Magnetohydrodynamics, Vol. 30, No. 3, 1994

DEVELOPMENT AND CREATION OF A LAID-ON LOW FREQUENCY INDUCTION PUMP WITH A SMALL LIQUID METAL FLOW RATE IN A CIRCULAR PIPE

V. V. Vylomov,[1] L. M. Dronnik,[1] A. V. Katkov,[1] S. Yu. Reutskii,[1] N. N. Oshkanov,[2] I. M. Tolmach,[3] and A. G. Sheinkman[2]

In complicated liquid-metal large-diameter pipe systems, it is sometimes necessary to maintain the metal flow in one of the pipes without violating the hermeticity of the whole system, as when, for example, the main pumps are stopped for inspection. To meet these requirements, a special inductor with a profiled magnetic core fitted to the outer contour of the pipe where the metal is pumped, was developed and manufactured. The pipe diameter is 325 mm, the design flow rate of sodium at 330°C is 140 m³/h, the pressure to be developed is 2 kPa, and frequency is 1 Hz. A special low-frequency power source was designed and built. No-load tests were performed, and "hot" ones are planned.

Introduction. During maintenance, it is necessary from time to time to stop the main circulating pumps of the secondary loop of a fast breeder reactor for routine inspection. However, for reactor cooling, at least one of the main pumps must remain working. At the same time, it is desirable to stop all the main circulating pumps, which allows one to shorten the total time of routine inspection and to improve the inspection quality. If this is done, some ordinary small pumps can work in the loop during this time, but if these are not installed beforehand when the loop is assembled, it is impossible to install them in a completed loop. To ensure a small flow rate in these conditions (when all main pumps are stopped) without cutting the sodium pipe, it is possible to use a special laid-on inductor. The existing sodium pipe (a part of the whole loop) serves as the pump duct.

1. Description of the Pump. The induction pump proposed has two linear inductors of the traveling magnetic field. As mentioned above, the loop pipe serves as the pump duct. Each inductor core has a depression so that the inductor can be placed tightly near to about one-fourth of the pipe perimeter (Fig. 1). Since the pipe diameter is 325 mm the nonmagnetic gap of the pump is large, and in order to reduce the influence of the skin effect it is necessary to use a three-phase low-frequency power supply.

At the MHD Laboratory (Khar'kov, Ukraine), such a pump was developed and manufactured. The design parameters are as follows: 1) flow rate 140 m^3/h; 2) pipe diameter 325 mm, wall thickness 12 mm; 3) liquid metal to be pumped, sodium at 330°C; 4) head 2 kPa, designed with a fourfold reserve to meet a possible increase of pressure losses due to velocity nonuniformity in the pipe; 5) frequency 1 Hz, with possibility of adjusting it in the range 0.5-12.5 Hz in order to choose the optimum value; the power source was designed and built at the Research Institute of the Khar'kov Electric Engineering Plant.

The inductor has a three-phase winding, with two inductors in parallel; for one of them, the phase current is 59 A; the total current is 118 A. The pump line voltage is 180 V, with possibility of adjusting in the range 30-230 V for a smooth

[1]MHD Laboratory, Khar'kov, Ukraine.
[2]Beloyarskii Nuclear Power Plant, Zarechnii, Russia.
[3]1017 46th Street, Apt. 3, Brooklyn, NY 11219, U.S.A.

Published in Magnitnaya Gidrodinamika, No. 3, pp.372-376, July-September, 1994. Original article submitted July 4, 1994.

 0024-998X/94/3003-0306$12.50

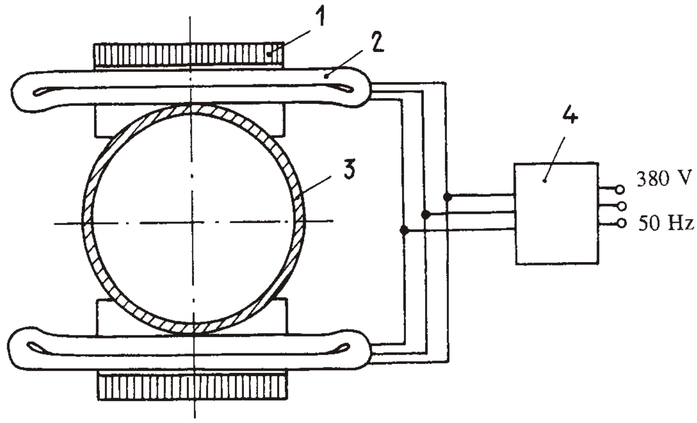

Fig. 1. Scheme of the induction pump. 1) Magnetic core with an arclike depression; 2) winding coil; 3) circular sodium pipe; 4) low-frequency power source.

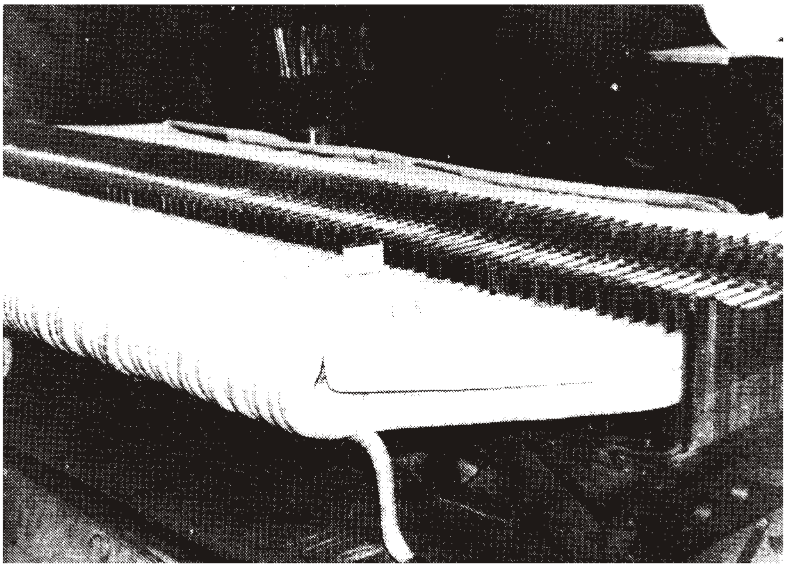

Fig. 2. Inductor with an arclike depression in the magnetic core.

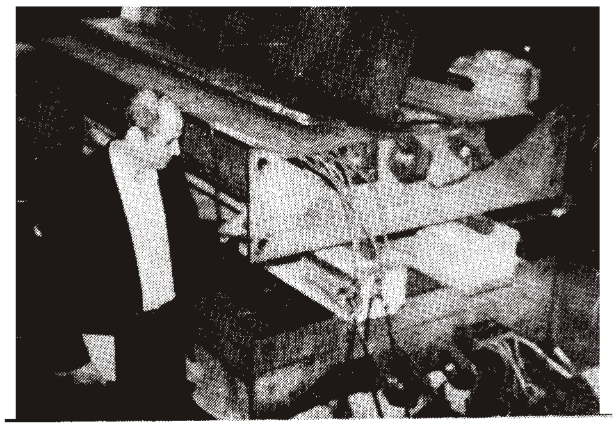

Fig. 3. Two low-frequency inductors during the no-load test.

TABLE 1. No-Load Test Results for the Pump and Low-Frequency Power Source

Test number		Phase	1	2	3
Primary side, 380 V, 50 Hz	Phase Voltage, V	A	220	222	222
		B	220	222	222
		C	220	222	222
	Phase Current, A	A	120	132	133
		B	119	133	134
		C	120	135	136
	Phase power, W	A	3600	5100	5250
		B	4200	5550	5700
		C	3720	5100	5400
Secondary side (pump)	Frequency, Hz		1.0	1.0	0.83
	Phase current, A		113.5	123.8	123.8

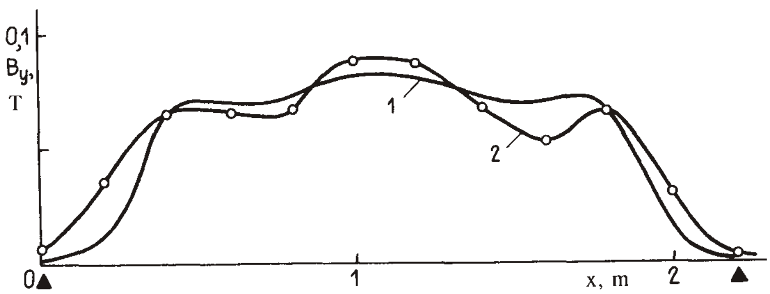

Fig. 4. Magnetic field distribution. 1) Calculation; 2) experiment. I_{ph} = 120 A. The positions of the inductor ends are marked by the shaded triangles.

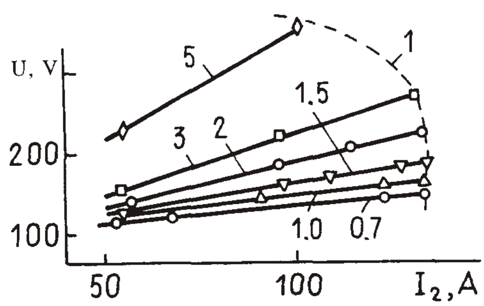

Fig. 5. Inductor voltage vs. phase current at the frequency (Hz) indicated on the curves.

flow rate control. The total active power consumed by the pump is 38 kW, the power source input line voltage is 380 V, and the frequency is 50 Hz. The inductor pole pitch is 0.55 m, and number of poles is 4. There is a two-layer winding with high-temperature insulation. The insulation material was produced at the Research Institute of Electric Insulating Materials ("VNIIÉIM"), Moscow, Russia.

In Fig. 2, one of the inductors is shown; Fig. 3 shows two inductors assembled for the no-load test.

In designing the inductor the following theoretical problems were solved.

1) The distribution of the applied traveling magnetic field in the pump working volume was calculated taking into account the shape (the presence of the depression) of the magnetic core. In Fig. 4, the calculated (by S. Lifits) and experimental curves of the field distribution are shown. These demonstrate a good agreement.

2) The induced current distribution in the liquid metal was found using the so-called electrodynamic approximation ($Rm << 1$). This allowed us to determine the head developed by the pump.

Table 1 presents the no-load test data. The inductors are connected in parallel; there was no liquid metal in the pipe.

When the phase current of the two inductors is 120 A, line voltage 150 V, frequency 1 Hz, and inductor temperature 50°C, the losses in both inductors is 14 kW. With hot (300°C) inductors, the losses grow up to 30 kW, which agrees well with the calculations.

In Fig. 5, the inductor voltage vs. phase current at different $f = 0.7$-5 Hz is presented. The power supply regulator allows us to vary the frequency by means of one resistor while maintaining the voltage constant, and, vice versa, by means of another resistor, the voltage can be adjusted while maintaining the frequency constant. As can be seen from Fig. 5, there is a limit for current (curve 1). This is a peculiarity of the power regulator.

The MHD Laboratory at Khar'kov can manufacture pumps of this type for pipe diameters 100-325 mm. When the diameter is smaller, the efficiency grows: at 100 mm, it is $\approx 5\%$, while at 325 mm, $\approx 1\%$. (These estimates do not take into account the possible inner flows in the pipe.)