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DEVELOPMENT AND OPERATION OF HELICAL-FLOW INDUCTION PUMPS

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Some actual models of helical-flow induction pumps with capacities of from 0.4 to 150 m^3/hr are discussed. Experience in designing, testing, and operating these pumps is described. The prospects for their further utilization are considered. Data are presented which indicate the suitability of the developed designs for long-term operation under extreme conditions.

Several years ago the authors developed and successfully tested a helical-flow induction pump with a capacity of 10 m^3/hr at a pressure of $6 \cdot 10^5$ N/m^2. In operation the pump proved convenient and reliable. To date, without once breaking down, it has pumped sodium-potassium alloy at 550-680°K for more than 20 thousand hours. Based on our experience with this pump, we developed pumps with different capacities and now have in operation a number of helical-flow pumps with capacities from 0.4 to 150 m^3/hr.

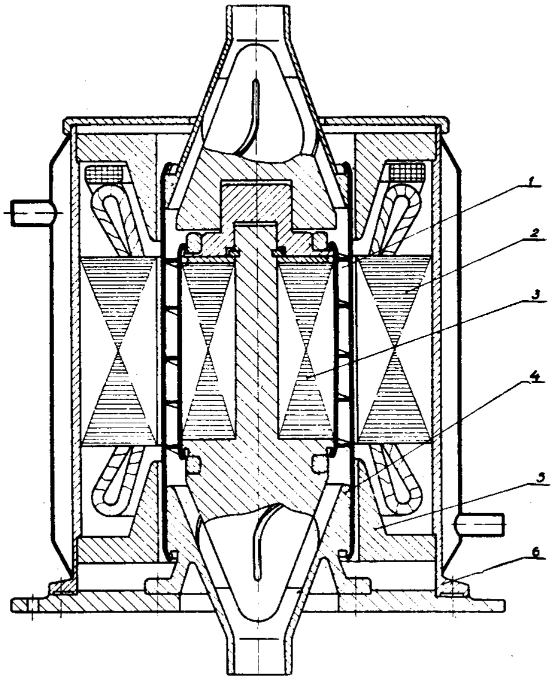

Fig. 1. Schematic view of pump construction: 1) working section, 2) stator, 3) core, 4) cone with vanes, 5) copper collar, 6) body.

Compared with other types of induction pumps – linear, plane, or coaxial – the helical-flow pump is somewhat less efficient. However, it does possess a number of advantages, among the most important of which is the possibility of making the inductor with stator plates from standard electric machines. The principal parameters of the pumps are given in Table 1.

The design of the pumps was based on the stator plates of the MAP series asynchronous motor. The construction is more or less uniform and is shown in Fig. 1.

The pump has a vertical configuration and axial metal flow. The stator 2 is built up from plates of electrical steel 0.5 mm thick from the MAP-42 asynchronous motor. The windings are made of PSDK-type wire impregnated with silicone lacquer. The ends are shielded from radiant heat from the liquid metal by copper collars 5, fitting tightly against the stator body 6. The body has a water jacket. The core 3, located inside the working section 1, is also made of 0.5 mm electrical steel and fits into a thin shell that simultaneously serves as the inside wall of the working channel. On the outer wall of the channel there are helical ribs 3.5 mm high. The channel walls are 1.25 mm thick and made of Kh18NT steel. To the ends of the outer channel wall special cones 4 are welded. These are fitted with vanes designed to transform rotary motion of the metal into axial motion and axial into rotary motion at the input.

The stator and the working section are supported on a flange, by means of which they can be mutually centered. A thin metal shield in the gap between the working section and the stator serves to restrict the heat flow to the stator.

TABLE 1

Principal Parameters of NaK Alloy Pumps

Type	Pressure, 10^{-5} N/m^2	Capacity, m^3/hr	Dimensions, mm		
			pump height	pump diameter	flange diameter
ENIV-1	4	0.5	325	230	330
ENIV-2	2.5	2	528	240	330
ENIV-3	6	10	800	385	500
ENIV-4	5	50	1150	385	500
ENIV-5	4.5	85	1180	458	620
ENIV-6	6	150	1310	537	615

Figure 2 shows a view of the assembled working section, and Fig. 3 the assembled ENIV-6 pump. The pumps are designed so that all the basic parts can be made with the equipment found in small machine shops.

The greatest difficulties are encountered in making the outer wall of the working channel. In the first models this was made of thin-walled tube on which a helical thread 2.5-10.5 mm high was formed, the final wall thickness being 1.25-1.5 mm. This is a difficult technique that wastes a lot of metal; besides, the possible dimensions of the working section are limited by the sizes of stainless steel tubing generally available.

It is now possible to make the working section from sheet material. Thus, from sheet of the required thickness a shell with butt-welded edges is made on a special apparatus. Then ribs are fitted along a predetermined helix and spot-welded to the sheet at 10-15 mm intervals. After this, the ribs are bored to the final inside diameter.

In contrast to the stator, the maximum temperature of which does not exceed 450-670°K, the inside core is heated approximately to the temperature of the pumped metal, i.e., to 620-720°K and above. Thus there arises the question of the choice of suitable electrical insulation for the laminations of the core.

The laminations were first insulated with waterglass, to which alundum powder had been added. This was dried in an oven at 470°K. But the waterglass molecule contains water which separates at higher temperatures. As a result, pressure developed in the hermetically sealed core and caused the shell to bulge; this, in turn, led to an increase in the internal flow friction and a reduced throughput. There was a case where the helical rib cut through the inside channel wall. As a result of short-circuiting of the plates by liquid metal, the current consumed by the pump increased by 50%. Therefore, to remove water, the individual laminations, coated with waterglass, were heated to 870°K and kept at this temperature for an hour.

A special high-temperature coating was also used to insulate the plates. Pumps with such coatings work well. However, here again it is necessary to outgas the coating carefully by heating it beforehand under special conditions.

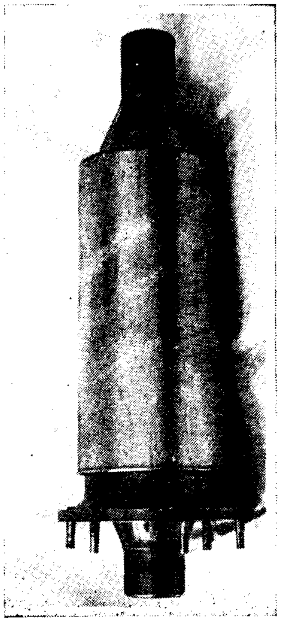

Fig. 2. Working section of the ENIV-6 pump.

Recently, several pumps have been built without a special coating. The core plates were first freed of contaminants and rust; then their surfaces were oxidized by heating to 770°K. The assembled core was hot-sealed (welded up) after being heated to 770°K and held there for an hour. The successful operation and simple construction of these pumps are evidence of the suitability of this solution.

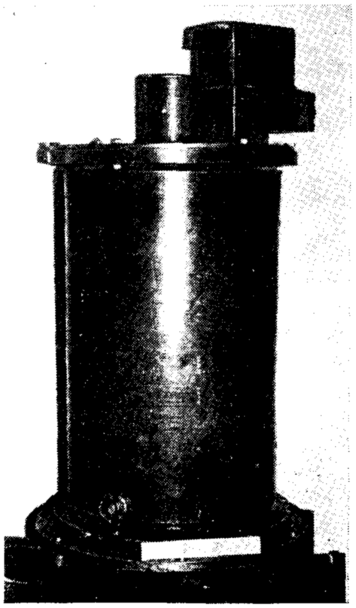

Fig. 3. External view of the ENIV-6 pump.

As noted above, the pump with a capacity of 10 m^3/hr was set up on a test stand to pump sodium-potassium alloy. The power came directly from an industrial power supply. In the first instants after switching on, with the alloy at room temperature the throughput was 10% below rating. With warmup it increased, and after about 40 min, when the alloy had reached 470°K, the pump began to operate at the rated capacity. Figure 4 shows the characteristics corresponding to 620°K. Since during startup the pump develops a pressure of up to $1.6 \cdot 10^6$ N/m^2, to avoid excessive hydraulic shock, the pump is switched on with the valve closed.

All the pumps indicated in Table 1 were designed for pumping sodium or sodium-potassium alloy. The most extensively tested are those with capacities up to and including 50 m^3/hr. These operate successfully at liquid metal temperatures ranging from 620-720°K, and individual pumps have operated for short times at 820°K. The total operating time of these pumps now exceeds 50 000 hours, and there have been no cases of the test stand breaking down due to pump failure.

The same pump, without modification, can handle either sodium or sodium-potassium alloy. Preliminary warmup is accomplished by the pump itself at reduced voltage (30-50% of the rated value). If the pump is designed to pump sodium-potassium alloy, which has a higher resistivity, then, when using it to pump sodium, the supply voltage must be reduced somewhat, since otherwise at small throughputs the pump may develop excessive pressures. To reduce the voltage special autotransformers are used. The voltage regulation capability was also used for smooth throughput control.

Most electromagnetic pumps, probably with the sole exception of the linear coaxial type, are very sensitive to contaminants in the fluid. The chief contaminants in alkali metals are the oxides of the metals themselves. These oxides are deposited on the channel walls, creating electrical contact resistances at the fluid-wall interface and restricting passage. This applies especially to helical-flow pumps, in which the channel height is small. There have been a number of cases where oxides have completely clogged the passage. The pump had to be demounted and the oxides flushed out with water, before it could be used again.

Since the channel height is small, one more thing must be borne in mind. Electromagnetic pumps are so arranged that they are always full of metal. Usually, in the upper part of the circulation loop there is a tank with a free surface, which acts as a compensator. The pump is sure to be full of metal, if during priming the metal moves through the pump under pressure. This is not always possible. Sometimes the metal goes first to the tank, and then the pump may even be primed by gravity. If the pump is mounted vertically and the metal enters from below, then, if the head is inadequate, the pump will not fill. This is probably connected with the capillarity effect in the presence of insufficient wettability. Thus, given a head of about 1 m fluid column (difference of level between tank and location of pump) a pump with a capacity of 0.4 m^3/hr can not start up.

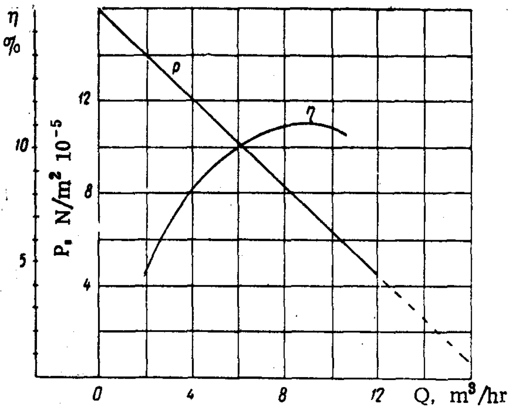

Fig. 4. Characteristics of the ENIV-3 pump.

When the liquid metal is regularly freed of oxides and good priming conditions are ensured during startup, the pumps work with perfect reliability and stability, are easily and smoothly regulated by varying the supply voltage, and can be connected directly to an ordinary power supply. In our own case, we have always tried to replace centrifugal pumps with helical-flow electromagnetic pumps at the first opportunity.

It is now necessary to organize the serial production of electromagnetic pumps, possibly based on those described above, which have been thoroughly tested over long periods of operation, including the pumping of radioactive metals.

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