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COMPRESSORS, PUMPS, REFRIGERATION ENGINEERING

TWIN-SCREW PUMPS FOR TRANSFERRING PETROLEUM–WATER–GAS MULTIPHASE MIXTURE OR DIESEL FUEL

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The successive stages in the development of multiphase pumps were reflected in [1–8]. The A1 2VV 15/40 pump (Fig. 1*a*) was designed for low outputs (8–15 m^3/h) at a differential pressure $p \le 4$ MPa. The A8 2VV 22/40 pump (Fig. 1*b*) was designed on the basis of a modernized A9 2VV 16/25 pump [9] in which the pressure was raised to $p = 4$ MPa, and face seals with a pressureless buffer system were used. Both pumps have an intake pressure of up to 2.5 MPa. When the intake is a multiphase mixture, a 100% water content is possible, but the screws are not allowed to touch the housing because of the poor lubricating qualities. Tolerances (in mm) were assigned since the screws bend during operation [1, 4, 5]: $D_e = 112^{-0.25}_{-0.30}$ for the external screw diameter and $D_i = 62^{+0.1}$ for the internal screw diameter. The dimension of the hole in the housing is 112(H7) mm, the center-to-center distance is $A = 87^{+0.03}$ mm, the lead (pitch S) of the single-threaded screw is $t = S = 25$ mm and the drum length is $L = 125$ mm. The actual side clearance between the screws and the housing is $S_0 = 0.13$–0.16 mm, the side clearance between the side profiles of the screws is $S_1 = 0.1$–0.125 mm, and the clearance between the crest of the thread of one screw and the root of the other is $S_2 = 0.09$–0.12 mm. The relative clearances are $S_0/D_e = (1.16–1.43)\cdot10^{-3}$, $S_1/D_e = (0.89–1.12)\cdot10^{-3}$, and $S_2/D_e = (0.8–1.07)\cdot10^{-3}$.

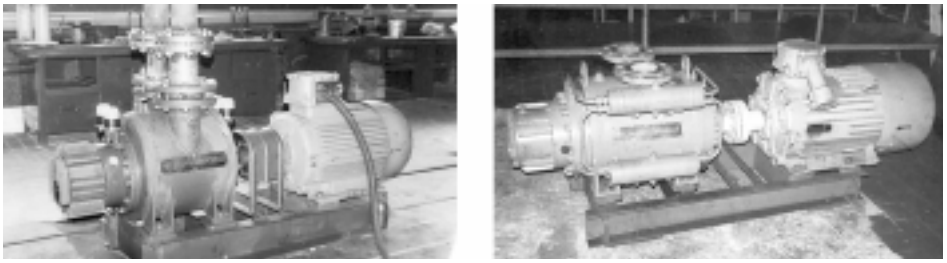
The pump was tested with oil, water, and diesel fuel. The experimental characteristics of the pump at $n = 1450$ rpm and various values of the vacuum head H_h are given in Fig. 2.

In the designation A1 2VV 15/40–8/30 the first fraction, 15/40, denotes a pump output capacity of 15 m^3/h at a pressure of 4 MPa when pumping an oil with a kinematic viscosity $\nu = 74$ cSt (74 mm^2/sec), and the second fraction, 8/30, denotes a pump output capacity of 8 m^3/h at a pressure of 3 MPa when pumping water. The operation of the A1 2VV 15/40–8/30 multiphase pump when pumping only water for a prolonged time is guaranteed for a differential pressure of no more than 3 MPa, and when pumping a mixture containing oil, for a differential pressure no higher than 4 MPa. The cavitation characteristic of the pump was taken at a pressure of 4 MPa and an oil kinematic viscosity of 90 mm^2/sec. At $H_h = 8$ m, the output capacity was 3.6% lower and the operation of the pump was stable.

When pumping a water/air mixture with a high air content, the pump operated vibration-free in various modes. At a screw speed $n = 1450$ rpm and absolute inlet and outlet pressures $p_{in} = 0.2$ MPa and $p_{out} = 2.2$ MPa. i.e., at a pressure increase ratio $\varepsilon = p_{out}/p_{in} = 11$, maximum gas content in mixture $\alpha = 100(Q_g/Q_m) = 86\%$, where $Q_m = Q_g + Q_{liq} = 11.65 + 1.9 = 13.55$ m^3/h; Q_m, Q_g, and Q_{liq} are the deliveries of the mixture, gas, and water, respectively.

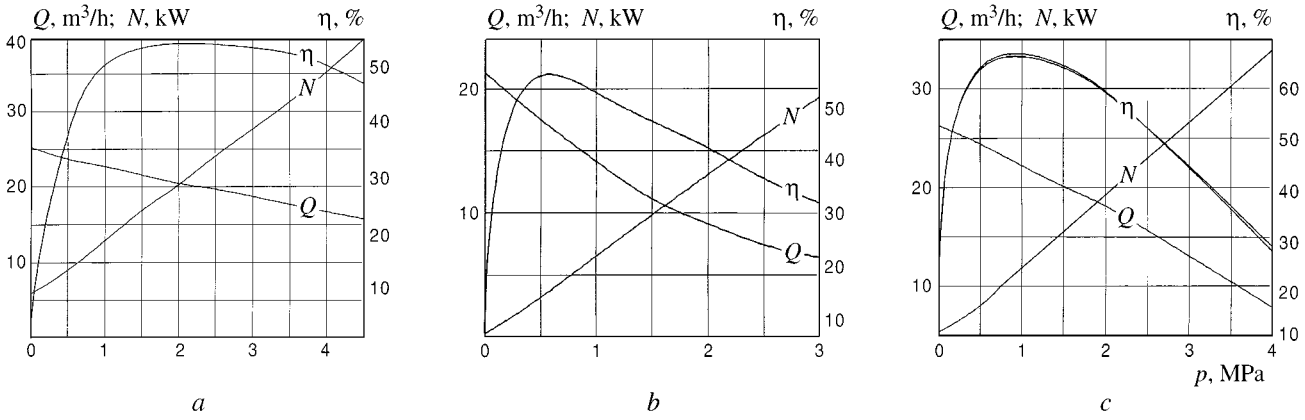
The profile of the screws and the number of enclosed chambers are of great importance for the leak-tightness of the working member (WM) of the pump. A UÉ + OG + ÉV + UKÉ + OÉ profile was chosen for the WM of that pump [6]. The number of enclosed chambers in one drum of a single-thread screw can be calculated from $N = L/S - 0.5 = 125/25 - 0.5 = 4.5$. The geometric output of the pump at $n = 1450$ rpm is 25.14 m^3/h.

Livgidromash OAO. Translated from Khimicheskoe i Neftegazovoe Mashinostroenie, No. 7, pp. 21–23, July, 2004.



a *b*

Fig. 1. Twin-screw pumps: *a*) A1 2VV 15/40; *b*) A8 2VV 22/40.



a *b* *c*

Fig. 2. Characteristics of the A1 2VV 15/40–8/30 multiphase pump ($D_e = 112^{-0.25}_{-0.30}$ mm, $D_i = 62^{+0.1}$ mm, S_1 = 0.1–0.125 mm, n = 1450 rpm); *a*) I-40 oil, ν = 90 mm^2/sec, H_h = 2.5 m; *b*) water, H_h = 2.7 m; *c*) diesel fuel, ν = 3.6 mm^2/sec, H_h = 0.

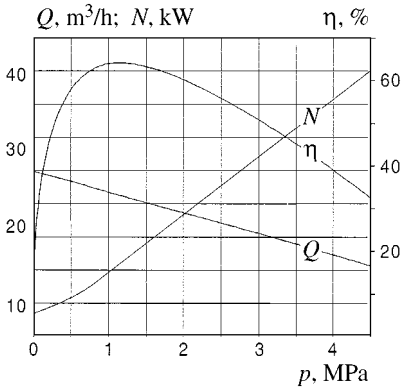


Fig. 3. Characteristics of the A1 2VV 15/40–12/35 D fuel pump ($D_e = 112^{-0.10}_{-0.15}$ mm, $D_i = 62 \pm 0.05$ mm, S_1 = 0.1–0.125 mm, n = 1450 rpm, H_h = 0.5 m, ν = 3.6 mm^2/sec).

The A1 2VV 15/40 pump can be used to deliver diesel fuel to boiler nozzles. Since the lubricating properties of the diesel fuel allow the screws to be in contact with the housing (that is how triple-screw diesel fuel pumps work [8]), we can improve the pump characteristics considerably by reducing the clearance of the WM. The following clearances (mm) were

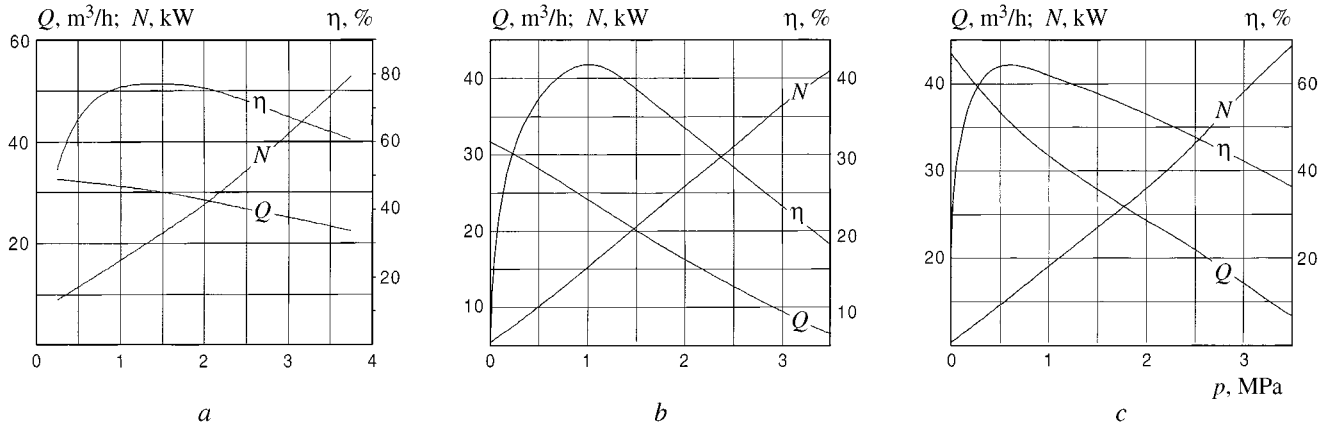


Fig. 4. Characteristics of the A8 2VV 22/40–10/30 multiphase pump ($D_e = 133^{-0.35}_{-0.40}$ mm, $D_i = 71^{+0.05}_{+0.05}$ mm, S_1 = 0.125–0.15 mm, n = 1450 rpm: *a*) I-40 oil, ν = 36 mm^2/sec, H_h = 4 m; *b*) water, H_h = 2 m; *c*) diesel fuel, ν = 3.6 mm^2/sec, H_h = 2 m.

assigned: $D_e = 112^{-0.1}_{-0.15}$, $D_i \pm 0.05$; the remaining dimensions were unchanged. The true clearances (mm) were: S_0 = 0.05–0.065, S_1 = 0.1–0.125, S_2 = 0.02–0.025; the relative clearances were $S_0/D_e = (0.45–0.58)\cdot10^{-3}$, $S_1/D_e = (0.89–1.12)\cdot10^{-3}$, $S_2/D_e = (0.18–0.22)\cdot10^{-3}$.

We note that German firms more frequently use $S_0/D_e = 0.5\cdot10^{-3}$ as well as very small clearances S_2 in the "choking" part of the WM. All of this improves the pump parameters when transferring diesel fuel: for example, at a pressure of 4 MPa the output increased 12.14/5.6 = 2.17 times! That version of the A1 2VV 15/40 pump has been named the A1 2VV 15/40–12/35 D fuel pump. Its characteristics are shown in Fig. 3.

The dimensions and clearances of the single-thread screw of the A8 2VV 22/40–10/30 multiphase pump are (mm): $D_e = 133^{-0.35}_{-0.40}$, $D_i = 71^{+0.15}_{+0.05}$, $t = S$ = 25, L = 150; the diameter of the hole in the housing is 133(H7); the center-to-center distance is $A = 102^{+0.03}$. The actual clearances (mm) are S_0 = 0.2, S_1 = 0.125–0.15, S_2 = 0.12; the relative clearances are $S_0/D_e = 1.5\cdot10^{-3}$, $S_1/D_e = (0.94–1.13)\cdot10^{-3}$, $S_2/D_e = 0.9\cdot10^{-3}$. The pump was tested with oil to a differential pressure p = 5 MPa, with water to p = 3.5 MPa and with diesel fuel to p = 3.5 MPa. The experimental characteristics of the pump are shown in Fig. 4.

The operation of the multiphase A8 2VV 22/40–10/30 pump for a prolonged time is guaranteed when water is pumped at a differential pressure of up to 3 MPa and when a mixture containing oil is pumped at a differential pressure up to 4 MPa.

When a water/air mixture is pumped at absolute pressures p_{out} = 1.1 MPa at the outlet and p_{in} = 0.25 MPa at the inlet, i.e., at ε = 4.4, the maximum percentage of gas in the mixture is $\alpha = 100(Q_g/Q_m)$ = 93%, where $Q_m = Q_g + Q_{liq}$ = = 21.85 + 1.56 = 23.4 m^3/h.

To check the ability of the pump to dissipate gas slugs, we shut off the water intake at absolute and intake outlet pressures p_{out} = 2.2 MPa and p_{in} = 0.2–0.25 MPa (pressure oscillations). The pump operated for roughly 3–5 min pumping only air. The pressure dropped to 1.5–1.8 MPa and the pump operated stably without increasing the noise and vibration level.

The profile UÉ + OG + ÉV + UKÉ + OÉ was used for the WM of that pump. The number of closed chambers in one drum of a single thread screw is $N = L/S - 0.5 = 150/25 - 0.5 = 5.5$. The geometric output of pump at n = 1450 rpm is 35.34 m^3/h.

Working members with small clearances (mm) $D_e = 133^{-0.1}_{-0.15}$ and $D_i = 71 \pm 0.05$ were prepared for the A8 2VV 22/40 pump, the remaining dimensions were unchanged. The real clearances (mm) were S_0 = 0.08, S_1 = 0.15, and S_2 = 0.09; the relative clearances were $S_0/D_e = 0.6\cdot10^{-3}$, $S_1/D_e = 1.13\cdot10^{-3}$, and $S_2/D_e = 0.68\cdot10^{-3}$. The decrease in the "working" clearance S_0 and the clearance S_1 at the "blocking" point of the WM substantially improved the pump characteristics. The pump was tested with diesel fuel to a pressure of 4.5 MPa (Fig. 5). At 3.5 MPa the output increased by a factor of 17.15/8.55, i.e., doubled. That version of the A8 2VV 22/40 pump was designated the A8 2VV 22/40–16/35 D fuel pump. The cavitation char-

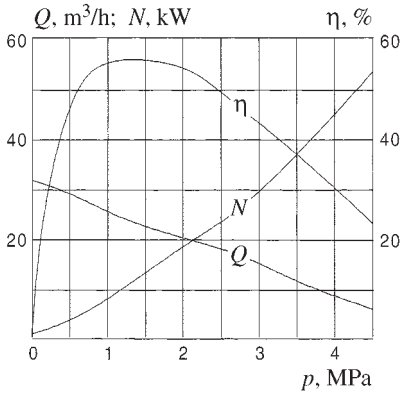


Fig. 5. Characteristics of A8 2VV 22/40–16/35 D fuel pump ($D_e = 133^{-0.10}_{-0.15}$ mm, $D_i = 71 \pm 0.05$ mm, $S_1 = 0.15$ mm, $n = 1450$ rpm, $H_h = 0.5$ m, $\nu = 3.6$ mm^2/sec).

acteristic of the pump was taken at a pressure of 2.5 MPa and a diesel fuel kinematic viscosity of 3.6 mm^2/sec. The output remained constant up to $H_h = 6$ m and decreased by 8.8% at $H_h = 8$ m, but the delivery was not cut off.

In conclusion we note that when developing a method for calculating the characteristics of multiphase twin-screw pumps [10], along with data from Bornemann and Flowserve, we also used experimental data from Livgidromash OAO [1, 9], which clearly agree with those of the foreign firms. This is indirect evidence that the proposed testing methods and the characteristics obtained for twin-screw multiphase pumps are correct.

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