Considerations on Making Test Stands for Small Hydraulic Turbines

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Abstract: *Hydraulic turbine test stands represent an important link in the efficient utilization of the energy potential of water flows. The realization of these turbines begins with an approximate design, based on the differential equations of motion of ideal fluids, and continues with successive stages of performance testing in the laboratory, on small-scale models. Using different similarity criteria based on geometric, kinematic and dynamic similarities, the conclusions drawn from the operation of the model will also be valid for the real machine. The purpose of the paper is to present some points of view on the realization of three types of stands for small hydraulic turbines, of which two are patented and one is a patent application. These stands simulate real operating conditions on permanent flowing water with velocities, flows and falls for small hydraulic turbines that can be installed on the water line, in locations that do not use dams or other expensive water storage facilities. The main author of the patent documentation makes a synthesis of the constructive-functional characteristics of the respective stands through this article.*

Keywords: *Test stands, small hydraulic turbines, permanent flowing waters, velocities, flows and water falls*

1. Introduction

The role of a test stand is to reproduce in total geometric similarity the physical phenomena that take place in an industrial turbine. The experimental research of hydropower aggregates is carried out in the laboratories of universities and institutes with concerns in the field, on experimental stands that simulate the real operating conditions of hydraulic turbines. Function of the type of hydraulic energy converted into electrical energy, hydraulic turbines are divided into two categories: "**flow (speed) turbines**", which harness the kinetic energy, respectively the flow rate Q [m^3/s] or the speed v [m/s] of the water and "**fall turbines",** which exploit the potential energy, respectively the fall H [m] of the water. Therefore, the experimental test stands for hydraulic turbines will be "flow (velocity) stands" [1,2], with larger horizontal dimensions and "drop stands" [3,4], with larger vertical dimensions.
The load of the hydraulic turbine mounted on the experimental test stand can be achieved with an electric generator, with the shaft coupled to the turbine rotor shaft, or simulated, with a mechanical / hydraulic braking system, which replaces the electric generator. Three constructive solutions of stands for small hydraulic turbines are presented below; two from the first category [5,6] and one from the second category [7].

2. Constructive stand solutions for testing small flow hydraulic turbines

This chapter presents the constructive solutions for two means of testing small hydraulic turbines, which differ from each other in the water flow (speed) regulation mode and the load simulation system, respectively:
- *a stand for the optimization of the hydrodynamic profile of the blades and functional tests of the rotors of hydraulic turbines*, with which the speed distribution on the rotor blades of axial hydraulic turbines of reduced dimensions and masses can be determined experimentally, successively in two stages, in order to optimize their hydrodynamic profile, in the first stage, as well as the mechanical parameters, speed and moment, of the hydraulic turbine rotors, with the previously experimentally optimized blade profile, in the second stage;
- *a stand with a tilting water ford*, for the experimental testing of scale models, with reduced dimensions and masses, of axial hydraulic turbine rotors, with a vertical or horizontal shaft.

2.1. Stand for optimizing the hydrodynamic profile of blades and functional tests of hydraulic turbine rotors

Constructive solution for this stand is shown in figures 1, 2 and 3.

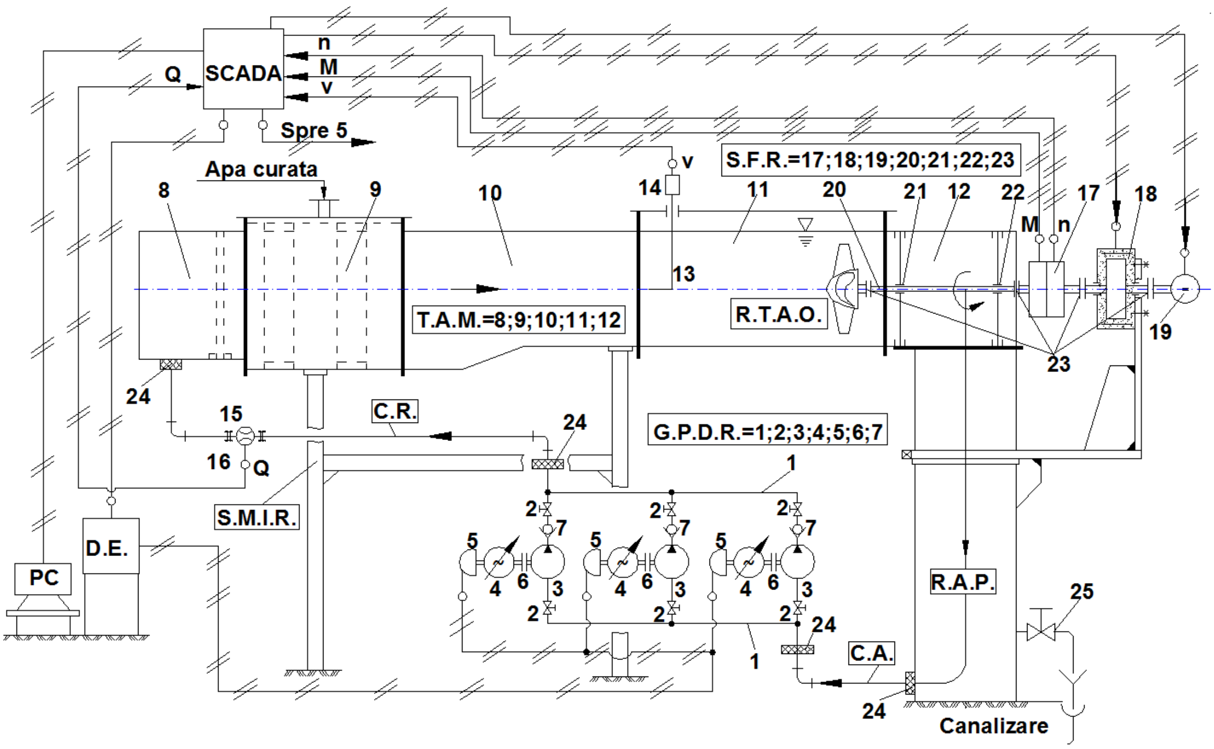

Fig. 1. Functional and constructional scheme of the stand

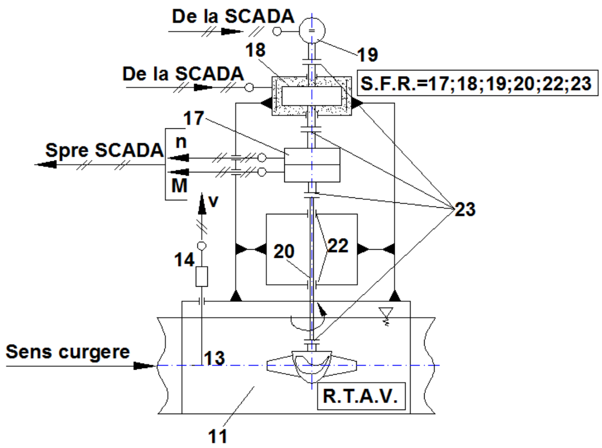

Fig. 2. The detail of the turbine with vertical shaft coupled at adjustable brake system

Fig. 3. The assembly of the main modules of the stand

The stand in figures 1, 2 and 3 forcibly circulates a volume of clean water in a closed circuit, made by a pumping group with adjustable flow **G.P.D.R**., which sucks from a suction tank of pumps **R.A.P.** and discharges into a modular water tunnel, **T.A.M**., consisting of five horizontal sections, removable and watertight, provided with covers, of which the first three rest on a metal support with adjustable height **S.M.I.R**., and the last one on the suction tank of the pumps **R.A.P.**, with which it communicates. The closed water circuit is made on the route **R.A.P.- G.P.D.R.- T.A.M.- R.A.P.**
The first three sections of the modular water tunnel **T.A.M**., from which two have a variable section, contribute to the stabilization and uniformity of the flow in the fourth section, made of a transparent and resistant material, in which the fixed rotor blades are mounted, to determine of the speed

distribution, respectively the axial turbine rotor with horizontal axis **R.T.A.O**., figure 1 or with vertical shaft **R.T.A.V**., figure 2, which is to be tried.

These models of hydraulic turbine rotors couple, through a vertical or horizontal shaft, to an adjustable braking system **S.F.R.,** which simulates the load of the rotor immersed in the modular water tunnel, when it is driven by the kinetic energy of the water.

Through a SCADA monitoring, control and data acquisition system, three transducers and a **PC** computer, the following is achieved: *the control* of the adjustable braking system and the flow regulation of the pumping group; *the monitoring and acquisition* of the adjustable parameters of the stand, namely the flow rate **Q** and the speed **v** of the water in the fourth section of the tunnel and the mechanical parameters of the adjustable braking system, namely the moment **M** and the rotational speed **n**.

The stand allows the experimental determination of three functional characteristics for the tested hydraulic turbine rotor models, respectively: moment at the rotor axis as a function of flow at constant load, i.e. $M=f(Q)$ ***at*** $M_r =const$., rotor speed as a function of load at constant flow, i.e. $n=f(M_r)$ at $Q=const.$ and rotor speed as a function of flow at constant load, i.e. $n=f(Q)$ at $Mr =const.$

The pumping group with adjustable flow **G.P.D.R.**, located under the modular water tunnel **T.A.M.**, consists of three centrifugal pumps **3**, identical and mounted in parallel to sum up the flows, which have a common suction collector and a discharge collector **1**, each of the three pumps can be separated from the collection pipes of the group by means of two isolation valves **2**, one on the suction and the other on the discharge, with a directional valve **7** installed before the valve on the discharge, and each pump being driven by a motor electric of 380 V ac. **4**, coupled to the pump shaft by means of an elastic mechanical coupling **6** and powered by means of an adjustable frequency converter **5**, with the help of which the drive rotational speed of the pump is regulated and, through it, the flow rate of the pump. The adjustable flow pump group sucks through a suction line **AC** from a suction tank of the pumps **R.A.P.** and discharges through a discharge pipe **C.R.** in a. modular water tunnel **T.A.M**; to prevent the propagation of vibrations generated by the pumping group towards the tunnel and tank, four elastic sleeves **24** are to be installed.

The modular water tunnel **T.A.M**. is composed of five sections provided with covers, removable and watertight, which form a continuous assembly, without thresholds near the joints. In the first section **8**, acting as a diffuser in the flow, the pumped water enters the tunnel through a cylinder made of PVC pipe, with a glued plastic cover, provided with large perforations on its side surface, then meets on its way a plate made of perforated sheet metal, mounted transversely to the flow direction. The second section **9**, of constant section and equal to the exit section of the first section, contains sieve packs, perforated sheet screens and honeycomb structures, all with the role of stilling the flow and equalizing the current lines. The third section **10**, is contraction because its output section is reduced to 1/6 of the input section. The first three sections of the modular water tunnel rest on a metal support with adjustable height **S.M.I.R**. Next comes the test/visualization section **11**, where the water flow is uniform and stable due to the shapes, sizes, quality of the inner surface and the quality of the joints of the first three sections of the tunnel, and the output section **12**, through which the water tunnel communicates and supports with/ on the suction tank of the pumps **R.A.P**.

The suction tank of the pumps, **R.A.P**., contains inside: a deflector, which directs the flow of water from the tunnel to the outlet of the tank; a fine screen, mounted transversely to the direction of water flow in the tank, to break air bubbles and a PVC elbow, at 90^o, mounted at the bottom of the tank, to reduce bottom vortexes in the suction area of the pumps.

The axial turbine rotor model with horizontal shaft **R.T.A.O.**, or with vertical shaft **R.T.A.V**., to be tried on the stand, is coupled by means of a horizontal or vertical shaft **20**, to an adjustable braking system **S.F.R.**

Adjustable braking system **S.F.R.** contains: two bearings, one radial **21** and another radial-axial **22**, in the case of coupling to **R.T.A.O**., two bearings radial-axial **22**, in the case of coupling to **R.T.A.V**; a torque and speed transducer **17**; a brake with magnetic powders **18**, with the possibility of horizontal or vertical mounting, with adjustable resistance moment depending on the supply current; a 24 V d.c. electric motor **19**, necessary for driving the brake before carrying out the tests on the stand, for the homogenization of the magnetic powder and the determination of the friction

in the bearings, and three mechanical couplings **23**, from the kinematic chain model shaft rotor-torque transducer and speed-brake-24 V d.c electric motor.
The monitoring, control and data acquisition system **SCADA** contains: an electric box, equipped with programmable controller, two electrical sources of supply, for brake and for electric motor of 24 V d.c., four numerical displays, for flow, for differential pressure, for torque and rotational speed; an electromagnetic flowmeter **15** and a flow transducer **16**, mounted on the discharge pipe **C.R**.; a Pitot-Prandtl tube **13**, movable in three orthogonal directions and a differential pressure transducer **14**, mounted on the frame of visualization test section; a **PC** calculator. The **SCADA** system ensures: monitoring and acquisition of four parameters, respectively water flow **Q** and speed **v** (indirect by converting the differential pressure in speed) in the test/visualization section, torque **M** and rotational speed **n** at the shaft of the test rotor model; three controls, one for adjusting the flow of the pumping group, one for adjusting the resisting torque of the magnetic powder brake and one for driving the 24 V d.c. electric motor.
Three frequency converters **5** and three electric fans for cooling the motors are mounted in the electric power cabinet **DE**, which supplies the three electric motors driving the pumps. The electric cabinet ensures: power supply for electric motors of 380 V a.c. starting and stopping the pumping group; monitoring and regulation of the pumping group flow, carried out locally, from the cap of the electric cabinet, by means of three rotatable potentiometers provided with numerical displays.

Table 1: The function of the stand and the tests carried out procedure

Name of the activity	Name of the stage	Description of the stages
Preparing stand for testing	Water tunnel rightness	*checking and restore* , if it is the case, of the water modular tunnel rightness;
	Filling the stand with water and pumps aeration	*filling the stand with* clean and filtered *water* until a preset level;
		adjustment water level in tunnel, from discharge pipe or filling pipe from the network;
		pump aeration by unscrewing / tightening vent caps of each pump.
Starting and preliminary checks of stand	Starting up pumping group and stand aeration	- *it starts successively* each pump, from minimum flow to maximum flow;
		- *with the maximum flow,* resulted by summation of maximum flows of the three pumps, *water is recirculated* through modular tunnel for *15 minutes*, for aeration, elimination of air bubbles being made at the transparent section level, the only one in which the flow is on the surface.
	Preliminary checks of the stand	Checking the water flow uniformity in transparent section: - *is done at maximum flow* of the pumping group, in three parts of the section (two at the ends and one in the middle), with Pitot-Prandtl tube; - *in each section is measured the water speed*, in five equidistant points of the section width; in each point of the width are measured five equidistant point on the depth section. The total number of measure points of water speed, in order to certificate placement of deviation of the speed fluctuation in an accepted interval, is of *75*; - *reduction of speed fluctuation*, is done by mounting of an additional sieves in the second section of the modular water tunnel.
		Optimization of hydrodynamic form of rotor blade. - *is injected* in the transparent tunnel, from exterior, a colored liquid heavy miscible in water; - *are successively introduced* in the transparent tunnel more blades with diverse hydrodynamic profiles, fixed and without possibilities of movement in the tunnel; - *for each introduced blade* the current spectrum lines for different speed rates of water are shot with a laser camera; - *spectral comparative analysis* of speed distribution around the blades profile establishes which is the blade with the best hydrodynamic profile.

Determination of functional characteristics of tested turbine model		*Stage 1*- brake with magnetic powder unfed with current: - *it starts up* the first electropump at a minimum flow corresponding to the adjusted frequency of the convertor at the value of *20Hz*; - *it increases progressively* the frequency of the first converter until at *50Hz*, respectively the flow of the first pump until a maximum flow, following the value of the flow at which the turbine starts to rotate; - *if it is the case,* the obtained flow rate by adjustment of the other two electropumps *is overlapped* over the maximum flow rate of the first pump, by slowly actuating the converters potentiometers of corresponding frequency; - *if the turbine does not rotate* neither at the maximum flow rate of the stand, nor at the maximum speed achieved in the transparent tunnel, it means that the turbine does not generate a couple greater than the minimum resistant torque of the **S.F.R** ; - *the value of the flow rate at which the turbine rotates with a minimum imposed speed* , for instance *50 rpm*, represents the flow rate at which the turbine generates a couple equal to the minimum resistant torque, (the minimum resistant torque of the unpowered brake and the low-friction bearings of the **S.F.R.)** denoted $Q_{0,1}$.
	Characteristic M=f(Q) at Mr=const.	*Stage 2 – the test will continue* with the flow adjustment from $Q_{0,1}$ to the maximum value, followed by the adjustment of the supply current of the brake with magnetic powders, respectively: - *the torque* at the turbine shaft will be determined for the maximum stand flow and the rotational speed of *50 rpm.* For this purpose, the three pumps will be connected at the maximum flow, the brake supply current will be progressively increased until the rotational speed drops to 50 rpm; after determining the torque value at maximum flow, M_{QMAX}, the test will continue as follows: - the resistant torque of the adjustable brake system will be progressively adjusted, in an increasing direction, with equal steps, for 10 values from the interval *Mmin...* M_{QMAX}; - *for each of ten current values* of the adjusted load, the flow will be progressively increased, from the value corresponding to the previous load up to the value corresponding to the rotational speed of *50 rpm* of the tested model; - *the 10 values of the flow* corresponding to the load increase and the rotational speed obtaining of *50 rpm* for the tested model will be acquired; - *the test will be repeated identically* also for the descending direction of the load, from M_{QMAX} to *Mmin*; - another *10 values of the flow* corresponding to the decrease of load and rotational speed obtaining of *50 rpm* for the tested *model will be acquired*, With the 20 pairs of values (flow, torque) can be drawn the characteristic *M=f(Q) / Mr=const*.
	Characteristic n=f(Q) at Mr=const.	- *the minimum flow rate* $Q_{0,1}$, at which the turbine generates a torque equal to the minimum resistant torque Mmin, as in the previous case, stage 1, and the torque of turbine rotor at the maximum flow rate M_{QMAX}, as in the previous case, stage 2 are found; - *the adjustable brake will be fixed* at a value of the resistant torque included in the range *Mmin...* M_{QMAX}, which will remain constant; - *for that load value* the flow that crosses the test /visualization section is varied in an increasing direction, from Q_{MAX} to $Q_{0.1}$; - *for each value of the flow*, the rotational speed value of the tested turbine model is acquired. A family of stationary characteristics can be build, rotational speed as a function of flow at constant load, where each characteristic of the family belongs to a constant value of the load in the interval *Mmin...* M_{QMAX}.
	Characteristic n=f(Mr) at	- *The minimum flow rate* $Q_{0,1}$, at which the turbine generates a torque equal with the minimum resistant torque *Mmin*, as in the first case,

	Q=const.	stage1 and the torque of the turbine rotor at the maximum flow rate M_{QMAX}, as in the first case, stage 2 are found; - *a water circulation flow value* will be set in the range $Q_{0,1}...Q_{MAX}$; - *for that value of the flow,* the resistant moment of the adjustable braking system is varied, in an increasing and decreasing direction, with a constant step, included in the interval *Mmin... M_{QMAX}*; - *for each value of the resistant moment,* the rotational speed value of the tested turbine model is acquired. A family of stationary characteristics can be build, rotational speed as a function of load at constant flow, where each characteristic of the family belongs to a constant value of the flow in the interval $Q_{0,1}...Q_{MAX}$.

2.2. Stand with tilted water ford for testing some hydraulic turbines

The **constructive solution** for this stand is shown in figures 4...8.

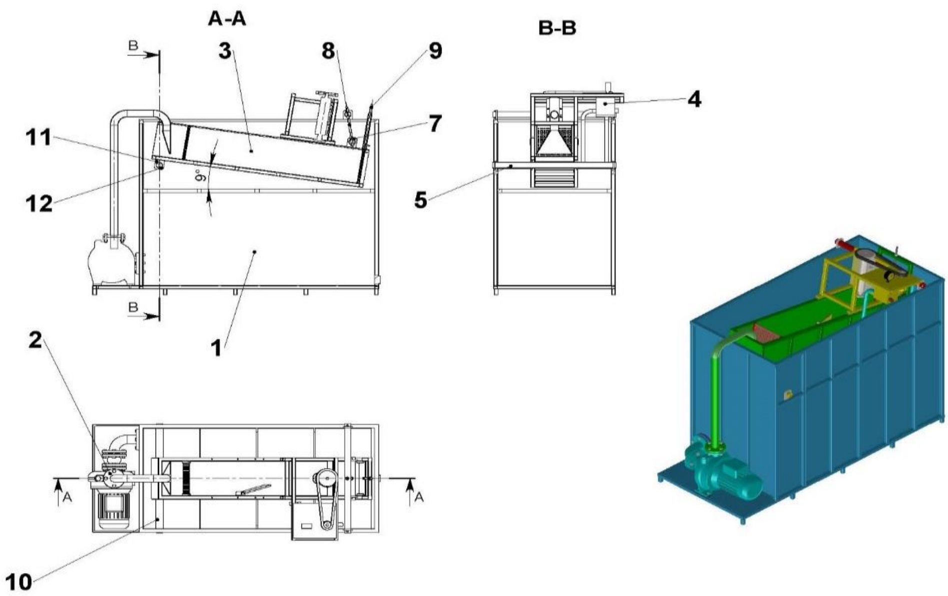

Fig. 4. Assembly-mounting drawing and isometric view of the stand

The hydraulic microturbines test stand with tilted water ford, figure 4, consists of a water tank **1**,an adjustable flow pumping module **2**, which sucks from the bottom of the tank and discharges at the left end of a water ford with constant section **3,** in the form or trough, mounted on the upper side of the tank, the water ford being equipped, at the opposite end of the water supply ,with a load simulation device **4**, and having the possibility of adjustable tilting, with maxim 9^o, to the right of the horizontal position, around a shaft **5**, equipped with two bearings and two spacers **10**, when a screw-nut mechanism **8** is manually actuated**,** which moves the lifting cross-bar **7,** mounted on the upper part of the right end of the ford , in front of the lifting cross-bar **6**, mounted at the superior side of the right end of the water tank , each of two cross-bars being equipped with two bearings.
The tilting shaft of the ford **5** and the two lifting cross-bars **6** and **7** are secured at the ends, against the detachment from the bearings, by two screws **11** and two nuts **12** each, and the stand also contains another mechanism screw-nut **9,** which actuates a flat weir, that regulates the water level upstream of it, in the ford **3**.

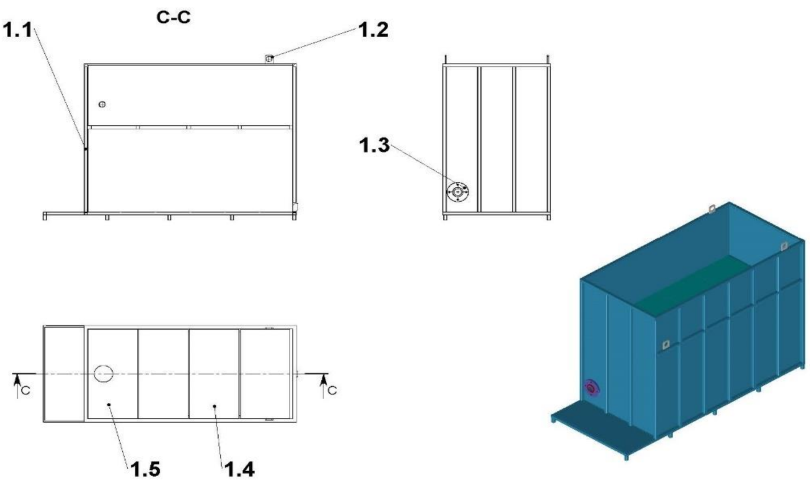

Fig. 5. Assembly-mounting drawing and isometric view of the water tank

The **water tank 1**, figure 5, built of pieces of stainless-steel sheet, welded on a resistance structure of metal profiles **1.1**, is provided at the top, at about half of its height, with a cover made of four tin plates, of which three whole, **1.4** and one perforated, **1.5**. The tank is provided with four bearing supports, **1.2**, of which two, for the ford tilting shaft, are positioned on the left side above the cover, and the other two, for the ford lifting cross-bar, are positioned on the right side. On the left side, close to the bottom of the tank, is positioned the suction flange of the pumping module.

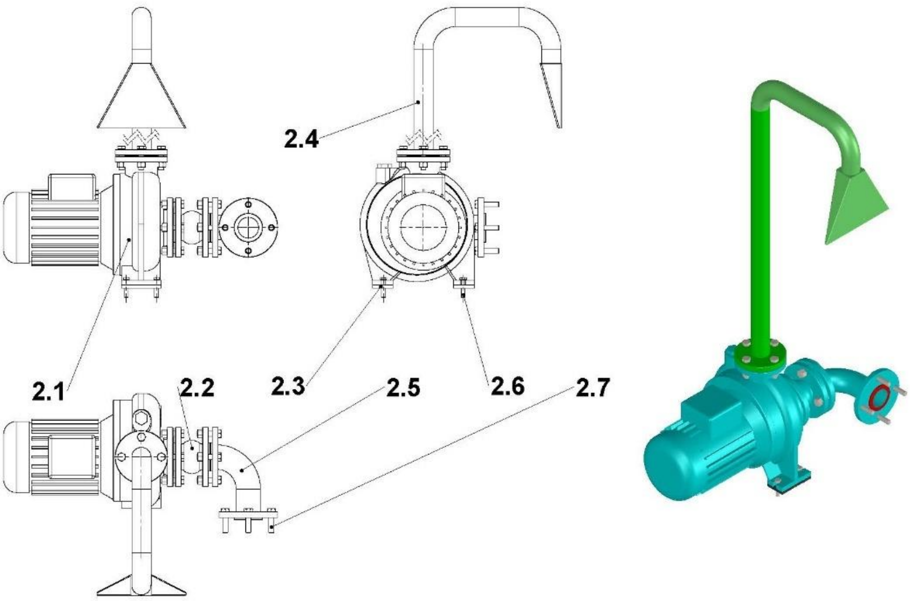

Fig. 6. Assembly-mounting drawing and isometric view of the pumping module

The pumping module **2**, figure 6, consists of an electric pump **2.1**, with adjustable flow rate by varying the frequency of the electric drive motor supply current, provided on the suction pipe with an anti-vibration connection **2.2**, a flange connection **2.5**, screws **2.6** and nuts **2.7**, and the discharge pipe **2.4** contains two welded elbows and a water flow diffuser (not figured) in the ford. The pump base is fixed on a pedestal, by means of two vibration dampers **2.3** and four screws **2.6**.

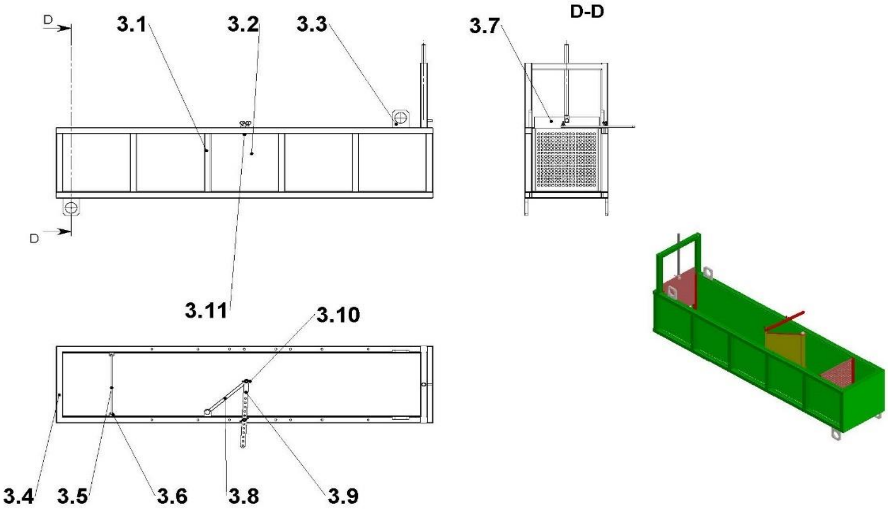

Fig. 7. Assembly-mounting drawing and isometric view of water ford

The water ford 3, figure 7, contains a tilting frame **3.1**, on which a water through **3.2** is welded, parallelepipedal in shape and made of pieces of stainless-steel sheet, which is closed at the front, on the left side, with a plate **3.4**, and at the opposite end with a **3.7** flat sluice, for regulating the water level in the trough. The ford is also equipped with four bearings **3.3**, two mounted on the lower-left side and two mounted on the upper-right side, a stainless steel sheet perforated screen for stilling the flow **3.5**, transversely mounted, with two skids **3.6**, inside the trough and a flap **3.8** for deflection the flow to the tested turbine, equipped with an angle adjustment lever **3.9**, with penetrated transverse holes, which can be locked in the desired position with the help of a screw **3.10** and a wing nut **3.11**.

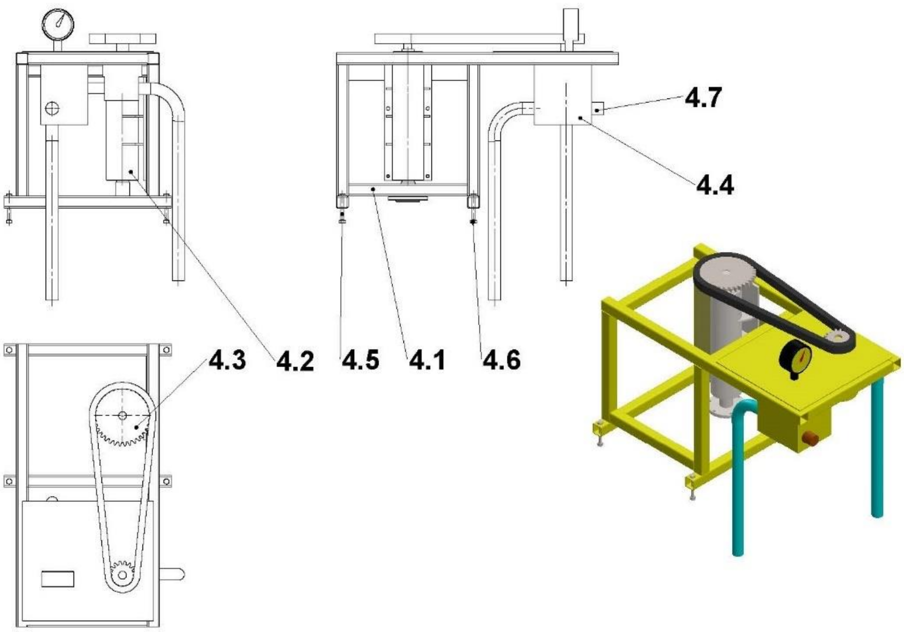

Fig. 8. Assembly-mounting drawing and isometric view of load simulation device

The load simulation device 4, figure 8, consists of a support **4.1**, on which the turbine to be tested is mounted, the turbine shaft being inserted into the bearing **4.2**, equipped at the bottom with a flange for holding the turbine rotor, and at the top with a large diameter gear for a transmission with toothed belt **4.3**, with a 10:1 ratio between the turbine shaft and the gear pump shaft (not figured) that sucks and discharges from/into the water tank , when is driven by the tested turbine, by means of the transmission with the toothed belt, the pump load being carried out by tightening an adjustable needle throttle (hydraulic resistance) **4.7**, mounted on the discharge pipe of the gear pump, and the pressure created by the load being read on a pressure gauge (not positioned). The load simulating device is fixed with four screws **4.5** and four nuts **4.6** to the upper edge of the water ford **3**, on which a bracket with performed holes for screws is welded. To carry out the tests, the stand is equipped with three transducers (not positioned): one for rotational speed, which measures the rotational speed in the shaft of the tested turbine, one for speed and one for level, which measures the speed / water level in the ford.

The **test flow** is measured indirectly by means of velocity and level transducers. It is expressed with the relation: $Qp=v{\cdot}S=v{\cdot}l{\cdot}h$, where Qp is the test flow rate $[m^3/s]$; v is the water velocity in the ford $[m/s]$; S is the water flow section in the ford $[m^2]$;

The **load** with which the tested turbine is loaded is measured indirectly with the help of the manometer (not figured) on the load simulation device **4**. It is expressed by the relation: $Mr = p{\cdot}c$ where Mr is the resisting torque (couple) [Nm] with which device loads the tested turbine; p is the pressure on the discharge pipe of the gear pump of the device $[10^5{\cdot}N/m^2]$, read on the manometer and adjusted from the needle throttle **4.7**; c is the gear pump capacity $[10^{-6}{\cdot}cm^3/rot]$ of the device.

Table 2: Stand functionality and the ways of carrying out the tests

Name of the activity	Name of the stage	Description of the stages
Preparing stand for testing	Water ford rightness and turbine rotor mounting on stand	*The water ford is horizontally positioned **3**,* by means of the screw-nut mechanism **8-9** and is totally opened the flat sluice **3.7**;
		The hydraulic turbine rotor for tested is mounted in the bearing and the flange of the load simulation device **4**;
		*The device of load simulation **4*** is fixed on the frame of water ford **3**, with the four screws **4.5** and the four nuts **4.6**;
		*The water ford **3** is deflected,* by adequate positioning of the flap **3.8**, followed by its fixation on position with screw **3.10** and butterfly nut **3.11**;
	Filling the water tank, pump aeration, checking flow adjustment	*The tank is filled with clean and filtered water from the network,* with a volume equal with ¾ from the maximum volume, bounded by the side walls, bottom and the cover.
		The pump is started and aerates by unscrewing / tightening of the vent cap. After starting, the centrifugal pump of the electric pump **2.1** will work in a closed circuit (sucks from the tank **1**, through the flange connection **2.5**, discharges into the free surface water ford **3**, through the flow diffuser, then the volume of water "flows" through the ford, passes under the sluice, drains on the tank cover and ends up in the tank);
		It is being checked the flow adjustment of the centrifugal pump with the help of the frequency converter, in the range of 20 Hz, corresponding to the minimum flow and 50 Hz, corresponding to the maximum flow*;*
		*It is being checked the easy adjustment, without stiffening, of the angle of inclination of the water ford **3**, by operating the screw-nut mechanism **8-9**.*
Determination of functional characteristics of tested turbine model	Characteristics n=f(Q) at Mr=const.	*The load is kept constant, the flow rate* in the water tank is varied and the speed at the turbine shaft is measured.
	Characteristics n=f(Mr) at Q=const.	*The flow is kept constant in the ford, the load* in the turbine shaft is varied and the speed at the turbine shaft is measured.

The variation of the flow rate, regarding the determination of the first characteristic, is carried out in two steps, respectively:

- *establishing a water level upstream of sluice* **3.7** at the minimum flow rate of pumping group **2** and for the horizontal position of ford **3**;
- *maintaining the predetermined level*, when the ford is positioned horizontally, for its inclined positioning. In this sense, the tilting of the ford with an angle in the range of 1...9^o will be followed

by the increase of the flow rate of the pumping group in the range of $Q_{min}...Q_{max}$, by the variation of the electric motor supply frequency in the range of 20...50 Hz.
By adjusting the angle of inclination of the ford, with a step of 1^o, in the ranges $0^o...9^o$ and $9^o...0^o$, followed by the adjustment of the centrifugal pump flow, so that the water level in the ford to remain constant (with a tolerance of ±5%),18 distinct turbine test flow values can be obtained.
The load variation, regarding the second characteristic, is achieved by actuating the needle throttle **4.7** of the load simulation device **4**. The needle throttle has a fine adjustment characteristic (pressure on the gear pump discharge depending on the throttle opening) which allows that the load simulator device to make a fine-tune of the load of the tested turbine.

3. Constructive stands solutions for testing small head hydraulic turbines

A constructive solution for a stand fed with a constant level reservoir, intended for testing low head hydraulic turbines, is presented in figure 9.

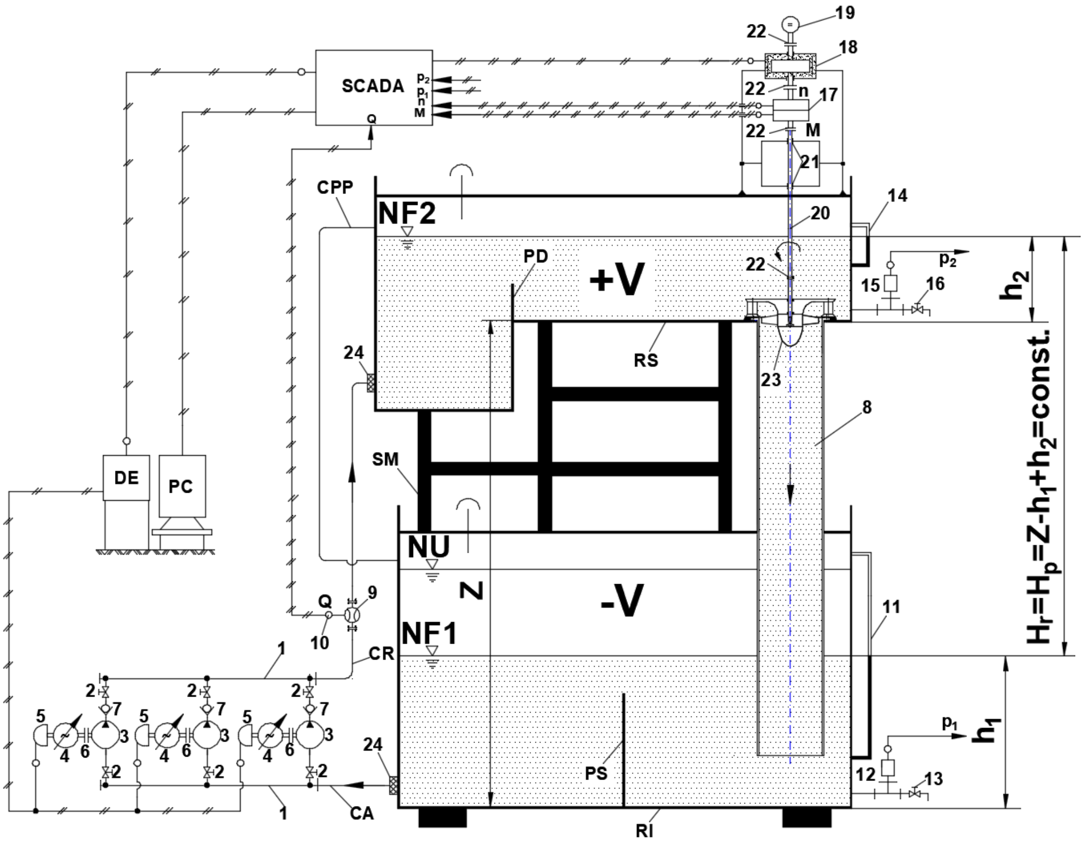

Fig. 9. Constructive-functional diagram for a hydraulic turbine test stand fed with constant level tank

The stand from figure 9 circulates a flow of clean water in a closed circuit, with the help of a pumping group with adjustable flow, consisting of three centrifugal pumps **3**, identical and connected in parallel to sum up the flows, each of them having a common suction manifold and a common discharge manifold **1**, each of the three pumps being able to be separated from the collection pipes of the group by means of two isolation valves each **2**, one on the suction and the other on the discharge, a one-way valve **7** being mounted before the valve on the discharge, and the drive of each pump being made by an electric motor of 380 V AC, **4**, coupled to the pump shaft by an elastic mechanical coupling **6** and powered by means of an adjustable frequency converter **5**, with the help of which the drive rotational speed of the pump is adjusted and, by through it, the flow of the pump is adjusted.
The adjustable flow pumping group sucks through a suction pipe CA from a first suction tank **RI**, mounted on the ground, inside which a wall **PS** is provided to separate the discharge / suction compartments, and discharges through a pipe discharge **CR** into a second upper tank **RS**,

mounted at a height and overlapped on the first one, which has a spillway **PD** separating two compartments, one connected to the discharge pipe and another connected to a transparent vertical pipe connected to the lower tank RI, both tanks having caps that communicate with the atmosphere and being fixed on the same metal support **SM**, equipped with screws for adjusting the verticality of the subassembly tanks-covers-support (not shown in the diagram).
The tributary flow, with which the pumping group feeds the upper tank, drains by gravity into the lower tank through a transparent vertical pipe **8**, provided with a flange glued at one end, which is mounted between the tanks, the flanged end of the pipe being fixed to the bottom of the upper tank, inside, and the other end, which penetrates the cap of the lower tank, remaining permanently completely immersed in water. To prevent the propagation of vibrations, generated by the pumping group, to the two overlapping tanks are equipped with two elastic sleeves **24**.
Each of the two tanks also contains: an emptying valve, **13** and **16**, mounted in a T-shape connection, in which the hydrostatic pressure transducers **12** and **15** are also mounted; one level indicator each, **11** and **14**. In case of accidental damage to the automatic flow regulation system, an overflow pipe **CPP** is considered, through which any excess flow will be discharged from the upper tank to the lower tank***.***
The model 23 low-head hydraulic turbine to be tested on the stand is mounted inside the upper tank, with the turbine stator fixed to the flange of the transparent tube and the rotor coupled to the shaft **20** of an adjustable braking system resting on the upper tank cap.
The adjustable braking system contains: two radial-axial bearings **21**; a torque and rotational speed transducer **17**; a brake 18 with magnetic powders, with adjustable resistance moment depending on the supply current; an electric motor 19 of 24 V d.c., necessary to drive the brake before the start of tests on the stand, to homogenize the magnetic powder and determine the value of the friction moment in the bearings, and four mechanical couplings 22 on the kinematic chain of the components of the braking system.
The SCADA system for monitoring, control and data acquisition contains: an electrical box, equipped with a programmable controller and power source; two transducers, **12** and **15**, mounted at the base of the tanks, which measure the hydrostatic pressures, $\mathbf{p_1}$ and $\mathbf{p_2}$, in each tank, and are used to measure the water levels $\mathbf{h_1}$ and $\mathbf{h_2}$ in each tank; an electromagnetic flow meter **9** associated with a flow transducer **10**, mounted on the discharge pipe of the pumping group; a brake **18** with magnetic powders; a torque and a rotational speed transducer **17** in connection with a **PC** computer, by means of which the adjustable braking system is controlled, i.e. the regulation of the flow to the pumping group, so that the drop **H** achieved by the transfer of a volume **V** of water from the lower tank to the upper tank and defined so that the distance between the free surfaces of the water in the two tanks remains constant, at a prescribed value, during the tests. Through the **SCADA**, the test flow rate **Q**, the levels $\mathbf{h_1}$ and $\mathbf{h_2}$ of the water in the two tanks and the mechanical parameters of the tested turbine (rotational speed **n** and moment **M**) are monitored.
By changing the prescribed H_p drop, respectively the stabilized **NF1**, **NF2** levels of tank operation, measured with transducers **12** and **15**, the **SCADA** system of the stand can adjust the achieved drop **Hr**, in an interval of length proportional to the volume of the tanks and the **Z** elevation of the front positioning of soil of the **RS** tank. Each adjusted value of the drop H will correspond to a value of the influent flow rate to the upper tank, equal to the effluent flow rate of the tank that flows through the transparent tube, respectively the flow rate required to test the model 23 of the tested low-head hydraulic turbine.
The determination of the functional characteristics of the low-head hydraulic turbine models tested on the stand is done after the homogenization of the magnetic powder from the brake, by operating it in empty position, for 10-15 min., with the help of the electric motor of 24 V d.c.**19,** followed by its dismantling.

Table 3: Stand functionality and the ways of carrying out the tests

Name of the activity	Name of the stage	Description of the stages
	Verticality tanks	*Checking and restoring,* if it is necessary of the verticality of the overlapping tanks assembly;
		Fill the lower tank, with clean and filtered water from the mains, until

Preparing stand for testing	Filling the stand with water, adjusting the water level, pumps aeration, mounting the turbine and braking system	the water reaches the **NO** filling level, visualized on the level indicator **11**. This level is calculated so that the volume of water in the tank ensures the filling of the pumping circuit consisting of: suction pipe + pumping group + discharge pipe + upper tank maximum level + transparent vertical pipe;
		Water level adjustment. If it is necessary, discharge valve **13** is also used to adjust the filling level;
		Pump aeration by unscrewing / tightening of the vent caps of each pump;
		The turbine model **23** *is mounted,* on the flange of the stand transparent tube.
		The adjustment braking system is mounted on the superior tank cover, then this is coupled at the shaft of the turbine model which will be tested;
		The value of the fall $\mathbf{H_p}$ is prescribed from the programmable automaton, defined as the distance between the free surfaces of the water in the two tanks, respectively: $\mathbf{H_p=Z-h1+h2}$, in which: **Z** represents the positioning elevation of the bottom of the upper tank **RS** in the compartment to the right of the spillway threshold, against the bottom of the lower tank **RI**; $\mathbf{h_1}$ represents the water level in the lower tank **RI**, measured indirectly with the hydrostatic pressure transducer **12** ($\mathbf{h_1=p_1/\rho g}$); $\mathbf{h_2}$ represents the water level in the upper tank **RS**, measured indirectly with the hydrostatic pressure transducer **15** ($\mathbf{h_2=p_2 / \rho g}$).
	Start group of pumping and flow control program initiation	**step 1:** the pumps of the group are started, at ½ of the nominal rotational speed, to fill the hydraulic circuit and the upper tank up to the level of the overflow threshold **PD**, which separates the tank into two compartments;
		step 2: water reaches the level of the spillway in the tank **RS** and drains by gravity through the transparent tube into the lower tank **RI**. The discharge flow **Qs** through the transparent vertical tube (effluent flow of the upper tank **RS**), which depends on the shape of the tested turbine and the vortex formed at the exit of the turbine is compared with the flow **Qp** of the pumping group (tributary flow of upper tank **RS**) by analyzing the water levels in the tanks.
		for **Qs>Qp**, because in the upper tank the water stagnates at the level of the spillway threshold for a calculated time interval, in which the hydrostatic pressure transducer **15** does not transmit information of the level increase in the upper tank **RS,** the **SCADA** system commands the automatic increase of the flow of the pumping group, by increasing the drive rotational speed of the pumps, until the achieved drop $\mathbf{H_r}$ equals the prescribed drop $\mathbf{H_p}$**.** From that moment, when the operating levels **NF1** and **NF2** are stabilized in the two tanks, and a volume V of water is transferred by pumping from the lower tank **-V** to the upper tank **+V,** the **SCADA** system will provide a closed-loop adjustment of the rotational speed of the pumps, implicitly of the influent flow to the upper reservoir, for the constant maintenance of the drop $\mathbf{H_r=H_p=Z-h_1+h_2}$, implicitly of the effluent flow to the upper reservoir;
		if **Qs<Qp**, the **SCADA** system commands the automatic reduction of the pump rotational speed, and upon receiving the prescribed value of the fall $\mathbf{H_p}$, the system acts to keep it constant, implicitly the effluent flow to the upper tank;
Determination of functional characteristics of tested turbine model	Characteristic M=f(Q) at Mr=const.	*the moment at the turbine axis as a function of flow at constant load* is determined experimentally for several constant drops **H**;
	Characteristic n=f(Q) at Mr=const.	*the rotational speed at the turbine shaft as a function of flow at constant load*, is determined experimentally for several constant drops **H**;
	Characteristic	*the rotational speed as a function of load at constant flow rate*, is

	n=f(Mr) at Q=const.	determined experimentally for several constant flow rates **Q**.

4. Conclusions

The summary of the main conclusions is presented in table 4.

Table 4: Synthesis of the main conclusions

Stand / Particularity	Subchapter 2.1	Subchapter 2.2	Chapter 3
Stand destination.	Determining speed distributions on rotor blades and testing small flow axial hydraulic turbines, with vertical or horizontal axis.	Testing small flow axial hydraulic turbines, with vertical or horizontal axis.	Low-head, vertical axis axial hydraulic turbine testing.
The technical problem that the stand solves	It accumulates two functions in a single means of testing, respectively: *optimization* of the hydrodynamic shape of the rotor blades*; rotor experimenta*l *test*.	Simple solutions for: *fine adjustment of the flow rate* in three successive steps flat weir + adjustable centrifugal pump + water ford tilting angle adjustment; *load simulation* with a gear pump with adjustable needle throttle mounted on the discharge, which is driven by the tested turbine.	The stand is fed by a *constant-level height tank*, *for which the influent flow*, respectively the supply flow of the stand, *is equal to the effluent flow*, respectively the useful flow of the stand for low-head hydraulic turbine tests.
The main functional characteristic of the stand	Regulates *the speed / flow* of water in the horizontal test section of the turbine; keeps the adjusted value constant.	Regulates *the speed / flow* of water in the horizontal test section of the turbine; keeps the adjusted value constant.	Regulates the fall of water in the vertical test section of the turbine; keeps the adjusted value constant.
Stand simulated natural conditions, for in-situ assembly of small hydraulic turbines	Flow from permanent watercourses is simulated in a transparent horizontal plexiglass section.	The flow from permanent watercourses is simulated in a tilting water ford, with a maximum inclination of 9° from the horizontal, made of stainless steel.	The fall of water from permanent streams is simulated in a transparent stainless steel vertical pipe fed by a constant level reservoir.
Functional characteristics determined on the stand	M=f(Q) at Mr=const.; n=f(Q) at Mr=const.; n=f(Mr) at Q=const.	M=f(Q) at Mr=const.; n=f(Q) at Mr=const.; n=f(Mr) at Q=const.	M=f(Q)at Mr=const.; n=f(Q) at Mr=const.; n=f(Mr) at Q=const.
How to adjust the flow	Pumping group consisting of 3 centrifugal pumps, connected in parallel, driven by electric motors with adjustable speed.	Flat sluice, plus an adjustable centrifugal pump, plus adjustment of the inclination of the tilting water ford.	Pump group consisting of 3 centrifugal pumps, connected in parallel, driven by electric motors with adjustable rotational speed.
Load simulation mode	Magnetic powder brake.	Gear pump and needle adjustable throttle.	Magnetic powder brake.

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