E. E. Balabin and V. S. Kasulin

Economy in donors' blood during operations using an artificial circulation is an urgent problem in medical engineering in connection with the production of "heart-lung" apparatuses [1-3].

The total primary filling volume of the oxygenator of the foam-film type can be divided conventionally into elementary volumes, which together determine its functional qualities as a gas-exchange system and the performance of the apparatus as a whole [4]. One of these elementary volumes, a reduction of which must be first on the list during the redesigning of the AIK-5M, is the volume determined by the characteristics of the electromechanical drive [5]. The size of this elementary volume is determined by the combined dynamic characteristics of the system of the electromechanical drive and pump; it depends on the load, the inertia of the moving parts, and their speeds.

Using the familiar physicomathematical relationship [5], the volume can be expressed as a function of the parameters of the system:

\[ V = \frac{q \omega}{2 M_i}, \]  

where \( V \) is the blood volume (in ml); \( q \) the stroke volume (in ml/beat); \( \omega \) the angular velocity of rotation of the electric motor shaft before stopping (in rad/sec); \( I \) the moment of inertia of the moving parts connected to the motor shaft (in nm·sec²/rad); \( i \) the transmission ratio of the mechanical drive (in rad/stroke), and \( M_i \) the loading factor of the electric motor (in Nm).

Considering that

\[ M_i = \frac{w_i}{i}, \]

\[ \omega = n \cdot i, \]

where \( t \) is the time of stopping the system (in sec), \( n \) the number of strokes of the pump per second (the pulse rate), and substituting these values in equation (1), we obtain

\[ V = q \cdot n \cdot \frac{t}{2} \]

This equation is convenient because the stopping time is easy to obtain experimentally from the oscillogram. The worst conditions from the point of view of obtaining the greatest possible stopping time must be chosen for the investigation. It follows from equation (1) that these conditions are satisfied by the maximal initial velocity of rotation of the electric motor shaft and the minimal loading moment, obtained by the use of a minimal pressure in the pump chamber.

Oscillograms of the process of stopping the electromechanical drive of the AIK-5M apparatus under the conditions given in Table 1 are shown in Fig. 1.
Fig. 1. Oscillograms of the process of stopping the electromechanical drive of the AIK-5M apparatus. Time markers on records correspond to 0.1 sec. a) large pump, q = 6 ml/stroke; b) large pump, q = 60 ml/stroke; c) small pump, q = 4 ml/stroke; d) small pump, q = 38 ml/stroke.

**TABLE 1. Conditions of Stopping Electromechanical Drive**

<table>
<thead>
<tr>
<th>Type of pump</th>
<th>Pulse rate, strokes/sec</th>
<th>Stroke volume, ml/ stroke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>1.67</td>
<td>60</td>
</tr>
<tr>
<td>Small</td>
<td>1.67</td>
<td>38</td>
</tr>
</tbody>
</table>

**TABLE 2. Results of Calculations from Experimental Data**

<table>
<thead>
<tr>
<th>Type of pump</th>
<th>Stroke volume, ml/ stroke</th>
<th>Blood volume, ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large</td>
<td>60</td>
<td>35</td>
</tr>
<tr>
<td>Small</td>
<td>38</td>
<td>28.5</td>
</tr>
</tbody>
</table>

Analysis of the oscillograms showed that the stopping time of the electromechanical drive varies from 0.7 to 1.2 sec. The results of the calculation by equation (4), with substitution of the experimental results in it, are given in Table 2.

It will be clear from Table 2 that the greatest volume is obtained with the worst conditions of operation of the electromechanical drive. Obviously, the test must be carried out when the apparatus is working under those conditions.

The writers have shown [5] that the analogous volume for the AIK-63 apparatus is 200 ml. In the AIK-5M apparatus this volume is reduced to 35 ml, as a result of the use of basically new systems for controlling the stroke volume and pulse rate of the pumps.

The stroke volume in the AIK-5M apparatus is controlled by a mechanism based on a floating cross-coupling, which increases the loading moment of the driving electric motor by several times. The considerable decrease in the moment of inertia of the moving parts, when an electric motor of the same type is used, is achieved by the use of an automatic drive, providing for stabilization of the speed of rotation of the electric motor shaft despite changes in the load.

The incorporation of the results of these various investigations and technical solutions in the design of the mass-produced AIK-5M apparatus will lead to further economies in the consumption of donors' blood.