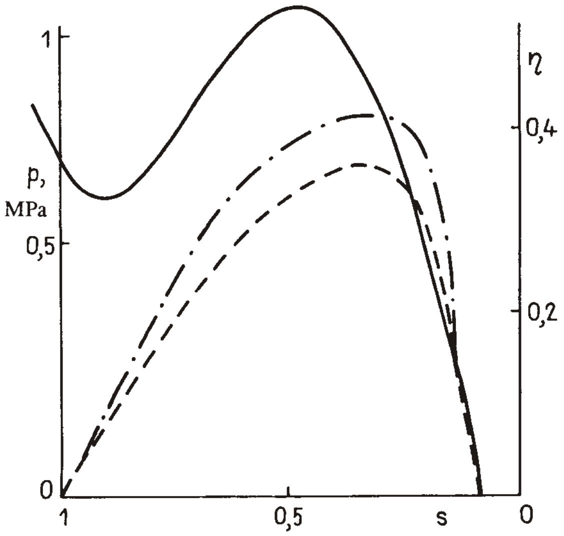

Fig. 3. Predicted dependences of pressure (head) (solid line) and efficiency (the dashed line refers to the pump as a whole; the dot-dash line — without accounting for the losses in the winding and the inductor core) on the slip s. B_m = 0.42 T.

In the first stage, a medium-range two-module induction pump was developed and built (sodium at 350°C; 300 m^3/h, 0.43 MPa, efficiency 26%, frequency 148 Hz, mass 1.6 tons [3]). The frequency was chosen very high to ensure that the magnetic Reynolds number Rm is approximately 4, which is close to the value in the final (real) pump. It was proved experimentally that the flowrates in both modules are equal and that the pump operation was a stable, without any cavitation phenomena even when the inlet pressure was reduced to some 0.5 atm (absolute); this was obviously due to the application of an active inlet nozzle, where the term "active" means that it has a three-phase winding exciting the traveling field. The pump has an autonomous power supply, a synchronous generator with a power of 125 kW, voltage 600 V, 3000 rpm, 148 Hz. Due to its inertia, this generator ensured the operation of the pump for 60 sec in case the power supply to the asynchronous motor driving the generator is cut off from the mains.

After testing of the above pump was successfully completed, it was decided to build a pump of considerably greater power with similar characteristics. This was done in 1991. The design scheme of the pump is presented in Fig. 1. The pump has an inlet pipe 9 and two flat channels 5 each of which consists of two sections. The latter turn, in the upper part of the pump, toward the left and right sides, and are then connected to circular tubes 7 and then joined with the collector 10 and the outlet (pressure) pipe 8. The two sections are separated from each other by an insulating layer. As calculations have shown, this layer helps to improve the pump characteristics. Moreover, each section is divided into four subsections in order to

Fig. 4. The hydraulic part of the high-power two-module pump.

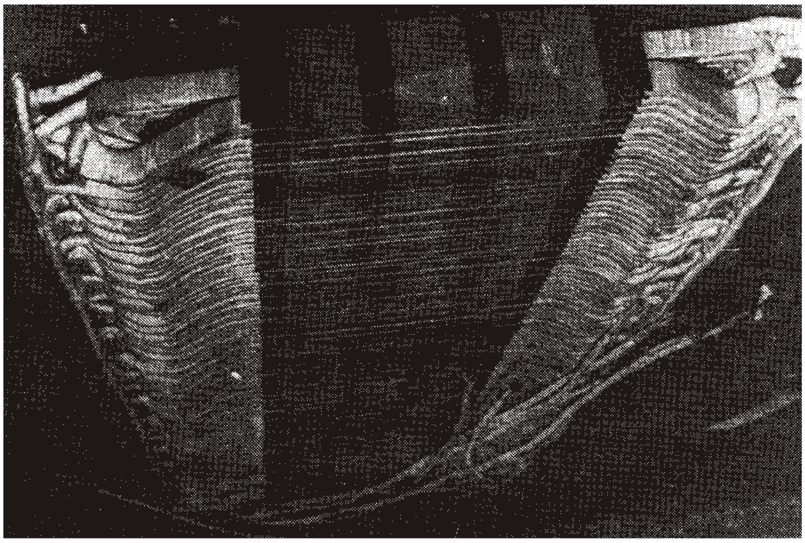

Fig. 5. One of the flat linear inductors of the pump.

suppress possible internal flows (i.e., to prevent intermixing of the liquid sodium). In this pump, the values of Rm are large, 3-10 depending on the slip. At such large values of Rm, the pump efficiency is greater if the above insulating layer is present than when it is not. There are four flat inductors 6 containing laminated cores and corresponding windings. The cores are assembled on hollow plates 14. A relatively small part of the liquid sodium flow circulates through the holes of these plates, which is sufficient for cooling the winding.

There are also bellows 12 in the pump (Fig. 1). The dimension A is a little bit less than the distance (gap) between the ducts of the two modules. Therefore, the inductors can be easily moved into the gap between the ducts from above to below with the assistance of parts 1-3 and 13. When the inductors have been moved down to the very bottom of the whole device, compressed air is supplied to the bellows 12, and the inductors are pressed tightly to the duct walls. Thus, removal and

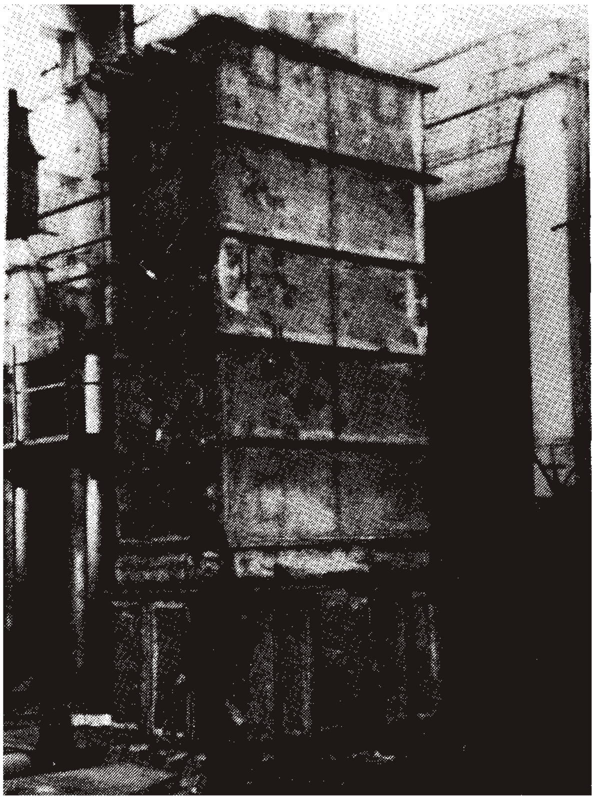

Fig. 6. A general view of the large two-module induction pump.

exchange of inductors can occur without violating the hermeticity of the hydraulic tract. The design parameters of the pump are: working medium sodium at 350°C, flow rate 3000 m^3/h, head 0.5 MPa, frequency is 37.5 Hz, efficiency 38%, number of poles 10, pole pitch 276 mm, wall thickness 6 mm, and pump mass 25 tons.

The velocity and electromagnetic force distributions along the width of one of the sections (consisting of four subsections) are presented in Fig. 2. Figure 3 shows the predicted dependences of head (in the generally accepted form of pressure vs. flow rate characteristics) and efficiency on the slip. Figure 4 shows the pump ducts. A hermeticity test has been performed with the latter. Compressed air under a pressure of 13 atm (absolute) was supplied to the hydraulic part; then the latter was separated from the air supply system and a manometer left on it only. After 20 days, there were no notable changes in the pressure.

Figure 5 presents one of the flat linear inductors. A no-load test was done with them.

In Fig. 6, the general view of the pump, an impressive device 5.5 m in height, is presented.

The problem of "hot" tests of the pump still remains to be solved. At the beginning it was planned to arrange these tests at the Institute of Power Engineering Physics (Obninsk, Russia) and, if the tests proved to be successful, to leave it there for operation, say, in a large experimental loop. However, this plan was abandoned because of the generally unfavorable situation both in Russia and Ukraine. It is hoped that specialists in the U.S.A. and France, where there are fast breeder reactors in operation, may be interested in the pump. If so, the pump can be sold for an agreed price, tested, and used, presumably with the participation of the employees of the MHD Laboratory (Kharkov), in some large experimental loop. More detailed information on this pump as well as on the devices described in this issue can be obtained from: Ludmila Dronnik, Geroev Staingrada Street, 163, kv. 31, 310100 Kharkov, Ukraine; tel. (0572) 97-05-44 or (0572) 26-00-55; or: Isaak Tolmach, 1017 46th Street, Apt. 3, Brooklyn, NY 11219, U.S.A.; tel. (718) 633-7133.

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