

# The DLR-Heart: A New Implantable, Pulsatile Left Ventricular Assist Device. First In Vitro Testing.

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## Abstract

The DLR-Heart is designed as an implantable left ventricular assist device (VAD). It is connected to the left heart chamber and pumps blood back to the aorta using high pressure. The DLR heart works on the pumping principle of simultaneous suction and forward pumping with the help of two chambers that lie on top of each other. This arrangement makes it possible for the unit to intake blood and pump it out simultaneously as one chamber is compressed and the other concurrently released. For compression, a very thin pusher plate is used. The two chambers lie very close together so that only when one chamber is compressed can the other fully open. This allows for an extremely flat construction. The chambers are formed in an arc with the propulsion unit placed directly underneath minimising the system size. The pump housing is 46 mm thick, 118 mm long and 157 mm wide. The weight of the system including connectors and valves is 480 g, the housing volume is 543 ml and the stroke volume of one chamber is up to 72 ml. Two heart valve prostheses (St. Jude Medical) are attached to the entrance to the pressure tubes. A so-called sail valve is embedded at the outflow adapter reducing the risk of hemolysis and thromboses. Y-form connectors are used for the intake and outflow of the support unit to the heart and from the unit to the aorta. The VAD is driven by an electric motor.



Fig. 1 The DLR-Heart, a Left Ventricular Assist Device

## Methods and Materials

The DLR-VAD works with new computer-aided designed, curved flow chambers with variable diameters. The chambers are built out of medical silicon rubber (NUSIL). For the driving unit, a brushless DC motor (WITTENSTEIN) and a HARMONIC-DRIVE gear (HARMONIC Inc.) was used. The motor is speed controlled and rotates continuously. The housing is made of STL and is completely closed.

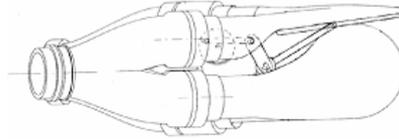


Fig. 2 Artificial heart chambers with pusher plate

## Test Objectives and Results

For evaluation of the VAD, a specially designed circulatory, closed mock loop was used. This included a holding tank, a so-called Windkessel and a compliance chamber. The blood analogue fluid used is a DMSO-water-seperan mixture with a density of  $1050 \text{ kg/m}^3$  and non-Newtonian flow behaviour. Pressure and flow were measured at the inflow and outflow conduits with pressure transducers (Druck GmbH) and flow probes (Transsonic). Temperature sensors were used inside the VAD, near the motor, on the surface of the VAD and at in- and outflow conduits. An electronic analyser was designed at DLR to measure energy loss and efficiency of the system. The VAD was tested within a frequency range of 60 to 120 beats per minute. Parameters of the systemic simulator were varied: The pre- and afterload and the Windkessel- setting. A Motor speed of only 2150 rpm was necessary to obtain a pulse rate of 100 b.p.m. and a pump output of 4.4 L/min. Due to two chamber technique, VAD generates a suction effect at the inlet. The system was tested at preloads between 4 to 20 mmHg and afterloads between 80 to 100 mmHg. The VAD provides output pressure up to 180 mmHg. The energy consumption is in between 10 Watt at 70 b.p.m. and 18 Watt at 120 b.p.m.

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